Selection of Unmanned Aircraft Development Model in Indonesia using the AHP Method

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***Abstract*—Countries worldwide are attempting to acquire or create Class 3 unmanned aircraft as part of their armies' primary weapons systems. The development of medium altitude long endurance (MALE) unmanned aircraft in Indonesia forms part of the national strategic program. Based on documentation studies, three alternative MALE-class unmanned aircraft development models were identified. This study aims to determine the most appropriate unmanned aircraft development model for the MALE class for Indonesia's current situation. This will aid decision-making by the government and stakeholders related to the drone development model. The analytical hierarchy process (AHP) method was used to analyze the decision-making for the selection of an unmanned aircraft development model. The study began with a questionnaire survey of 11 experts from various institutions. The results show that the priority criterion should be the benefits obtained, followed by the opportunity and budget criteria, and, finally, the risk. The consortium model, which had the highest score of 0.548, is the most suitable for Indonesia's development of MALE-class unmanned aircraft. The results of the study are expected to provide useful input for AHP researchers, government institutions, and stakeholders.**

Keywords*—Analytical Hierarchy Process (AHP); decision-making; development model; medium altitude long endurance (MALE); unmanned aircraft

I. Introduction

Countries worldwide are attempting to acquire or create Class 3 unmanned aircraft as part of their armies' primary weapons systems. More and more nations are trying to compete in the race to create and offer ever-more advanced drones for sale on the international market. Long-simmering conflicts and rivalries are expected to change due to the emergence of a race for drones [1]. The primary rivalries in this arms race are between the United States of America, China, Russia, South Korea, and the European Union [2]. Unmanned aircraft are divided into three classes based on maximum take-off weight, namely Class 1 (<150 kg), Class 2 (150–600 kg), and Class 3 (>600 kg) [3]. Countries around Indonesia such as China, India, Pakistan, Singapore, and Thailand already have Class 3 unmanned aircraft. Meanwhile, countries that are growing and intend to obtain them include Australia, Bangladesh, Japan, Malaysia, the Philippines, South Korea, Taiwan, and Indonesia [4].

Examples of the deployment of unmanned aircraft in warfare include the United States of America's use of the Predator MQ-1 against Osama bin Laden in Afghanistan beginning in 2002. The Turkish military used Bayraktar TB2s against Syrian Army targets in March 2020 [5]. During the Nagorno–Karabakh war of 2020, Azerbaijan employed the Bayraktar TB2 against the Armed Forces of Armenia [6]. More recently, Russia has reduced the military power of Ukraine. Drones have played a significant role in the former's operations and Russia has improved the aiming speed for long-range indirect fire through the use of multiple drone types that fly at varying altitudes [7]. The conflict in Ukraine is swiftly bringing future trends for drone use into view [8]. The use of an Unmanned Aerial System (UAS) in a hostile environment reduces risk [9]. Drones can be used to solve a variety of problems related to the needs of the users, such as illegal fishing, illegal immigrants, piracy, floods, forest fires, terrorism, and military infiltration of other countries [10].

According to Presidential Regulation of the Republic of Indonesia, number 109 for the year 2020, numerous inventions and research projects are being executed efficiently to strengthen the country's technological independence. The national strategic program includes the development of medium altitude long endurance (MALE) unmanned aircraft in Indonesia. The Black Eagle unmanned aerial vehicle (UAV) system is part of several governmental research and innovation initiatives [11]. Based on documentation studies, three alternative development models for MALE-class unmanned aircraft have been identified, namely: 1) The BRIN model based on a letter from the Deputy for Research and Innovation Utilization of the National Research and Innovation Agency (BRIN) to the Secretary General of the Ministry of Defense dated 23-11-2021 regarding an explanation of the follow-up to the MALE UAV program, 2) A consortium model based on Minister of Research, Technology and Higher Education Regulation no. 38 of 2019 concerning the 2020-2024 national research program, the Agency for the Assessment and Application of Technology (BPPT) as coordinator of the combat PTTA development program, and based on a cooperation agreement (PKS) between the Ministry of Defense, Indonesian National Army Air Force (TNI AU), BPPT, Bandung Institute of Technology (ITB), PT Dirgantara Indonesia (PTDI), and PT LEN dated 08-21-2017, and 3) An international cooperation model based on the invitation letter and minutes of the coordination meeting for the implementation of the offset procurement of the Bayraktar TB2 UAV from the Director General of Defense Ministry of Defense dated 01-03-21.

The consortium-based MALE class UCAV development program started in 2017 but has been discontinued since 2020 due to the establishment of the National Research and Innovation Agency (BRIN). This study aims to determine the most appropriate unmanned aircraft development model for the MALE class for Indonesia's current situation. This will aid decision-making by the government and stakeholders related to the drone development model. In this case, an analytical hierarchy process (AHP) based on the criteria provided for selecting current models can aid in making a superior choice.

The following section contains a literature review on UAV design, opportunities, product budgets, benefits, risks, and the AHP method. Section III presents the methodology: system design, the AHP method, sampling and data collection, research instruments and measurements, and methods of analysis. The findings of the analysis are discussed in Section IV. Finally, the study will end with conclusions and recommendations for future research in Section V.

