Indonesian Naval Technology College,STTAL
Postgraduate International Conference, Vol. 7th
ICMST 2023 May, 17th 2023

IDENTIFICATION AND MAPPING OF THE RELATIONSHIPS BETWEEN CRITERIA IN DECISION-MAKING FOR THE SELECTION OF UNMANNED AERIAL VEHICLES USING THE DEMATEL METHOD

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ABSTRACT

Decision-making is the process of selecting from several alternatives. Decision-making in selecting an alternative is a series of long processes, starting with identifying problems, seeking information about the alternatives to be selected, and analyzing how good each alternative is, leading to alternative decisions to be made. At the stage of identifying the criteria of an alternative, it is not only about identifying these criteria but also knowing the interrelationships between the criteria of the alternative to be selected. The DEMATEL method is one of the methods in multi-criteria decision-making that can be used to identify the interrelationships between criteria. In this study, calculations were carried out using the DEMATEL method to identify twenty criteria used in the selection of unmanned aircraft. From the results of this study, the DEMATEL method was able to identify and describe the relationship between the criteria quantitatively in the form of a table of the number of relationships and an impact-digraph map. The results of this study indicate that of the twenty criteria, four of the most influential criteria were obtained in the decision-making process for selecting an unmanned aircraft, with the payload criteria being the most influential criterion with the largest value of 0.412, followed by the political criteria in second place with a value of 0.356, while the endurance criteria and range are in third and fourth place on the four criteria that most influence the decision-making process for selecting an unmanned aircraft with a value of 0.355 and 0.341, respectively.

Keywords*: *Decision Making, MCDM, UAV, and DEMATEL

1. INTRODUCTION.

At this time, the Indonesian Air Force plans to purchase unmanned aircraft defense equipment to be placed at the 53rd Air Squadron Anang Busra Tarakan Air Base in order to support defense in the Koopsud II air area. In making the decision to determine the aircraft, careful consideration is needed so that the aircraft or defense equipment to be purchased can truly support the operational needs carried out. One of the stages in decision-making is determining the criteria that influence the decision. Decision-making is a series of processes carried out by decision-makers to identify problems related to the need to find information about a problem faced, then analyze and solve the problem. The decision in purchasing or selecting the defense equipment to be purchased or selected is the stage of the decision-making process, namely when consumers know the problem in choosing the defense equipment to be purchased or selected and the criteria required in selecting the defense equipment. These criteria are used in the selection process to find information about alternative choices and to evaluate the advantages and disadvantages of each alternative before moving on to the decision-making process.

According to the definition, a purchasing decision is a process carried out to identify all possible options for solving a problem, assess the choices systematically and objectively, and determine the targets for the advantages and disadvantages of each alternative choice. In this case, the product maker must be able to understand the various influences that can affect buyers and must be able to develop a model for understanding consumer decision-making. The product maker or manufacturer must be able to identify who is the decision maker, the types of purchasing decisions, and the steps in the buying process. In the research conducted (Do et al., 2017; Mulia et al., n.d.), it was found that technical factors such as aircraft quality and capabilities are factors that greatly influence a decision-making process in purchasing aircraft for military purposes. Based on the research data that has been processed, it can be concluded that the technical influence and capabilities of aircraft have a large or significant influence on decision-makers in determining the type of aircraft to be used or purchased to strengthen their military air power.

Meanwhile, in research conducted by (Do, 2019; Doži & Kali, 2014), the results of the analysis show that when purchasing aircraft for commercial purposes, non-technical factors such as brand image and price greatly influence the decision-making process. Based on the research data that has been processed, it can be concluded that the influence of the brand or type of aircraft and prices has a large or significant effect on the sale of airline tickets. So that this becomes one of the factors that influence decision makers, in this case the airlines, in determining or choosing alternative aircraft to buy. Based on the description above, there are two differences of opinion: the first opinion (Do et al., 2017; Mulia et al., n.d.) say that technical factors or criteria greatly influence the decision-making process in purchasing aircraft for military purposes. Meanwhile, the second opinions (Do, 2019; Doži & Kali, 2014) said that non-technical factors such as brand image and price greatly influence the decision-making process for purchasing an aircraft.

