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JURNAL BPPK

ENHANCING CUSTOMS SURVEILLANCE WITH REMOTELY-PILOTED AIRCRAFT SYSTEM USING ANALYTICAL HIERARCHY PROCESS AS SELECTION TOOL

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ABSTRACT

Salah satu peran Direktorat Jenderal Bea dan Cukai yang berada di bawah Kementerian Keuangan adalah melindungi masyarakat dari aliran barang ilegal alias penyelundupan, keluar masuk negara. Dengan meminimalkan penyelundupan, Direktorat Jenderal Bea dan Cukai dapat menyelamatkan potensi kehilangan pendapatan dengan menerapkan denda dan menciptakan perdagangan yang lebih sehat untuk komoditas legal. Untuk memberantas penyelundupan, petugas Direktorat Jenderal Bea dan Cukai dilatih menggunakan senjata api, pemindai sinar-X, detektor narkotika, unit K-9, laboratorium kimia, dan kapal patroli yang berkisar dari panjang 7m hingga 60m. Sebelumnya, Direktorat Jenderal Bea dan Cukai mengoperasikan beberapa pesawat, tetapi sejak awal 2000-an aset udara tersebut tidak lagi beroprasi. Untuk menghadapi ancaman penyelundupan yang terus meningkat, Direktorat Jenderal Bea dan Cukai perlu mempertimbangkan penggunaan aset udara guna mendukung patroli darat dan laut, terutama di wilayah perbatasan. Kemajuan dalam teknologi Sistem Pesawat Terbang yang Dijalankan dari Jarak Jauh atau *Remotely-Piloted Aircraft System* (R.P.A.S.) dapat menjadi dasar aset udara masa depan Direktorat Jenderal Bea dan Cukai untuk pengawasan di perbatasan. Studi ini bertujuan untuk membantu Direktorat Jenderal Bea dan Cukai dalam memilih opsi R.P.A.S. terbaik di pasar. Dengan menggunakan Proses Hierarki Analitik (A.H.P.) untuk membantu pengambilan keputusan dan penilaian rata-rata tertimbang untuk menentukan urgensi dari enam kriteria utama, studi ini membandingkan lima opsi yang tersedia dari produsen lokal dan asing. Penelitian ini menyimpulkan bahwa Alternatif A adalah pilihan terbaik, menggabungkan harga dan biaya pemeliharaan yang relatif terjangkau dengan kinerja dan sensor yang layak.

One of the roles of Directorate General of Customs and Excise -which is positioned under the Ministry of Finance- is to protect the community from illegal flow of goods aka smuggling, into and out of the country. By minimizing smuggling, D.G.C.E. saves potential revenue losses through fines and promotes healthier trade in legal commodities. To support this effort, its officers are trained in firearms and equipped with X-ray scanners, narcotic detectors, K-9 units, chemical laboratories, and patrol vessels ranging from 7m to 60m. Previously, D.G.C.E. also operated several aircraft as aerial asset to detect potential smuggling activities. With the last aircraft rendered inoperative at the early 2000s, D.G.C.E. are now practically have zero aerial asset. To keep up with the ever-increasing smuggling threat, D.G.C.E. must consider to implement aerial asset to support its land and marine patrol unit in detecting potential smuggling activities, especially at the border. Advancement in Remotely-Piloted Aircraft System (R.P.A.S.) technology could serve as the basis of D.G.C.E.'s future aerial asset for surveillance at the border. This study aims to help D.G.C.E. in choosing the best R.P.A.S. option in the market to fulfill their need. Using Analytical Hierarchy Process (A.H.P.) to aid the decision-making step and weighted average scoring to determine the urgency of six main criterion, the study compares five available options from local and foreign manufacturers. This research concludes that the Alternative A is the best choice, combining relatively affordable price and maintenance cost with decent performance and sensor.

