Development of Fuzzy Analytic Hierarchy

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Development of Fuzzy Analytic Hierarchy Process(F-AHP) For The Selection Of Alternative New Product Development Ideas In Coconut Downstream Agroindustry

S Wardah*[1], T Baidawi[2]

[1]*Universitas Islam Indragiri, Tembilahan, Indonesia*
[2]*Universitas Bina Sarana Informatika, Jakarta, Indonesia*

**sitiwardahst@yahoo.co.id*

Abstract. Downstream coconut agro-industry can increase added value, strengthen industrial structure, grow industrial population, provide employment, create business opportunities, and improve the national economy. The low level of downstream coconut agro-industry is due to the low development of new products that are key to long-term agro-industry. One important success step in developing new products is making the right decision in choosing a new product development idea. The choice of ideas is important to reduce risk in various uncertainties and market conditions. Based on this, this research aims to develop the Fuzzy Analytic Hierarchy Process (F-AHP) method for selecting the right idea to develop new products so that the downstream coconut agro-industry can develop. To achieve this goal, we use the F-AHP approach with an expert confidence level of 0.5. From this approach, the results are obtained that the critical criteria are product specificity, product superiority, product safety, product demand trends, the number of similar industries at the national level and the number of similar industries at the international level with alternative ideas for new product development are coconut meat, coconut shell coconut water towards the food industry and coconut fiber towards the transportation industry.

Keywords— Downstream, F-AHP, idea new product development

1. Introduction

Downstream coconut agro-industry is the development of new products in the coconut agro-industry. Downstream Coconut agro-industry has the potential to be developed because coconut commodities play a large role in the national economy because the coconut business is dominated by smallholder plantations so that coconut commodities are commodities that can prosper farmers' [2]. Agro-industry down streaming can increase product value-added, strengthen industrial structure, grow industrial populations, provide employment and create business opportunities. Agro-industry down streaming can be developed by increasing the development of new products. New product development and innovation are often recognized as the key to the success of every business [1]. Today, the market in general wants high-quality, higher-performance, lower-cost products [2].

The stages in developing new products [3] are (1) New Product Strategies: Linking the process of developing new products with company goals can provide a focus for making ideas / concepts and guidelines for setting filtering criteria, (2) Generation of ideas: Finding product ideas that meet company objectives, (3) Screening: Consists of initial analysis to determine which ideas are appropriate and deserve to be studied in more detail, (4) Business Analysis: Further evaluating ideas based on quantitative factors, such as earnings, Return on Investment (ROI), and sales volume, (5) Development:

Turning ideas on paper into products that can be shown and produced, (6) Testing: Conducting commercial experiments needed to verify previous business assessments, (7) Commercialization: Launching a product. One important stage in the development of new products is the decision to choose the best alternative or idea for developing new products. The method that can be used in the selection of new product development ideas is F-AHP [4].
Based on that, the purpose of this study is to develop the Fuzzy Analytic Hierarchy Process (F-AHP) method for the selection of new product development ideas in the downstream coconut agro-industry.

2. Methodology

The framework for developing the AHP Fuzzy method in choosing alternative ideas for developing new products in downstream coconut agro-industry is as follows:

2.1. Comparison of score

Fuzzy triangle numbers are used to perform the relative importance of each pair of elements in the same hierarchy. The level of importance with the resolution of each fuzzy number in Table 1.

Table 1. Definition and membership function of fuzzy numbers.

Level of Importance	Fuzzy Numbers	Definition	Membership function
1	$\tilde{1}$	Equally important	(1,1,3)
3	$\tilde{3}$	A little more important	(2,3,4)
5	$\tilde{5}$	More important	(4,5,6)
7	$\tilde{7}$	Very more important	(6,7,8)
9	$\tilde{9}$	Absolute more important	(8,9,10)

2.1. Making a fuzzy comparison matrix

Fuzzy numbers through pairwise comparisons make the fuzzy assessment matrix Ã (aij) as follows:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix}$$

with $\tilde{a}ij$ $a = 1$ if i = j, and $\tilde{a}ij$ $a = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$ if $i \neq j$ 3.