2. MATERIAL.

2.1. *Decision Making Trial And Evaluation Laboratory* (DEMATEL)

The DEMATEL method was developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976 in a Swiss Research Center project to evaluate and solve complex problems. In DEMATEL, visualization of the structure of complex causal relationships with a matrix or image is performed. The basis of DEMATEL is the theory of description, which allows us to realize the relationship between criteria based on the relationship of interests to cause and effect (Taghizadeh, 2021). In the DEMATEL structure, each factor or part can get influence either from other factors at a higher level or from a level below it. This technique is one of the best in decision-making methods that apply feedback. (Taghizadeh, 2021) recommends using the DEMATEL method for several reasons, one of which is as follows:

a. This method details the interrelationships with graph theory and displays the degree of association with a number or score.

b. This method uses a feedback relationship; each element can affect and be affected by other elements at the same level, either from the top level or from the bottom level.

c. The importance and weight of each element in the model are determined by all the factors contained in the model.

The steps in the DEMATEL method are as follows:

a. Determine the strength of association (evaluation scale) between criteria. At this point, the impact and potential linkages are evaluated by assessing the relationship between the criteria. The rating scale used varies according to the aims and objectives of the researcher himself. The larger the rating scale, the greater the probability that experts will assess the DEMATEL questionnaire. The rating scale used in this study refers to (Taghizadeh, 2021) between criteria. At this point, the impact and potential linkages are evaluated by assessing the relationship between the criteria. The rating scale used varies according to the aims and objectives of the researcher himself. The larger the rating scale, the greater the probability that experts will assess the DEMATEL questionnaire. The rating scale used in this study refers to (Taghizadeh, 2021), which is 0-4. A value of 0 means no effect (no relation or effect), 1 means low effect, 2 means moderate influence (medium effect), 3 has a high effect, and 4 has a very high effect.

b. Create a direct-relation matrix. Based on the assessment obtained from the expert regarding the relationship of influence, the next step is to list it in the direct relationship matrix. In this stage, if more than one expert is used, the average value between experts is calculated. In the matrix, Gij is the impact of the consequences caused by i to j. While the main diagonal line of the matrix is set to 0.

$$G = \begin{bmatrix} 0 & g_{12} & g_{1n} \\ g_{21} & 0 & g_{2n} \\ g_{n1} & g_{n2} & 0 \end{bmatrix} \quad (1)$$

c. The direct relationship matrix is normalized. Equations (2) and (3) are used to normalize the resultant direct relation matrix G to become an X matrix. The largest number in each row and column is 1, and the main diagonal matrix remains 0.

$$X = v.G \quad (2)$$

where,

$$v = \, min_{ij}\left\{\frac{1}{max_i \sum_{j=1}^{n} g_c^{ij}}, \frac{1}{max_j \sum_{i=1}^{n} g_c^{ij}}\right\} i, j\epsilon\{1,2,\dots,n\} (3)$$

Direct and indirect relation matrix After getting the X matrix build direct and indirect (Tc)

matrix relationship using equation 4.

$$T_c = (I - X)^{-1} \;\; , I_{=matriks\ Identitas} \quad (4)$$

d. Calculates row and column totals. After obtaining the Tc matrix, the next step is to calculate the total row (Di) and total column (Rj) with equations (5) and (6).

$$Di = \left[\sum_j^n T_{c_{ij}}\right] \;\; , i = 1,2,\dots,n \quad (5)$$

$$Ri = \left[\sum_i^n T_{c_{ij}}\right] \;\; , j = 1,2,\dots,n \quad (6)$$

e. Construction of the DEMATEL causal model The causal DEMATEL model is presented as a digraph. In a cause-and-effect diagram, the horizontal line is (Di+Ri), while the vertical line is (Di-Ri). The relationship (Di-Ri) shows that the various levels of variables affect and influence each other, while (Di+Ri) describes the overall level of variables that influence each other. A positive value (Di-Ri) indicates that certain variables have a stronger influence than others and therefore are given priority over others. These variables are referred to as dispatchers. Variables that have negative values (Di-Ri), which are usually referred to as beneficiaries, are given more weight and are considered to be given the last priority. The greater the value of a variable (Di+Ri), the greater the relationship between variables, which is indicated by its value.

f. Get the relationship in the form of an impact diagram. This map is obtained by converting the x and y coordinates into a Cartesian diagram. If y is positive, then the criterion is a causal group where the criterion affects other criteria and vice versa. If x is negative, then these criteria are influenced by other criteria.