1. INTRODUCTION

As the largest archipelagic state in the world, Indonesia faces a huge challenge in protecting its border which shared with ten other countries. With more than 6 million km^2 total water area (including Exclusive Economic Zone), 54 thousand km of coastline, 3.100 km of land border, and 17 thousand islands, preventing smuggling along the border is such an enormous task for D.G.C.E. With more than 20.000 apprehended cases each year, less than 5% are attributed to border crossing case (whether by sea or land). Table below shows the total apprehensions by D.G.C.E. since 2021 to 2024.

Table 1 Apprehension data by D.G.C.E. from 2021-2023

Amount of Apprehension	2021	2022	2023		Value of Apprehended Goods	2021
Overall	20.800	33.512	32.912		Overall	Rp 24.450.000.000.000
Land border	352	410	656		Land border	
	1,69%	1,22%	1,99%			

(internal data from Directorate of Enforcement and Investigation)

The small percentage of apprehension case from border crossing, potentially causes survivorship bias for observer, which could further lead into false sense of security at the border. That's why, the strengthening of D.G.C.E.'s means of intelligence gathering, surveillance and reconnaissance at the border is an absolute necessity. To implement this, D.G.C.E. must be adapted to technological advancement. R.P.A.S. technology, which is now readily available and already proven by many, should be an option D.G.C.E. has to explore. As an aerial asset, R.P.A.S. could cover huge swath of land or sea area in a relatively short amount of time, and more often than not, less expensive compared to manned aircraft and satellite imagery, hence classified as a sort of force multiplier. With more land border and sea areas covered by surveillance, chance to find potential smuggling activities could be increased. The more D.G.C.E. could intercept, or at least, disrupt the illegal trade, the more potential revenue could be saved, the more people could be protected from harmful substances brought into the country, the more Indonesia's natural resources could be protected from export-oriented over-exploitation, and the less disturbance on local trade. All of these chain reactions reflect the core function of D.G.C.E.; as a revenue collector, trade and industrial facilitator and community protector. Since previously D.G.C.E. had implemented aerial surveillance by manned aircraft, re-enacting this concept could complete the long-lost piece of puzzle in its enforcement concept.

This study would delve deeper into the natural aspect of border patrol mission held by D.G.C.E. with the help of capable expert group in enforcement field, and how aerial assets could potentially impacting customs enforcement at the border. Further, this study aims to help D.G.C.E. to choose various market- ready R.P.A.S. option, which could benefit D.G.C.E. the most. The implementation of R.P.A.S. should also be cost-effective, safe, and responsive, which means, lots of aspect should be taken into consideration. Utilizing A.H.P. as a proven method to calculate the proportional importance of each factor, and objective scoring on each respective criterion for each alternative, the priority weight on the alternatives should represent the closest option to D.G.C.E.'s need for aerial asset to support its border patrol mission.

2. LITERATURE REVIEW

Remotely-Piloted Aircraft System

Remotely-Piloted Aircraft System (R.P.A.S.) is defined by International Civil Aviation Organization as a set of configurable elements consisting of a remotely piloted aircraft, its associated remote pilot station(s), the required command and control link and any other system elements as may be required, at any point during flight operation. While the aircraft itself, commonly referred as Unmanned Aerial Vehicle (UAV), unmanned aircraft, Remotely-Piloted Aircraft, or simply drone, R.P.A.S is more appropriate to use in this paper, since the capability needed to be implemented is more than just the aircraft.

Started as practice target for anti-aircraft artillery since 1916 in United Kingdom, R.P.A.S. gained significant civil utilization around a decade ago, with quadcopter model become widespread popularity for radio-controlled aircraft hobbyist. Various models are available at the market, with various categorization exists both in military or civilian use. However, to limit the scope of the explanation, this paper will focus on civilian R.P.A.S with vertical take-off and landing capability, to be used as intelligence, surveillance and reconnaissance mission, using day and night camera that could stream live video to the controller. Military grade drone, nor hobbyist quadcopter as the extreme examples of R.P.A.S. technology, are excluded from this paper.

The benefit of the system had been proven by many, especially concerning cost constraints. For example, Godshaw (2014) wrote about its cost-effectiveness and compared it to satellite imagery. Dinazar (2021) compared R.P.A.S. with arrays of manned system choices to support marine patrol unit. Today more Customs Institution are implementing R.P.A.S. worldwide, including U.S. Customs and Border Protection, Netherland Customs, and Dubai Customs.