II. Literature Review

Manned aircraft and UAV designs share certain similarities and contrasts. They both consist of a design procedure, limitations, and core UAV parts (autopilot, ground station, communication, sensors, and payload). A UAV designer must be well versed in the most recent UAV advancements, modern technologies, the lessons learned from previous failures, and the diversity of UAV design possibilities, and they must understand the environment, the requirements, and the design problems, as well as how to integrate complex, multi-disciplinary systems [12]. A step-by-step layout design study was conducted using precision tools and computational simulations to define the essential layout parameters and choose the ideal airframe-engine combination [13].

When Inertial Navigation System data are not sufficiently precise to minimize drift from a planned trajectory, Synthetic Aperture Radar (SAR) can assist in UAV navigation [14]; [15]. Stability and maneuverability are key trade-offs in aircraft construction for civil or military use. The UAV and its handling characteristics are both addressed in the design of the flight control system [16]. While every technological product carries the risk of malfunction or operational error, pilots can respond to a failure by using the best mitigation that has been designed, such as by disabling automatic power control or completing the operation manually [17].

The initial model in the B787 Dreamliner program represented a disruptive technology product innovation within the industry. The program fundamentally altered the supply chain of the industry partnership model [18]. Many strategies and thematic lenses have arisen in the academic community to address various questions in innovation management [19]. Similarities exist in the new product development innovation process within the stages of identifying issues and opportunities, creating and processing ideas, market projections, business analysis, visualization, and execution, as well as expressing the model in service organizations [20]. The current research contains various outstanding challenges concerning the discovery of technology opportunities [21]. Only an appropriate product structure will allow the benefits of product portfolio management to be fully realized [22]. With a restricted budget, a government could determine the appropriate level of subsidy to boost the sales of remanufactured products. The best subsidy is offered when a budget is limited [23]. The creation of a project selection and evaluation tool may potentially be applied to a wide range of research, technology, and investment decisions [24].

An organization that creates a new product invests time and money in the hope that the product will provide a sufficient return on investment. An effective and efficient risk management strategy must be selected to match the specific product development case. Firms that develop products use risk identification, assessment, and mitigation to support their risk management procedures and decision-making [25], where the risks are detectable and manageable. Product development industries are also assisted in incorporating sustainability into strategic, tactical, and operational decision-making [26].

The AHP method is effective for analyzing a complex problem involving the selection of an alternative as a decision from several choices. A problem's complexity stems partially from the presence of numerous influencing criteria. AHP offers a means of breaking down a complicated unstructured scenario into multiple components in a hierarchical order by assigning a subjective value to the relative relevance of each variable and identifying which variable has the highest priority in terms of impacting the outcome of the situation [27]. The AHP method developed by Professor Thomas L. Saaty is widely used for business purposes in companies, government interests, and research.

The AHP method has been widely used in several research fields, for example: The AHP method enables for the evaluation and rating of the device's design elements, resulting in a more reasonable and comprehensive device design [28], The VAHP model is a helpful decision-making tool for transportation planners, policymakers, and other stakeholders in the industry [29].

III. Methodology

The research method employed in this study combined the survey method by distributing questionnaires to experts in the field of UAV development with the AHP method to determine the global priority of the alternatives offered. The research flow is shown in Fig. 1. A literature review was conducted in step one, the criteria for the alternatives presented were determined in step two, a questionnaire was developed in step three and distributed to expert respondents in step four, the data were analyzed in step five, and conclusions were drawn from the research findings in step six. The research questionnaire can be seen in Appendix 1.

A. *System Design*

In this study, four important criteria were determined, namely: 1) Opportunity (Op): With government policies, sufficient and qualified human resources, and infrastructure for product development, the opportunity is enormous, 2) Budget (Bu): Budgets are needed for initial investment, expert and employee salaries, tool and material purchases, and testing costs, 3) Benefits (B): These include speedier technological mastery, achieving defense industry independence, avoiding embargoes, creating jobs, and producing foreign exchange, and 4) Risk (Ri): The identified risks would manifest in forms such as the program not running smoothly, the goal time being delayed, the product failing, or there being no partner. Fig. 2

shows the AHP structure chart with the existing goals, criteria, and alternatives.

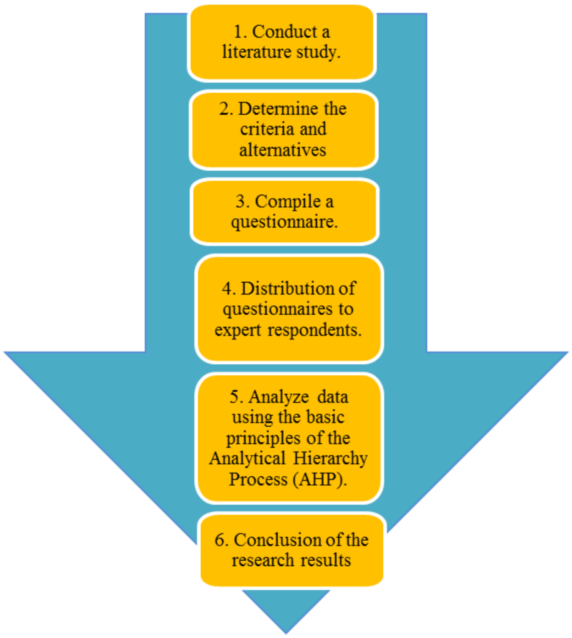

Fig. 1. Research flow.