2.2. Methodology

Prosedur penelitian yang dilaksanakan dalam penelitian untuk melakukan pemodelan DEMATEL ditunjukkan pada Gambar 1 berikut.

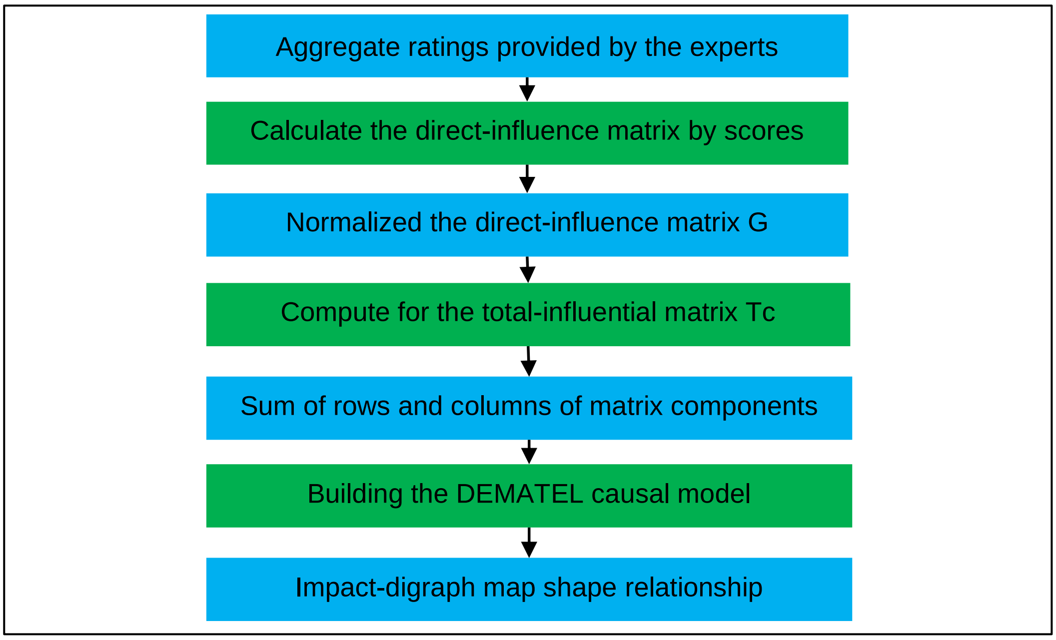

Figure 1. Step of DEMATEL Method

Figure 1 shows the steps for working with the Dematel method. The first step is to calculate the average value of the questionnaire obtained from experts. This average value is then used as input in the direct relationship matrix. The next step after obtaining the direct relationship matrix is to normalize the matrix. After getting the normalized matrix, calculate the total value of the relationship between the criteria. After obtaining the value of the total relationship between the criteria, the next step is to build the DEMATEL causal model, and the last step is to make a map of the relationship between the criteria in the form of an impact-digraph map.

3. RESULT AND DISCUSSION.

In this study, the DEMATEL method was used to describe the relationship that occurred between the criteria obtained by conducting a questionnaire with the experts. The assessment carried out is a pairwise comparison with a scale to describe the influence of the relationship between one criterion and other criteria, from a zero value indicating no effect to a maximum value of four, which indicates a very high influence of one criterion on other criteria. From the results of this assessment, it can be described how the causal relationship that occurs between these criteria The criteria used in this study were obtained based on references from several studies that have been conducted (Francisco et al., 2022; Hamurcu & Eren, 2020; Rodríguez, 2020), as can be seen in Table 1.