Analytical Hierarchy Process

A.H.P. is a multi-criteria decision-making tool developed by Thomas Saaty in 1980s. This method could help us reaching a goal which has several criteria to be calculated, and several options to be chosen from. Using this method, problems are explained in three hierarchy: the goal to be achieved, the criteria to be considered, and an array of alternatives to be opted for. Knowing that not all criteria could be valued equally, this method included a comparison between two criteria, repeated until all criteria are compared one-by-one against each other; namely pairwise comparison. The comparison is using scale from 1 to 9; 1 implies that both criteria are of equal importance, 2 reads that one criterion is slightly more important than the other, up to 9 which shows that one criterion is massively more important than the other. The comparison then formed into a square matrix, where math begins to join the calculation. In this paper, specific calculation tools are used to simplify the process, while simultaneously calculating the eigenvector, Consistency Ratio, and weighted priority of the criteria.

After the priority of all the criteria are known, the next step is to compare the score of each alternative in regard to all the criteria. By multiplying the score of each alternative in every criterion with the weighted priority of the said criteria and repeating this process until each alternative is calculated in all the mentioned criteria, a priority weight and alternative rank could be determined, thus completing the decision-making process with a solid calculation backup.

3. RESEARCH METHODOLOGY

This research conducted by using A.H.P. as the main framework to determine which R.P.A.S. alternative is the best fit for D.G.C.E., based on criteria mentioned from interview with an expert group. The experts interviewed are those with relevant capability, experience, and authority in regard to the subject. To maximize data capture, more experts are interviewed until no more significant information is added with each additional expert, commonly called snowball sampling as opposed to population sampling where proportional number of individuals are interviewed to represent the whole population.

After the interview, the transcript then being extracted to find significant nodes or important points mentioned multiple times by multiple interviewees. These nodes then being clustered and labeled as criteria. The criteria then compare each other to count which one is more important, and how much. The larger the value given, signifying larger the importance on the criteria. This pairwise comparison was done multiple times with each respondent. Each comparison then counted again to find geometric mean value. After the geometrical mean was found, the data will be placed into a square matrix to find an eigenvector. The eigenvector value was calculated by multiplying the matrix with itself or using A.H.P. calculator application. Simultaneously, Consistency Ratio could be counted and made sure to be below 0,1 or 10%. This means that the comparison could make sense, with comparison not conflicting in value and importance. For example:

A. An expert said that criteria A is three times more important than criteria B, and criteria B is twice as important as criteria C. Then it could be concluded that criteria A is even more important than criteria C, logically speaking, six times more important than criteria C. If the said expert said that criteria A is 5 times more important than criteria C, this opinion is still considered acceptable.
B. An expert said that criteria A is three times more important than criteria B, and criteria B is twice as important as criteria C. But if the said expert said that criteria A is as important as criteria C, this opinion is considered illogical or has higher inconsistency.
C. An expert said that criteria A is three times more important than criteria B, and criteria B is twice as important as criteria C. But if the said expert said that criteria C is more important than criteria A, this opinion is considered unacceptable or has even higher inconsistency.

Five alternatives are identified, one from local manufacturer, two from European-based manufacturers, and two from China-based manufacturers. Relevant technical specification as follows, as per data stated by manufacturer.

Operational performance might differ in reality, subject to in flight condition.

Alternative A has a conventional hybrid Fixed-wing VTOL design, utilizing basic fixed wing design with T-tail combined with four motors placed on a spar on each wing for take-off/landing vertically.

Alternative B has blended body-wing fuselage with propeller behind its body and equipped with 4 VTOL motor. The efficiency of its fuselage design boost impressive flight performance of up to 3 hours under ideal condition.