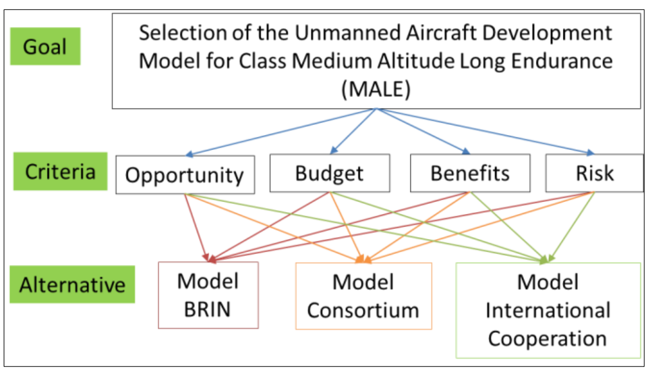

Fig. 2. AHP structure chart.

B. Sampling and Data Collection

The population in this study comprised individuals involved in national research and development on MALE-class drones and their use on the territory of the Republic of Indonesia. Samples were selected by purposive sampling, which is a technique suitable for data sources with specific considerations, such as identifying the person considered to be the most knowledgeable in the area under consideration [30]. Some questionnaires were distributed online to respondents while other respondents were visited face to face. The data were collected from July to August 2022. While the AHP method has no specific formulation for the number of respondents, it must include a minimum of two. The priority in applying the AHP method is the quality of the data derived from the respondents, not the quantity. The respondents in AHP assessments must be experts in order to decide between the alternatives proposed. The experts in this case were competent individuals who had truly mastered and comprehended the situation, influenced policymaking, or knew the information needed.

Table I contains the characteristics of the respondents and shows that 36.4% had undergraduate or diploma degrees while 63.6% had postgraduate degrees, thus indicating a group of participants with a high level of education. In terms of the respondents' age, 18.2% of the population were aged between 41 and 50, 63.6% were aged between 51 and 60, and 9.1% were aged between 61 and 75.

TABLE I. CHARACTERISTICS OF THE RESPONDENTS

Respondent	Age (years)	Education level	Institutions
1	51–60	S3	Head of Aeronautics Technology Research Center, Nasional Research and Innovation Agency (BRIN)
2	51–60	S3	Member of the House Of Representatives - Commission VII (Energy, Mineral Resources, Research and Technology, Environmental Affairs)
3	51–60	S2	Secretary General of Indonesian Aeronautical Engineering Center (IAEC)
4	41–50	S1	Chairman of Unmanned Technology Systems Association (ASTTA) and Director of PT Aeroterra Indonesia
5	31–40	S1	Senior Vice President (SVP) Technology and Research Development Centre of PT LEN Industry
6	51–60	S2	Director of Commerce, Technology, and Development of PT. Dirgantara Indonesia (Indonesian aircraft industries)
7	51–60	S1	Head of Combat Power Division, Research, and Development Agency of the Ministry of Defense
8	51–60	S3	Head of sub-directorate Europe and Africa, Directorate of Defense International Cooperation, Directorate General of Defense Strategy Ministry of Defense
9	41–50	S3	Lecturer at the Faculty of Mechanical and Aerospace Engineering and Head of the Center for Unmanned Studies, Bandung Institute of Technology (ITB)
10	61–75	S3	Head of Technology Transfer and Offset Defense Industry Policy Committee
11	51–60	S1	Head of the Indonesian Air Force's Research and Development Department

C. Research Instruments and Measurements

The research instrument used was a questionnaire with a comparison matrix between the criteria (four criteria) and a comparison matrix between the alternatives (three alternatives) based on the four existing criteria. This study used the nine-point Saaty scale, where 1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance, 9: extreme importance, and 2, 4, 6, 8: intermediate values. In addition, demographic questions were asked, such as age, education, and employment institutions. The research questionnaire is shown in Appendix 1. The researcher then inputted data from the questionnaire results into a matrix table in Excel software based on the stages in the AHP method (see Appendices 2 to 6).

D. Methods of Analysis

Fig. 3 illustrates the 11 main steps used to obtain the priorities for the unmanned aircraft development model evaluation using AHP, as in [31]; [32]. The study in [33] has written that The AHP is sufficient for decision-making.

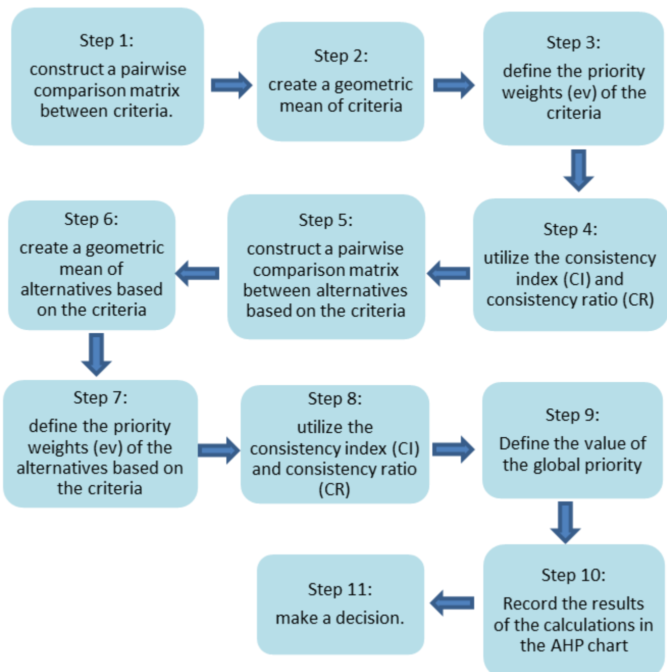

Fig. 3. The main steps used to obtain the global priority.