2.2. Solution for fuzzy eigenvalue

The fuzzy eigenvalue is a fuzzy number to solve the equation:
$\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x}$ (1)
Ã is (n x n) fuzzy matrix containing fuzzy numbers $\tilde{a}ij$
$\tilde{x}$ is (n x 1) fuzzy vector which contains fuzzy numbers $\tilde{x}i$
The upper and lower limits of the fuzzy number are then determined based on the α-cut value using the following equation:

$\tilde{1}_{a}$ = [1, 3-2α] (2)

$\tilde{3}_{\alpha}$ = [1 + 2α, 5-2α] ; $\sim 3_{\alpha}^{-1} = \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right]$ (3)

$\tilde{5}_{\alpha}$ = [3 + 2α, 7-2α] ; $\sim 5_{\alpha}^{-1} = \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right]$ (4)

$\tilde{7}_{\alpha}$ = [5 + 2α, 9-2α] ; $\sim 7_{\alpha}^{-1} = \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right]$ (5)

$\tilde{9}_{\alpha}$ = [7 + 2α, 11-2α] ; $\sim 9_{\alpha}^{-1} = \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right]$ (6)

α-cut is the level of trust of experts or decision-makers in their assessment. The degree of satisfaction of the assessment matrix A is estimated by the optimism index ω. The higher the index value ω indicates a higher level of optimism. The optimism index is a combination of linear convex defined in the following equation:

$\widetilde{\alpha}_{ij}^{\alpha} = \omega\, \widetilde{\alpha}_{iju}^{\alpha} + (1-\omega)\, \widetilde{\alpha}_{ijl}^{\alpha}$; $\vee\, \omega \in [0,1]$ (7)

determining priority weights can be simplified by the following equation:

$$x_i = \frac{\sum_{i=1}^{n}\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)}{n} \quad (8)$$

Normalization in pairwise comparisons and priority weight calculations are carried out with eigenvector calculations. To control the results of this method, the consistency ratio for each matrix and the entire hierarchy is calculated. The measurement of consistency index is done by using the equation: The consistency index (CI) in the study is <0.1, which can be determined by Equation 9 and Equation 18.

$$CI = \frac{\lambda\, max - n}{n-1} \quad (9)$$

$$CR = \frac{CI}{RI} \quad (10)$$

With = CI: Consistency index, CR: Consistency Ratio, λmax: Inconsistency vector, RI: Average weight index, n: Number of alternatives

According to Saaty [5], the value of random consistency index (RI) according to matrix size

2.3. Determination and total sum of priority weights

The priority weights for each alternative are obtained using the following equation:

$$k = \sum_{i=1}^{t} i(bobot\ atribut\ x\ penilaian_{ik}) \quad (11)$$

for i = 1,2, ... t with = i: attribute t: total number of attributes k: alternative

3. Results and Discussion

3.1. Determination of alternative ideas for developing new products for downstream coconut agro-industry

Based on the literature review that the alternatives provided for determining ideas for developing new products for downstream coconut agro-industry [6]–[8] are the food industry (FI), the pharmaceutical, cosmetics, and medical devices (PI) industries, Textile Industry, Leather, Footwear, etc. (ITK), electronic / ICT industry (EI), and transportation industry (IT) while the criteria are product specificity (PC), product excellence (PE), product safety (PS), product demand trends (PDT), the number of similar industries at the national level (SITNL) and the number of similar industries at the international level (SITIL). The pairwise comparison hierarchy can be seen in Figure 1.