Table 1. UAV Selection Criteria

Criteria	Description
Altitude (C1)	Relating to the ability to fly the aircraft
Endurance (C2)	Relates to how long the plane can be in the air
Range (C3)	Relates to the minimum operating radius of the aircraft

Sensor system (C4)	sensor capabilities possessed to carry out observation, reconnaissance, recording and target action.
Communication system (C5)	completeness of the channel The frequency of the link used
Number of operators (C6)	the number of personnel required for the operation of the aircraft
Length (C7)	The length of the aircraft is measured from front to back
Wingspan (C8)	The length of the wing of the aircraft from the tip of the left wing to the right
Payload (C9)	the maximum weight of the weapon carried
Engine Power (C10)	maximum engine power that can be generate
Cruise speed (C11)	aircraft cruising speed that can be generated
Fuel capacity (C12)	the maximum amount of fuel that an aircraft can carry or transport
Maximum take off weight (C13)	the maximum weight of the aircraft for takeoff
GCS size (C14)	GCS control room dimensions
Spare parts (C15)	availability of spare parts and the impact of a possible embargo
Maintenance tools (C16)	availability of maintenance and care tools
Price (C17)	The budget for the purchase of 1 unit of aircraft
Political (C18)	bilateral and multilateral diplomatic relations that can influence decision making
Transfer of Technology (C19)	Complete packages offered such as training and manual books for maintenance
Strategic (C20)	deterrence effect or influence on military strength in regional countries

Table 1 is a collection of criteria that will be used in making decisions on the selection of unmanned aircraft for the 53rd air squadron of the Anang Busra Tarakan air base. Twenty criteria were used, namely: altitude (C1), endurance (C2), range (C3), sensor system (C4), communication system (C5), number of operators (C6), length (C7), wingspan (C8), payload (C9), engine power (C10), cruise speed (C11), fuel capacity (C12), maximum takeoff weight (C13), GCS size (C14), spare parts (C15), maintenance tools (C16), price (C17), political (C18), transfer of technology (C19), and strategic (C20).

After carrying out the initial identification regarding the criteria used, the next step is to evaluate the relationships and interactions between the criteria. Assessment of the intensity of the relationship (interaction) is carried out with the aim of determining the impact and effectiveness of the relationship or the influence of the relationship between one criterion and another. In accordance with the steps for working on the DEMATEL algorithm in Figure 1, The steps for working with DEMATEL according to the algorithm shown in Figure 1 are as follows:

a. Intensity Evaluation (Rating) Scale

Relations between criteria The size of the rating scale used in this study is a scale of 0–4. A value of 0 means no influence or interaction; a value of 1 means a small level of influence or interaction; a value of 2 means a moderate level of influence or interaction; a value of 3 has a strong influence or interaction; and a value of 4 has a very strong influence or interaction. The rating scale used refers to research by Li and Tzeng (2009). In Table 2, it can be seen that the meaning of the correlation assessment or influence relationship, namely (C2, C17), is rated 4, which means that criterion (C2) has a very large level of influence on criterion (C17). At (C1, C5), it is rated 3, which means that criterion (C1) has a strong degree of influence on criterion (C5). At (C4, C2), a score of 1 means that criterion (C4) has a small degree of influence on (C2). While the value 0 is given to mean that the risk event does not have the level of influence as in (C1, C14).

b. Direct Relationship Matrix

In this stage, the results of the assessment of risk events are summarized according to the rating scale. This matrix is then called matrix G. The main diagonal of the matrix is assigned a value of 0. Table 3 is a recap of the results of calculating the average result of a direct relationship between criteria.

c. The direct link matrix is normalized.

With equations (2) and (3), the direct relationship matrix (G) is then normalized to become a matrix (X). The maximum number of rows and columns in a fixed matrix is 1, while the main diagonal is 0. The all-relationship matrix equation (4) produces a total relationship matrix (Tc). Microsoft Excel software is used in this phase to assist with calculationsThe direct link matrix is normalized.