1) Step 1: Construct a pairwise comparison matrix between the criteria.

Given that there are m responders, there are m pairwise comparison matrixes with n criteria, as shown in Table II below, where, R denotes Respondent:

TABLE II. PAIRWISE COMPARISON MATRIX BETWEEN CRITERIA: INPUT ANSWERS FROM ALL RESPONDENTS

R1	C1	C2	...	Cn		Rm	C1	C2	...	Cn
C1	1	X_{12}	...	X_{1n}		C1	1	X_{12}	...	X_{1n}
C2	$1/X_{12}$	1	...	X_{2n}		C2	$1/X_{12}$	1	...	X_{2n}
...	...	...	1	...		...	...	...	1	...
Cn	$1/X_{1n}$	$1/X_{2n}$	...	1		Cn	$1/X_{1n}$	$1/X_{2n}$	...	1

2) Step 2: Create a geometric mean of criteria

After entering the comparative assessment into the matrix above, an average measurement using the geometric mean (see Appendix 7) (GM) of the m respondents' replies was entered using the formula below, with the values shown in Table III:

$$GM_{12} = \sqrt[m]{X_{12(R1)} * X_{12(R2)} * X_{12(R3)} * \dots \dots * X_{12(Rm)}} \quad (1)$$

$$GM_{21} = \sqrt[m]{X_{21(R1)} * X_{21(R2)} * X_{21(R3)} * \dots \dots * X_{21(Rm)}} \quad (2)$$

$$GM_{n1} = \sqrt[m]{X_{n1(R1)} * X_{n1(R2)} * X_{n1(R3)} * \dots \dots * X_{n1(Rm)}} \quad (3)$$

$$GM_{1n} = \sqrt[m]{X_{1n(R1)} * X_{1n(R2)} * X_{1n(R3)} * \dots \dots * X_{1n(Rm)}} \quad (4)$$

TABLE III. GEOMETRIC MEAN OF M MATRIX OF RESPONDENTS' ANSWERS

GM	C1	C2	...	Cn
C1	1	GM_{12}	...	GM_{1n}
C2	GM_{21}	1	...	GM_{2n}
...	...	...	1	...
Cn	GM_{n1}	GM_{n2}	...	1

3) Step 3: Define the priority weights (ev) of the criteria

Formulas (5) and (6) below were used to calculate and assign the priority weights:

$$\begin{bmatrix} 1 & GM12 & \dots & GM1n \\ GM21 & 1 & \dots & GM2n \\ \dots & \dots & 1 & \dots \\ GMn1 & GMn2 & \dots & 1 \end{bmatrix} \times \begin{bmatrix} 1 & GM12 & \dots & GM1n \\ GM21 & 1 & \dots & GM2n \\ \dots & \dots & 1 & \dots \\ GMn1 & GMn2 & \dots & 1 \end{bmatrix} = \begin{bmatrix} Z11 & Z12 & \dots & Z1n \\ Z21 & Z22 & \dots & Z2n \\ \dots & \dots & \dots & \dots \\ Zn1 & Zn2 & \dots & Znn \end{bmatrix} \quad (5)$$

the GM sum in the 1 row	priority weights	criterion or alternative
Y1 = Z11 + Z12 + ... + Z1n	ev1 = Y1 / Q	C1 or A1
Y2 = Z21 + Z22 + ... + Z2n	ev2 = Y2 / Q	C2 or A2
Y... = Z... + Z.... + ... + Z...n	ev...= Y.../ Q	....
Yn = Zn1 + Zn2 + ... + Znn	Evn = Yn / Q	Cn or An
total: Q = Y1 + Y2 + Y... + Yn		

(6)

4) Step 4: Utilize the consistency index (CI) and consistency ratio (CR) to evaluate logical consistency via the following steps:

a) Calculate the value of Vector [A]; Multiplication of the geometric mean (GM) matrix with the weight matrix priority (ev) = Vector [A]:

$$\begin{bmatrix} 1 & GM12 & \dots & GM1n \\ GM21 & 1 & \dots & GM2n \\ \dots & \dots & 1 & \dots \\ GMn1 & GMn2 & \dots & 1 \end{bmatrix} * \begin{bmatrix} ev1 \\ ev2 \\ \dots \\ evn \end{bmatrix} = \begin{bmatrix} A1 \\ A2 \\ \dots \\ An \end{bmatrix} \quad (7)$$

b) Calculate the value of Vector [B];

$$Vector\ |B| = \left| \frac{A1}{ev1} \quad \frac{A2}{ev2} \quad \frac{\dots}{\dots} \quad \frac{An}{evn} \right| \quad (8)$$

c) Calculate the maximum Eigenvalue:

$$\lambda_{max} = \frac{summary\ of\ the\ value\ of\ Vector\ B}{number\ of\ criteria\ (n)} \quad (9)$$

d) Calculate CI:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (10)$$

e) Determine the Random consistency index (RCI):

n (criteria)	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

f) Calculate CR:

$$CR = \frac{CI}{RCI} \quad (11)$$

If the CR value does not exceed 10% or < 0.1, then the pairwise comparisons between criteria data are consistent/valid.