Alternative C utilizes an unconventional method of minimizing dead weight by implementing tilting mechanisms on all four motors. When taking off/landing vertically, the front motors are tilted up and the ones at the back of the wing will be tilted facing down. When cruising (horizontal flight), the front motor will be tilted 90^0 forward and acted as twin tractor propeller in front of its wings, and the back ones will be tilted 90^0 backward to serve as twin pusher propeller (as the image above). By combining four motors in cruise flight, Alternative C has the highest wind tolerance among others, up to 19m/s.

Alternative D has conventional hybrid Fixed-wing VTOL design, utilizing basic fixed wing design with V-tail combined with four motors placed on a spar on each wing for take-off/landing vertically.

Alternative E utilizes unique approach by using tandem motors stationed at the front and back, and tilted motors at each wingtip. When taking off/landing, all four motors will be activated, and those wingtip motors will be faced upward. When cruising, the wingtip motors will be faced forward to act as twin tractor propellers, while the tandem motors on its main fuselage halted and locked to minimize air resistance.

4. RESULTS AND FINDINGS

Based on the interview, several criteria could be grouped into four main categories as follows:

- Cost (acquisition cost, maintenance cost and operational cost);
- Preparation (legal aspect, necessary permit and human resources as the operator);
- Performance (flight duration, control range, sensor capability, and take-off/landing method, operational easiness); and
- Risk (wind resistance, data safety, operation secrecy).

To simplify the comparison, the alternatives chosen in this study have a lot of commonalities in regard to various aspects such as:

- power source (which could impact operational cost; all alternatives are battery-powered, so no fuel needed), so comparison between alternatives could be done by comparing battery capacity;
- take-off/landing method (all alternatives have vertical take-off/landing or VTOL capability);
- usage of Line-of-sight telemetry (minimum 20km, maximum limited to 40 km ideally, affected by the earth's curvature).

Moreover, several criteria could be dropped from the equation thus simplifying equation. like:

- 'Preparation' criteria could be omitted from the equation, since regardless of the alternative, D.G.C.E. should prepare the same level of legal aspect, permit and crew training;
- Data safety could be omitted since all R.P.A.S. alternatives are not directly linked to foreign cloud storage;
- operational secrecy could be omitted, since all alternatives has VTOL capability, eliminating the needs of airstrip or catapult to launch the R.P.A.S., nor net to catch it after the mission, maintaining operational independence and secrecy from possible contra-intelligence party.

The criteria then being compared to find out the relative importance between them, using weighted average data from the expert group. The square matrix for the criteria comparison is stated as follows in appendix (table 7). From the table 7, it could be stated that 'Capability' is twice as important as 'Cost' or 'Risk', while 'Cost' and 'Risk' are equally important. If translated into priority, 'Capability' holds half the importance (50%) of the decision making for D.G.C.E.'s drone procurement, while 'Cost' and 'Risk' each hold a quarter of the importance (25% each). For 'Cost' criteria, since there are 2 sub-criteria, which is acquisition cost and maintenance cost, there's no need to make a square matrix. The weighted average value for those criteria is 1:2, which means that maintenance cost is perceived as twice as important as acquisition cost. Globally, the priority for acquisition cost will be 1/3 of the priority of 'Cost' criteria, and maintenance cost will be 2/3 of the priority of 'Cost' criteria. For 'Capability' criteria, the square matrix is stated as follow in appendix (table 8).

From the table 8 in appendix, it could be stated that 'Duration' is more important than

'Sensor'; with 'Sensor' itself is more important than 'Easiness'. Overall, 'Duration' holds 41,3% value for 'Capability', 'Sensor' holds 32,7% and 'Easiness' holds 26%. While at 'Risk' criteria, only 'Wind Resistance' matters, since another aspect of the 'Risk' criteria could be omitted.

Thus, the weighted average of the criteria's importance stated as follows (from the most important to the least important): Wind resistance (25%), flight duration (20,65%), maintenance cost (16,67%), sensor capability (16,35%), operational easiness (13%), and acquisition cost (8,33%). As for the alternatives, scores were given based on factors affecting sub-criteria stated as follows:

- Cost (Acquisition cost): the price to be paid for a whole system. The lower the price, the better the score for the said alternative. In this sub-criteria, a solid 1 point is given to the most affordable option, while the less-affordable alternatives will get a fraction of 1 point, based on the ratio of its price compared to the best alternative.