3.2. Making a fuzzy comparison matrix on the criteria

Through Figure 2, we made a paired comparison questionnaire between criteria and alternatives. The pairwise comparison questionnaire is arranged based on the hierarchical structure shown in Figure. 1. Pairwise comparison questionnaire using linguistic variables. This is based on verbal statements used by Saaty [5]. The selection of respondents was based on their expertise in developing new products in the coconut agro-industry. TFN converted respondents' verbal statements. The TFN values used are shown in Table 1. The results of the pairwise comparison of each criterion can be seen in Table 2.

3.3. Completion of fuzzy eigenvalues on criteria

Fuzzy eigenvalue solving, begins by determining the α-cut value using equations (1) - (6). The α value or the average confidence level at the time of assessment is 0.5. The α-cut fuzzy comparison matrix is shown in Table 3. The value of the α-cut fuzzy comparison matrix is converted into crisp values with

equation 7 with an optimism index ω = 0.5 which indicates that the assessment given is not too optimistic and not too pessimistic. The Vector Eigen or level of importance of elements can be calculated by solving the equation characteristic matrix of α-cut fuzzy comparison and then entering the largest eigenvalue into equation 1. By normalizing the value of xi, the level of importance of the element will be obtained. To determine the consistency of expert judgment, consistency was examined using equations 9 and 10. The crisp value, the importance value for each criterion, the highest eigenvalues, the consistency index, the consistency ratio in each paired comparison matrix are shown in Table 4.

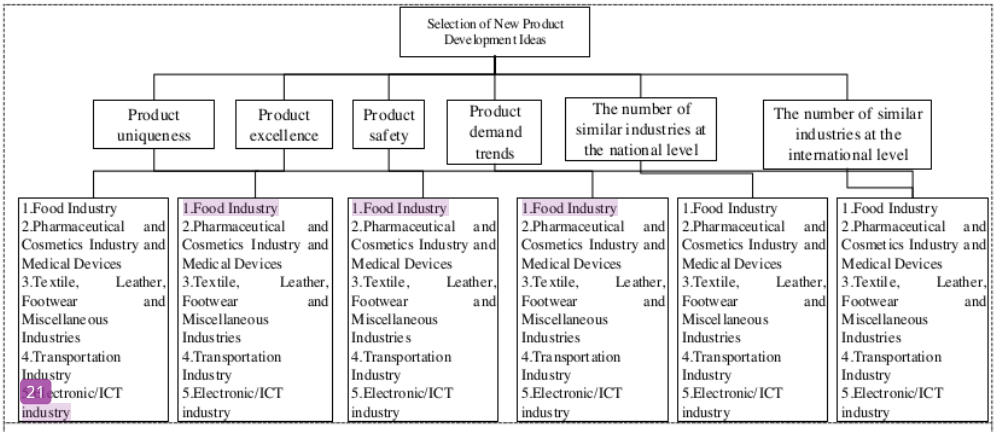

Figure 1. Hierarchy of Choosing New Product Development Ideas.

Table 2 The results of the pairwise comparisons of each criterion.

	PC	PE	PS	PDT	SITNL	SITIL
PC	1	$1^{\sim}$	$3^{\sim}$	$9^{-1^{\sim}}$	$1^{\sim}$	$3^{\sim}$
PE	$1^{\sim}$	1	$3^{\sim}$	$3^{-1^{\sim}}$	$3^{-1^{\sim}}$	$3^{\sim}$
PS	$3^{-1^{\sim}}$	$3^{-1^{\sim}}$	1	$7^{-1^{\sim}}$	$3^{-1^{\sim}}$	$3^{\sim}$
PDT	$9^{\sim}$	$3^{\sim}$	$7^{\sim}$	1	$3^{\sim}$	7
SITNL	$1^{\sim}$	$3^{\sim}$	$3^{\sim}$	$3^{-1^{\sim}}$	1	$3^{\sim}$
SITIL	$3^{-1^{\sim}}$	$3^{-1^{\sim}}$	$3^{-1^{\sim}}$	$7^{-1^{\sim}}$	$3^{-1^{\sim}}$	1