5) Step 5: Construct a pairwise comparison matrix between alternatives based on the criteria

6) Step 6: Create GM of alternatives based on the criteria

7) Step 7: Define the priority weights (ev) of alternatives based *on the criteria*

8) Step 8: Utilize the consistency index (CI) and consistency ratio (CR) to evaluate logical consistency; The processes in steps 5 to 8 are the same as in steps 1 to 4.

9) Step 9: Define the value of the global priority; Global priority = priority weight of each alternative multiplied by the priority weight of the criteria.

*10)*Step 10: Record the results of the calculations in the AHP *structure chart; and finally*

11)Step 11: Make a decision.

IV. Results And Discussion

A. Priority Weights of Criteria

Table IV shows the priority weights of the criteria. The benefits criterion obtained the highest ratings with a priority weight value of 0.471. This was followed by opportunity, budget, and risk, respectively. Meanwhile, the risk criterion has a very small priority weight, namely 8.8%. The development of MALE-class drones will have significant benefits for the nation, including speedier technological mastery, defense industry independence, and the avoidance of embargoes, job creation, and foreign exchange production.

TABLE IV. Priority Weights of the Criteria

	Op	Bu	Be	Ri	Sum	Priority weight (ev)	Rank
Op	0.255	0.179	0.278	0.338	1.050	0.262	2
Bu	0.243	0.171	0.149	0.148	0.711	0.178	3
Be	0.436	0.548	0.476	0.426	1.885	0.471	1
Ri	0.066	0.102	0.098	0.088	0.354	0.088	4
Sum	1	1	1	1	4	1	

B. Priority Weights of Alternatives Based on the Opportunity Criterion

Based on the calculations in Table V, the following priorities among the alternatives were obtained regarding the opportunity criterion: 1) The consortium (CO) model with a priority weight value of 0.595, 2) The international cooperation (IC) model with a priority weight value of 0.240, and 3) The BRIN (BR) model with a priority weight value of 0.165. A CO model for the development of MALE-class drones has a better chance of success, with the smallest opportunity for the BRIN model.

C. Priority Weights of Alternatives Based on the Budget Criterion

Using the calculations in Table VI, the following priorities among the alternatives were obtained based on the budget criterion: 1) The CO model with a priority weight value of 0.483, 2) The IC model with a priority weight value of 0.357, and 3) The BR model with a priority weight value of 0.160. A larger budget is required to develop the MALE-class drone using a CO model. Budgets are required for initial investment, tool and material purchases, and testing costs. The BRIN model requires the smallest budget.

TABLE V. Priority Weights Of Alternatives Based On The Opportunity Criterion

	BR	CO	IC	Sum	Priority weight (ev)	Rank
BR	0.158	0.148	0.189	0.495	0.165	3
CO	0.633	0.590	0.562	1.785	0.595	1
IC	0.209	0.262	0.249	0.720	0.240	2
Sum	1	1	1	3	1	

TABLE VI. Priority Weights of Alternatives based on the Budget Criterion

	BR	CO	IC	Sum	Priority weight (ev)	Rank
BR	0.158	0.147	0.175	0.479	0.160	3
CO	0.512	0.476	0.460	1.449	0.483	1
IC	0.330	0.377	0.365	1.072	0.357	2
Sum	1	1	1	3	1	

D. Priority Weight of Alternatives Based on the Benefits Criterion

Based on the results of the calculations in Table VII, the following alternative priorities were obtained when considering the benefits criterion: 1) The CO model with a priority weight value of 0.588, 2) The IC model with a priority weight value of 0.260, and 3) The BR model with a priority weight value of 0.152. As such, the use of the CO model when developing the MALE-class drone would yield greater benefits, with the BRIN model providing the lowest benefits.

TABLE VII. Priority Weights of Alternatives based on the Benefits Criterion

	BR	CO	IC	Sum	Priority weight (ev)	Rank
BR	0.143	0.129	0.183	0.456	0.152	3
CO	0.642	0.579	0.543	1.764	0.588	1
IC	0.214	0.292	0.274	0.780	0.260	2
Sum	1	1	1	3	1	

E. Priority Weights of Alternatives Based on the Risk Criterion

The calculation results in Table VIII show that the risk criterion produced the alternative priorities as follows: 1) The IC model with a priority weight value of 0.453, 2) The CO model with a priority weight value of 0.326, and 3) The BR model with a priority weight value of 0.221. The development of a MALE-class drone with an IC model would carry greater risk, such as the program not running smoothly, a delayed goal time, and product failure. In contrast, the lowest risk is with the BRIN model.

TABLE VIII. PRIORITY WEIGHTS OF ALTERNATIVES BASED ON THE RISK CRITERION

	BR	CO	IC	Sum	Priority weight (ev)	Rank
BR	0.221	0.228	0.216	0.664	0.221	3
CO	0.317	0.328	0.333	0.978	0.326	2
IC	0.462	0.444	0.451	1.358	0.453	1
Sum	1	1	1	3	1	

F. Verify the CR

Tables IX and X show the results obtained from using the CR of the criteria and the alternatives. A CR value < 0.1 indicates that both the pairwise comparison data between the criteria and the pairwise comparisons between the alternatives are consistent or valid.