Value of alternative x on acquisition cost:

$$\frac{the\ most\ affordable\ acquisition\ cost}{the\ acquisition\ cost\ of\ alternative\ x}$$

- Cost (Maintenance cost): affected by replaceable and moving parts (motors and tilting mechanism, if any), which require periodic maintenance. More moving parts, battery amount per system, and the larger the battery capacity equals higher maintenance cost. In this criteria, 3 aspects being scored are: a) the amount and battery capacity, b) the number of motors, and c) the amount of tilting mechanism. Solid 1 point are given to the alternative with the smallest battery unit and capacity, alternative with smallest number of motors and moving parts, while other alternatives will be given a fraction of 1 point based on battery capacity/moving parts component ratio compared to the best option.

Value of alternative x on maintenance cost:

$$\frac{the\ smallest\ battery\ capacity}{the\ battery\ capacity\ of\ alternative\ x} + \frac{the\ least\ amount\ of\ motors}{the\ amount\ of\ motors\ on\ alternative\ x} + \frac{the\ least\ amount\ of\ tilting\ mechanism}{the\ amount\ of\ tilting\ mechanismon\ alternative\ x}$$

- Capability (Flight duration): longer the duration means better score for the said alternative. In this sub-criteria, a solid 1 point is given to the alternative with the longest flight duration, while other alternatives will get a fraction of 1 point, based on the ratio of flight duration compared to the best alternative.

$$\text{Value of alternative x on flight duration: } \frac{the\ flight\ duration\ of\ alternative\ x}{the\ flight\ duration\ of\ the\ best\ alternative}$$

- Capability (Sensor): the drone needs to have at least RGB camera with optical zoom capability and thermal capability to be able to help in night surveillance. The higher the resolution, the greater the magnifying capability/optical zoom of the camera, and additional sensor will give better score for the said alternative. In this criteria, 5 aspects being scored are: a) the resolution of main (RGB) camera, b) the optical zoom capability of said camera, and c) the resolution of thermal camera, d) the range of Laser-range-finder and e) the existence of another sensor. Solid 1 point are given to the alternative with highest resolution RGB camera, the most optical zoom capability, the highest resolution thermal camera, the furthest laser range finder, and the highest resolution of additional sensor, while other alternatives will be given a fraction of 1 point based on each aspect's ratio compared to the best option.

Value of alternative x on sensor capability:

$$\frac{the\ zoom\ capability\ of\ alternative\ x}{the\ zoom\ capability\ of\ the\ best\ alternative} + \frac{the\ camera\ resolution\ of\ alternative\ x}{the\ camera\ resolution\ of\ the\ best\ alternative} + \frac{the\ thermal\ camera\ resolution\ of\ alternative\ x}{the\ thermal\ camera\ resolution\ of\ the\ best\ alternative} + \frac{the\ range\ of\ laser\ range-finder\ of\ alternative\ x}{the\ range\ of\ laser\ range-finder\ of\ the\ best\ alternative} + \frac{the\ capability\ of\ another\ sensor\ of\ alternative\ x}{the\ capability\ of\ another\ sensor\ of\ the\ best\ alternative}$$

- Capability (Operational easiness): while all alternative incorporate detachable parts and components, the bigger and heavier the drone, means that the difficulties in assembly on site is greater. 2 aspects being scored are: a) maximum take-off weight (MTOW), and b) dimension, especially wingspan. In this sub-criteria, a solid 1 point is given to the alternative with the lowest weight and smallest dimension, while other alternatives will get a fraction of 1 point, based on the ratio of the weight and dimension compared to the best alternative.

Value of alternative x on operational easiness:

$$\frac{the\ MTOW\ of\ the\ best\ alternative}{the\ MTOW\ of\ alternative\ x} + \frac{the\ wingspan\ of\ the\ best\ alternative}{the\ wingspan\ of\ alternative\ x}$$

- Risk (wind resistance): the higher windspeed (m/s) tolerance during flight, the better score it gets. In this sub-criteria, a solid 1 point is given to the alternative with the highest wind resistance, while other alternatives will get a fraction of 1 point, based on the ratio of its wind resistance compared to the best alternative.