3.4.Determination and the total sum of priority weights on criteria

Based on Table 5, the priority for the idea of developing new products is the trend of product demand (PDT) having the highest weighting among several other criteria. Product demand trends (PDT) are needed to avoid market failures and corporate sustainability [9]. Furthermore, the specificity of the product (PC) and the number of similar industries at the national level (SITNL) has the next biggest weight. The company requires the uniqueness of a product because new products that are developed are not easily substituted by other products [1]. then the number of similar industries at the national level (SITNL) to develop new product developments with new market spaces [12] and not compete in existing market spaces [12].

3.5.Determination of alternative priorities for new product development ideas in the downstream coconut agro-industry

Through the same steps, sub-criteria weights are calculated for each criterion. Global weight values are generated by multiplying the weight values of each criterion. This is shown in Table 5. Table 5 shows

that the idea of developing a new product in coconut meat because coconut meat derivative products have a good effect on health [7], coconut shell towards the food industry because it has an addictive substance in the form of phenol which functions as a natural food preservative [13], coconut water towards the food industry because it can function as a functional food that accelerates the growth of the food industry, coconut fibre towards the transportation industry because of its mechanical properties, cheap and environmentally [14].

Table 3 The α-cut fuzzy comparison matrix.

	PC		PE		PS		PDT		SITNL		SITIL	
PC	1.0	1.0	2.0	0.3	2.0	4.0	0.2	0.3	2.0	2.0	2.0	4.0
PE	0.3	0.5	1.0	1.0	2.0	4.0	0.2	0.3	0.3	0.5	2.0	4.0
PS	0.3	0.5	0.3	0.5	1.0	1.0	0.1	0.2	0.3	0.5	2.0	4.0
PDT	4.0	6.0	4.0	6.0	6.0	8.0	1.0	1.0	2.0	4.0	6.0	8.0
SITNL	1.0	2.0	2.0	4.0	2.0	4.0	0.3	0.5	1.0	1.0	4.0	6.0
SITIL	0.3	0.5	0.3	0.5	0.3	0.5	0.1	0.2	0.2	0.3	1.0	1.0

Table 4 Crisp value, importance value for each criterion, highest eigenvalue, consistency index, consistency ratio in each paired comparison matrix.

	PC	PE	PS	PDT	SITNL	SITIL	x	Priority
PC	1.0	1.1	3.0	0.2	2.0	3.0	0.2	2
PE	0.4	1.0	3.0	0.2	0.4	3.0	0.1	3
PS	0.4	0.4	1.0	0.1	0.4	3.0	0.1	3
PDT	5.0	5.0	7.0	1.0	3.0	7.0	0.4	1
SITNL	1.5	3.0	3.0	0.4	1.0	5.0	0.2	2
SITIL	0.4	0.4	0.4	0.1	0.2	1.0	0.0	4

λ max = 6.6 CI=0.1 dan CR=0.1

Table 5 Priority Weight Selection of New Product Development Ideas on Coconut

	Coconut Meat	Coconut Shell	Coconut Water	Coconut Fiber	Priority
PI	0,36	0,21	0,33	0,35	1
FI	0,32	0,27	0,32	0,29	2
TI	0,31	0,20	0,32	0,31	3
EI	0,15	0,21	0,19	0,16	4
ITK	0,15	0,13	0,12	0,16	5

4. Conclusion

The results showed that this research had successfully developed the development of the F-AHP method in downstream coconut agro-industry. From this approach, the results are obtained that the critical criteria are product specificity, product superiority, product safety, product demand trends, the number of similar industries at the national level and the number of similar industries at the international level with alternative ideas for new product development are coconut meat, coconut shell coconut water towards the food industry and coconut fibre towards the transportation industry. Further research is continued regarding the stages of developing new products to produce prototypes of new products that are ready for mass production.

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