TABLE IX. RESULT OF UTILIZING THE CONSISTENCY RATIO (CR) OF CRITERIA

Vector [A]	Vector [B]	λ_{max}	CI	RCI	CR
$\begin{bmatrix}1.063\\0.725\\1.920\\0.359\end{bmatrix}$	|4.057 4.073 4.076 4.080|	4.0715	0.0238	0.9	0.0264

TABLE X. RESULT OF UTILIZING THE CONSISTENCY RATIO (CR) OF ALTERNATIVES

Based on criteria	Vector [A]	Vector [B]	λ_{max}	CI	RCI	CR
Opportunity	$\begin{bmatrix}0.496\\1.796\\0.722\end{bmatrix}$	|3.005 3.017 3.00	3.010	0.0049	0.58	0.0084
Budget	$\begin{bmatrix}0.479\\1.453\\1.074\end{bmatrix}$	|3.003 3.005 3.00	3.005	0.0024	0.58	0.0042
Benefit	$\begin{bmatrix}0.457\\1.784\\0.783\end{bmatrix}$	|3.009 3.034 3.01	3.019	0.0095	0.58	0.0164
Risk	$\begin{bmatrix}0.664\\0.978\\1.358\end{bmatrix}$	|3.001 3.001 3.00	3.001	0.0003	0.58	0.0005

G. Global Priority

Table XI shows that the CO model is the top priority with a score of 0.548, followed by the IC model with a value of 0.289, and, finally, the BR model with a value of 0.163. Fig. 4 shows the AHP structure chart with the priority weights of the criteria and the global priority for the development model of MALE-class unmanned aircraft.

A consortium is a collective structure, collaboration, or cooperation of individuals or institutions. Previous studies have reported its use in a variety of fields, including the tourism market [34], electronic products [35], new medical product development for transplant patients [36], and in the form of an agricultural industrialization consortium in low carbon agriculture [37].

TABLE XI. GLOBAL PRIORITY

Priority weight (ev) of alternatives						Priority weight (ev) of criteria		Global priority
	Op	Bu	Be	Ri				
Br	0.165	0.160	0.152	0.221		0.262		0.163
CO	0.595	0.483	0.588	0.326	X	0.178	=	0.548
IC	0.240	0.357	0.260	0.453		0.471		0.289
						0.088		

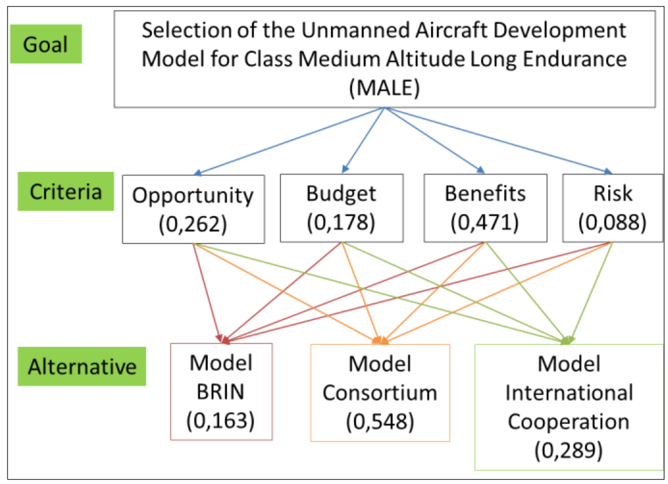

Fig. 4. AHP structure chart with priority weights of criteria and global priority.

V. CONCLUSION

This study sought to identify the most appropriate development model for the MALE class of unmanned aircraft using the AHP method. Based on the four criteria examined, the results show that the alternatives should be considered in the following order of priority: the benefits obtained, the opportunity, the budget required, and, finally, the risk that will arise. The results of the global priority calculation show that the consortium model has the highest value, at 0.548. It can therefore be concluded that the consortium model is the most suitable for the development of MALE-class unmanned aircraft in Indonesia.

A. Limitation

This study focused on respondents who were involved in national research and development for MALE-class drones, as well as their application in the Republic of Indonesia. The sample may thus differ from that of other countries and the findings of the study may not apply to all countries.

B. Recommendations for Future Research

It is recommended that future studies continue to examine the consortium model by studying and exploring the benefits and drawbacks of current such programs. It is hoped that this will provide input and guidance for implementing the next consortium program and help to ensure that the MALE-class unmanned aircraft development program runs smoothly and as expected.

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APPENDIX 1. AHP QUESTIONNAIRE

A	The pairwise comparison matrix of criteria																		
1	Opportunity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Budget
2	Opportunity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Benefits
3	Opportunity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk
4	Budget	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Benefits
5	Budget	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk
6	Benefits	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk
1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance, 9: extreme importance, 2, 4, 6, 8: intermediate values																			

B	The pairwise comparison matrix of alternatives: opportunity basis																		
1	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Consortium
2	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
3	Consortium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance 9: extreme importance, 2, 4, 6, 8: intermediate values																			

C	The pairwise comparison matrix of alternatives: budget basis																		
1	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Consortium
2	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
3	Consortium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance 9: extreme importance, 2, 4, 6, 8: intermediate values																			

D	The pairwise comparison matrix of alternatives: benefits basis																		
1	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Consortium
2	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
3	Consortium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance 9: extreme importance, 2, 4, 6, 8: intermediate values																			

E	The pairwise comparison matrix of alternatives: risk basis																		
1	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Consortium
2	BRIN	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
3	Consortium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International cooperation
1: equal importance, 3: moderate importance, 5: high importance, 7: very high importance 9: extreme importance, 2, 4, 6, 8: intermediate values																			

APPENDIX 2. RESULTS OF PAIRWISE COMPARISON MATRIX BETWEEN CRITERIA (11 RESPONDENTS)