Based on the specification data stated by the manufacturer, values are given as follows in appendix (table 9). With sub-criteria priority value already counted, and alternative scores given as per data above, the decision-making process could be continued by multiplying the score for each sub-criteria of each alternative with priority value of the said sub-criteria. From the table 10, it could be concluded that alternative A has the highest priority weight, owing to its good sensor capability, affordable acquisition cost, and operational easiness (ranked 1st), and decent maintenance cost (ranked 2nd), which could compensate for its relatively low and flight duration (ranked 4rd, on par with alternative D) and wind resistance (ranked 4th), which is the most dominant criteria.

While the decision-making process could be simplified and at the same time, being scientifically proven, this method isn't bias free. More expert could be added into the equation, which could minimize personal bias and preference. Moreover, the more criteria involved, the better for the choosing mechanism, albeit increasing difficulty and lengthening the process.

Another factor to be considered is how the real performance of the product, as per the specified technical specification, is compared to the real-world performance. Hence, field trial of the said alternative could give richer insight and proof for the alternatives.

Last but not least, there are lots of factors outside the brochure and pamphlets, such as the real capability of the manufacturer/distributor of the product, in regard to production quality, product delivery, and after-sales service, which could be even more important in practice but uncaptured in this paper.

Further research and exploration on those aspects could support the result of the paper, by providing solid data of the said R.P.A.S. technology mentioned at the paper. More criteria need more data to be scrutinized, lengthening the decision-making process, which more often than not, are time sensitive. However, further insight on those unexplored criteria could strengthening the scientific proof on the decision-making process, in hope of choosing the best alternative to enhance the capability of customs surveillance, especially at places where conventional patrol by land/sea poses more threat and challenges.

5. CONCLUSIONS

R.P.A.S. technology, while promising on paper, should be inspected further before implementation. Based on collected data and methods used, criteria could be determined up to its relative weight to each other, and alternatives could be calculated by its score on said criteria. The most important criteria are wind resistance, followed by flight duration, maintenance cost, sensor capability, operational easiness and acquisition cost. The alternatives are ranked as follows: alternative A, alternative D, alternative E, alternative B, and alternative C.

This study is limited to the fact that it couldn't capture technical aspect of the manufacturer/distributor of the product, which needed to be inspected more thoroughly, and the real capabilities of the said system, which need some sort of Proof-of-concept (PoC) session so it could be assessed. In addition, timeframe add more limitation for the researcher to look for more expert to be interviewed, hence limiting the criteria that could be assessed.

Conceptually, while A.H.P. could help D.G.C.E. in choosing which R.P.A.S. to be procured and implemented, further research is needed. The most urgent aspect is to widen the scope of the expert group to broaden the criteria to be taken into consideration. The next step is to scrutinize detailed technical specifications in regard to the aforementioned criteria. Last, the availability of the data related to the technical capability of the manufacturer/distributor of the product, and real capabilities of the said system, could be tested by field visit and trial as valid supporting data, in which decision-maker would love to refer during the procurement process.