R1	Op	Bu	Be	Ri
Op	1,00	3,00	0,33	5,00
Bu	0,33	1,00	0,20	3,00
Be	3,00	5,00	1,00	7,00
Ri	0,20	0,33	0,14	1,00

R2	Op	Bu	Be	Ri
Op	1,00	1,00	0,20	5,00
Bu	1,00	1,00	0,33	1,00
Be	5,00	3,00	1,00	3,00
Ri	0,20	1,00	0,33	1,00

R3	Op	Bu	Be	Ri
Op	1,00	3,00	0,17	6,00
Bu	0,33	1,00	0,33	3,00
Be	6,00	3,00	1,00	9,00
Ri	0,17	0,33	0,11	1,00

R4	Op	Bu	Be	Ri
Op	1,00	0,33	0,20	5,00
Bu	3,00	1,00	0,33	3,00
Be	5,00	3,00	1,00	5,00
Ri	0,20	0,33	0,20	1,00

R5	Op	Bu	Be	Ri
Op	1,00	0,14	6,00	7,00
Bu	7,00	1,00	0,17	5,00
Be	0,17	6,00	1,00	7,00
Ri	0,14	0,20	0,14	1,00

R6	Op	Bu	Be	Ri
Op	1,00	1,00	1,00	3,00
Bu	1,00	1,00	1,00	5,00
Be	1,00	1,00	1,00	5,00
Ri	0,33	0,20	0,20	1,00

R7	Op	Bu	Be	Ri
Op	1,00	0,14	1,00	1,00
Bu	7,00	1,00	1,00	7,00
Be	1,00	1,00	1,00	6,00
Ri	1,00	0,14	0,17	1,00

R8	Op	Bu	Be	Ri
Op	1,00	7,00	0,14	5,00
Bu	0,14	1,00	0,14	0,20
Be	7,00	7,00	1,00	7,00
Ri	0,20	5,00	0,14	1,00

R9	Op	Bu	Be	Ri
Op	1,00	5,00	1,00	5,00
Bu	0,20	1,00	0,14	0,33
Be	1,00	7,00	1,00	5,00
Ri	0,20	3,00	0,20	1,00

R10	Op	Bu	Be	Ri
Op	1,00	0,11	0,20	1,00
Bu	9,00	1,00	0,11	1,00
Be	5,00	9,00	1,00	5,00
Ri	1,00	1,00	0,20	1,00

R11	Op	Bu	Be	Ri
Op	1,00	7,00	7,00	7,00
Bu	0,14	1,00	1,00	1,00
Be	0,14	1,00	1,00	1,00
Ri	0,14	1,00	1,00	1,00

APPENDIX 3. RESULTS OF PAIRWISE COMPARISON MATRIX BETWEEN ALTERNATIVES CONCERNING THE OPPORTUNITY CRITERION (11 RESPONDENTS)

R1	BR	CO	IC
BR	1,00	3,00	5,00
CO	0,33	1,00	3,00
IC	0,20	0,33	1,00

R2	BR	CO	IC
BR	1,00	0,33	3,00
CO	3,00	1,00	3,00
IC	0,33	0,33	1,00

R3	BR	CO	IC
BR	1,00	0,17	0,11
CO	6,00	1,00	0,17
IC	9,00	6,00	1,00

R4	BR	CO	IC
BR	1,00	0,20	5,00
CO	5,00	1,00	7,00
IC	0,20	0,14	1,00

R5	BR	CO	IC
BR	1,00	0,11	5,00
CO	9,00	1,00	9,00
IC	0,20	0,11	1,00

R6	BR	CO	IC
BR	1,00	0,20	0,50
CO	5,00	1,00	3,00
IC	2,00	0,33	1,00

R7	BR	CO	IC
BR	1,00	0,14	0,14
CO	7,00	1,00	1,00
IC	7,00	1,00	1,00

R8	BR	CO	IC
BR	1,00	0,14	0,20
CO	7,00	1,00	7,00
IC	5,00	0,14	1,00

R9	BR	CO	IC
BR	1,00	0,11	0,11
CO	9,00	1,00	3,00
IC	9,00	0,33	1,00

R10	BR	CO	IC
BR	1,00	1,00	5,00
CO	1,00	1,00	9,00
IC	0,20	0,11	1,00

R11	BR	CO	IC
BR	1,00	0,14	0,14
CO	7,00	1,00	0,14
IC	7,00	7,00	1,00

APPENDIX 4. RESULTS OF PAIRWISE COMPARISON MATRIX BETWEEN ALTERNATIVES CONCERNING THE BUDGET CRITERION (11 RESPONDENTS)