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APPENDIX

Figure 1. Hierarchy of D.G.C.E. Drone Procurement

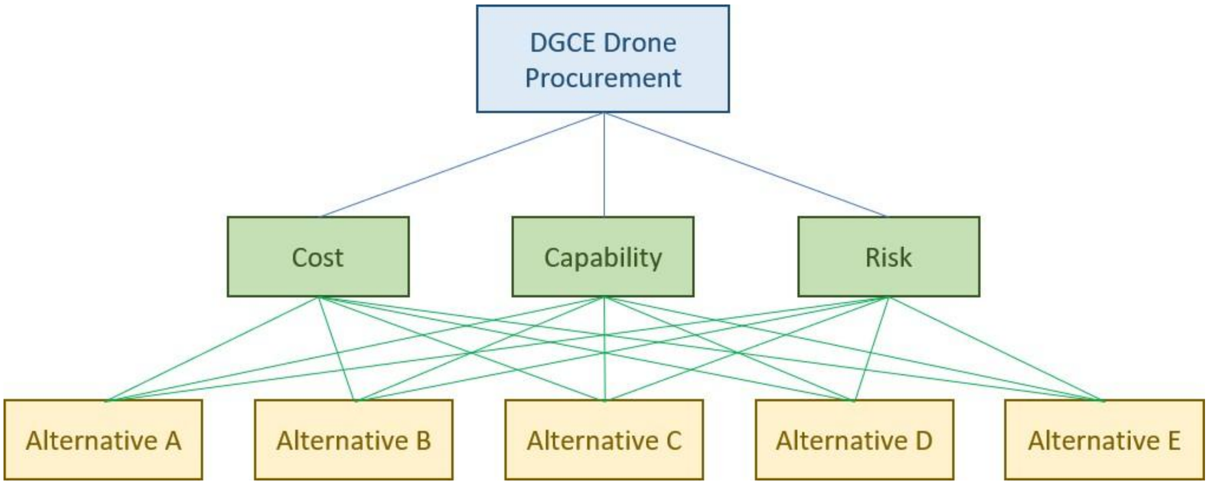

Table 2. Parameter for alternative A

<table>
<tr><td colspan="3">Drone Parameter</td><td>1.</td><td colspan="2">Acquisition Cost</td><td>Rp. 894.306.771</td></tr>
<tr><td>Manufacturer</td><td>Type</td><td>Country of Origin</td><td rowspan="2">2.</td><td colspan="3">Maintenance Cost Factor</td></tr>
<tr><td>BETA UAS</td><td>Omnibe</td><td>Indonesia</td><td>Battery</td><td>Motor</td><td>Tilt-rotor</td></tr>
<tr><td colspan="3" rowspan="8"></td><td></td><td>2 x 22,000 mAH</td><td>4+1 unit</td><td>none</td></tr>
<tr><td>3.</td><td colspan="2">Flight Duration (minutes)</td><td>120</td></tr>
<tr><td rowspan="3">4.</td><td colspan="3">Sensor Capability (SIYI ZT30)</td></tr>
<tr><td>RGB Camera</td><td>Thermal Cam</td><td>Other</td></tr>
<tr><td>4K (3840x2160), 30x optical zoom</td><td>640x512</td><td>2048 x 1080 wide lens, 1200m Laser Rangefinder</td></tr>
<tr><td rowspan="3">5.</td><td colspan="3">Operational Resonsiveness</td></tr>
<tr><td>Dimension</td><td colspan="2">Takeoff weight</td></tr>
<tr><td>2,7m wingspan</td><td colspan="2">13.5 kg (max)</td></tr>
<tr><td colspan="3"></td><td>6.</td><td colspan="2">Wind resistance (m/s)</td><td>12</td></tr>
</table>

Table 3. Parameter for alternative B

Drone Parameter		
Manufacturer	Type	Country of Origin
C-ASTRAL	SQA e-VTOL	Slovakia

No.	Parameter		
1.	Acquisition Cost	Rp. 3.500.000.000	
2.	Maintenance Cost Factor		
	Battery	Motor	Tilt-rotor
	1 x 20,000 mAH	4+1 unit	none
3.	Flight Duration (minutes)	180	
4.	Sensor Capability (EYE-X HD7)		
	RGB Camera	Thermal Cam	Other
	4K (1280x720), 20x optical zoom	640x480	None
5.	Operational Resonsiveness		
	Dimension	Takeoff weight	
	2,9m wingspan	10 kg (max)	
6.	Wind resistance (m/s)	12	

Table 4. Parameter For Alternative C

Drone Parameter		
Manufacturer	Type	Country of Origin
Germandrones	Songbird 150	Germany