R1	BR	CO	IC
BR	1,00	0,33	0,20
CO	3,00	1,00	0,33
IC	5,00	3,00	1,00

R2	BR	CO	IC
BR	1,00	0,33	3,00
CO	3,00	1,00	3,00
IC	0,33	0,33	1,00

R3	BR	CO	IC
BR	1,00	0,17	3,00
CO	6,00	1,00	9,00
IC	0,33	0,11	1,00

R4	BR	CO	IC
BR	1,00	0,33	4,00
CO	3,00	1,00	6,00
IC	0,25	0,17	1,00

R5	BR	CO	IC
BR	1,00	0,11	0,14
CO	9,00	1,00	0,11
IC	7,00	9,00	1,00

R6	BR	CO	IC
BR	1,00	0,20	0,50
CO	5,00	1,00	3,00
IC	2,00	0,33	1,00

R7	BR	CO	IC
BR	1,00	0,14	0,14
CO	7,00	1,00	1,00
IC	7,00	1,00	1,00

R8	BR	CO	IC
BR	1,00	0,20	0,20
CO	5,00	1,00	5,00
IC	5,00	0,20	1,00

R9	BR	CO	IC
BR	1,00	0,20	0,14
CO	5,00	1,00	0,20
IC	7,00	5,00	1,00

R10	BR	CO	IC
BR	1,00	9,00	1,00
CO	0,11	1,00	5,00
IC	1,00	0,20	1,00

R11	BR	CO	IC
BR	1,00	0,33	0,14
CO	3,00	1,00	0,14
IC	7,00	7,00	1,00

APPENDIX 5. RESULTS OF PAIRWISE COMPARISON MATRIX BETWEEN ALTERNATIVES CONCERNING THE BENEFITS CRITERION (11 RESPONDENTS)

R1	BR	CO	IC
BR	1,00	0,33	3,00
CO	3,00	1,00	5,00
IC	0,33	0,20	1,00

R2	BR	CO	IC
BR	1,00	0,33	3,00
CO	3,00	1,00	3,00
IC	0,33	0,33	1,00

R3	BR	CO	IC
BR	1,00	0,11	0,17
CO	9,00	1,00	3,00
IC	6,00	0,33	1,00

R4	BR	CO	IC
BR	1,00	0,33	5,00
CO	3,00	1,00	7,00
IC	0,20	0,14	1,00

R5	BR	CO	IC
BR	1,00	0,11	0,11
CO	9,00	1,00	0,11
IC	9,00	9,00	1,00

R6	BR	CO	IC
BR	1,00	0,20	3,00
CO	5,00	1,00	5,00
IC	0,33	0,20	1,00

R7	BR	CO	IC
BR	1,00	0,14	0,14
CO	7,00	1,00	1,00
IC	7,00	1,00	1,00

R8	BR	CO	IC
BR	1,00	0,14	0,33
CO	7,00	1,00	5,00
IC	3,00	0,20	1,00

R9	BR	CO	IC
BR	1,00	0,11	0,14
CO	9,00	1,00	3,00
IC	7,00	0,33	1,00

R10	BR	CO	IC
BR	1,00	1,00	5,00
CO	1,00	1,00	5,00
IC	0,20	0,20	1,00

R11	BR	CO	IC
BR	1,00	0,33	0,14
CO	3,00	1,00	0,14
IC	7,00	7,00	1,00

APPENDIX 6. RESULTS OF PAIRWISE COMPARISON MATRIX BETWEEN ALTERNATIVES CONCERNING THE RISK CRITERION (11 RESPONDENTS)

R1	BR	CO	IC
BR	1,00	3,00	5,00
CO	0,33	1,00	3,00
IC	0,20	0,33	1,00

R2	BR	CO	IC
BR	1,00	0,33	3,00
CO	3,00	1,00	3,00
IC	0,33	0,33	1,00

R3	BR	CO	IC
BR	1,00	3,00	0,17
CO	0,33	1,00	0,11
IC	6,00	9,00	1,00

R4	BR	CO	IC
BR	1,00	0,17	7,00
CO	6,00	1,00	8,00
IC	0,14	0,13	1,00

R5	BR	CO	IC
BR	1,00	7,00	0,11
CO	0,14	1,00	0,11
IC	9,00	9,00	1,00

R6	BR	CO	IC
BR	1,00	0,33	0,20
CO	3,00	1,00	0,50
IC	5,00	2,00	1,00

R7	BR	CO	IC
BR	1,00	0,14	0,14
CO	7,00	1,00	1,00
IC	7,00	1,00	1,00

R8	BR	CO	IC
BR	1,00	0,20	0,33
CO	5,00	1,00	5,00
IC	3,00	0,20	1,00

R9	BR	CO	IC
BR	1,00	0,33	0,11
CO	3,00	1,00	0,11
IC	9,00	9,00	1,00

R10	BR	CO	IC
BR	1,00	5,00	1,00
CO	0,20	1,00	1,00
IC	1,00	1,00	1,00

R11	BR	CO	IC
BR	1,00	0,33	0,14
CO	3,00	1,00	0,14
IC	7,00	7,00	1,00

APPENDIX 7. GEOMETRIC MEAN

Geometric mean of criteria

	Op	Bu	Be	Ri
Op	1,00	1,05	0,58	3,85
Bu	0,95	1,00	0,31	1,69
Be	1,71	3,20	1,00	4,85
Ri	0,26	0,59	0,21	1,00

Geometric mean of alternative based on opportunity criteria

	BR	CO	IC
BR	1,00	0,25	0,76
CO	4,00	1,00	2,25
IC	1,32	0,44	1,00

Geometric mean of alternative based on budget criteria

	BR	CO	IC
BR	1,00	0,31	0,48
CO	3,25	1,00	1,26
IC	2,09	0,79	1,00

Geometric mean of alternative based on benefit criteria

	BR	CO	IC
BR	1,00	0,22	0,67
CO	4,48	1,00	1,98
IC	1,49	0,50	1,00

Geometric mean of alternative based on risk criteria

	BR	CO	IC
BR	1,00	0,70	0,48
CO	1,44	1,00	0,74
IC	2,09	1,36	1,00