No.	Parameter		
1.	Acquisition Cost	Rp. 4.729.050.340	
2.	Maintenance Cost Factor		
	Battery	Motor	Tilt-rotor
	2 x 22,000 mAH	4 unit	4
3.	Flight Duration (minutes)	150	
4.	Sensor Capability (Next Vision System)		
	RGB Camera	Thermal Cam	Other
	1280x720, 20x optical zoom	1280x720	None
5.	Operational Resonsiveness		
	Dimension	Takeoff weight	
	3,12m wingspan	15 kg (max)	
6.	Wind resistance (m/s)	19	

Table 5. Parameter for alternative D

Drone Parameter		
Manufacturer	Type	Country of Origin
Ahead X	QP530	China

No.	Parameter		
1.	Acquisition Cost	Rp. 3.427.680.000,	
2.	Maintenance Cost Factor		
	Battery	Motor	Tilt-rotor
	2 x 32,000 mAH	4+1 unit	none
3.	Flight Duration (minutes)	120	
4.	Sensor Capability (PG343TL)		
	RGB Camera	Thermal Cam	Other
	1920x1080, 30x optical zoom	640x512	1920 x 1080 wide lens, 2000m Laser Rangefinder
5.	Operational Resonsiveness		
	Dimension	Takeoff weight	
	3m wingspan	17 kg (max)	
6.	Wind resistance (m/s)	17	

Table 6. Parameter For Alternative E

Drone Parameter		
Manufacturer	**Type**	**Country of Origin**
Autel Robotics	Dragonfish Pro	China

No.	Parameter		
1.	Acquisition Cost	Rp. 5.332.440.000	
2.	Maintenance Cost Factor		
	Battery	Motor	Tilt-rotor
	2 x 35,000 mAH	4 unit	2
3.	Flight Duration (minutes)	145	
4.	Sensor Capability (DG LT20T)		
	RGB Camera	Thermal Cam	Other
	4K (3840x2160), 20x optical zoom	640x512	4000 x 3000 wide lens
5.	Operational Resonsiveness		
	Dimension	Takeoff weight	
	3,09m wingspan	17 kg (max)	
6.	Wind resistance (m/s)	15	

Table 7. Square Matrix And Priorities For Criteria

	A.H.P.	K1	K2	K3	Priority
Cost	K1		0.5	1	25%
Capability	K2	2		2	50%
Risk	K3	1	0.5		25%

(Consistency Ratio: 0%, which means the comparison make sense and could be accepted.

Table 8. Square matrix and priorities for criteria

		K2a	K2b	K2c	Priority
Duration	K2a		1	2	41,30%
Sensor	K2b	1		1	32,70%
Easiness	K2c	0,5	1		26,00%

(Consistency Ratio: 5,6%, which means the comparison makes sense and could be accepted.

Table 9 Scores given to each alternative

Criteria	Cost		Capability			Risk	Weighted Priority Value
Sub Criteria	Acquisition	Maintenance	Flight Duration	Sensor Capability	Operational Easiness	Wind Resistance	
Alt. A	1,00	2,25	0,67	3,18	2,00	0,68	1,55
Alt. B	0,26	2,80	1,00	1,75	1,90	0,63	1,38
Alt. C	0,19	1,70	0,83	1,80	1,77	1,00	1,25
Alt. D	0,26	2,11	0,67	3,08	1,69	0,89	1,46
Alt. E	0,17	1,79	0,81	3,00	1,69	0,79	1,39

Table 10 Alternative's Priority Weight and Rank

Criteria	Cost		Capability			Risk	Result		
Sub Criteria	Acquisi-tion	Mainte-nance	Flight Duration	Sensor Capability	Easiness	Wind Resistance	Priority Value		Rank
Priority value	8,33%	16,67%	20,65%	16,35%	13,00%	25,00%	Total	Weighted percentage	
Alt. A	1,00	2,25	0,67	3,18	2,00	0,68	1,55	22,04%	1
Alt. B	0,26	2,80	1,00	1,75	1,90	0,63	1,38	19,71%	4
Alt. C	0,19	1,70	0,83	1,80	1,77	1,00	1,25	17,74%	5
Alt. D	0,26	2,11	0,67	3,08	1,69	0,89	1,46	20,78%	2
Alt. E	0,17	1,79	0,81	3,00	1,69	0,79	1,39	19,73%	3