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d. Calculating the total number of rows and columns

After creating the Tc matrix, the total row (Di) and column total (Rj) calculations are performed with equations (5) and (6). The calculation of the total row (Di) and total column (Rj) is carried out with the aim of obtaining the importance and relationship of each criterion. Table 6 is a calculation of Di minus Ri (Di-Ri) and Di adding up Ri (Di+Ri).

Table 2. the value of the relationship between the criteria

Criteria	**Di**	**Ri**	**Di + Ri**	**Di-Ri**
Altitude (C1)	1.807	1.712	3.520	0.095
Endurance (C2)	2.020	1.665	3.686	0.355
Range (C3)	2.114	1.772	3.886	0.341
Sensor system (C4)	2.347	2.041	4.388	0.307
Communication system (C5)	2.060	1.989	4.049	0.071
Number of operators (C6)	1.108	1.008	2.116	0.099

Length (C7)	1.688	1.418	3.106	0.270
Wingspan (C8)	1.685	1.442	3.128	0.243
Payload (C9)	2.091	1.679	3.769	0.412
Engine Power (C10)	2.228	1.999	4.227	0.228
Cruise speed (C11)	1.769	1.813	3.582	-0.044
Fuel capacity (C12)	1.464	1.626	3.090	-0.162
Maximum take off weight (C13)	1.370	1.577	2.948	-0.207
GCS size (C14)	1.155	1.228	2.382	-0.073
Spare parts (C15)	1.975	1.912	3.887	0.063
Maintenance tools (C16)	1.378	1.924	3.302	-0.547
Price (C17)	2.343	2.764	5.107	-0.422
Political (C18)	1.966	1.611	3.577	0.356
Transfer of Technology (C19)	1.413	1.879	3.292	-0.466
Strategic (C20)	1.130	2.049	3.179	-0.919

The calculation results (Di-Ri) in Table 4 illustrate the magnitude of the influence between the various criteria. A positive score (Di-Ri) designates the criterion as a sender because it indicates that the criterion has more weight than the other criteria and should be given priority over the others. Negative scores (Di-Ri) designate criteria as recipients because they may be considered to have the lowest priority and receive more weight. The calculation results (Di+Ri) show how closely the criteria are related. A stronger association is indicated by a higher (Di+Ri) value.

e. Establish a causal relationship. DEMATEL

The DEMATEL causal relationship is made in the form of a diagram. Value (Di+Ri) is defined as importance or superiority, while value (Di-Ri) is defined as a relationship and shows priority. The mapping in the diagram uses (Di+Ri) as the horizontal line and (Di-Ri) as the vertical line. (Di+Ri) shows the overall level of criteria that influence each other, and (Di-Ri) shows a relationship that means different levels of criteria will be influenced and affect the others.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
C1	0	0.09649	0.100312	0.117932	0.11607	0	0	0	0.0899	0.1186	0.1026	0.0963	0	0	0	0	0.1436	0	0	0.1153
C2	0.105135	0	0.10405	0.11225	0.10992	0	0.099097	0.1	0.0883	0.1305	0.1132	0.121	0	0	0.1081	0.0885	0.1649	0.0949	0.0947	0.1333
C3	0.108121	0.10599	0	0.121437	0.11933	0	0.099088	0.1	0.1075	0.1362	0.1162	0.1078	0.095	0	0.1092	0.0949	0.173	0.1034	0.0986	0.1377
C4	0.123682	0.105506	0.115567	0	0.1375	0	0.088182	0.092	0.1084	0.1172	0.1032	0.0996	0.1079	0.1044	0.1363	0.1374	0.1919	0.1168	0.1439	0.1449
C5	0.114847	0.096738	0.116938	0.12891	0	0	0	0	0.0911	0.0933	0	0	0.0965	0.0983	0.1231	0.1263	0.167	0.0925	0.123	0.1286
C6	0	0	0	0.09201	0	0	0	0	0	0	0	0	0	0.0929	0	0.0918	0	0	0	0
C7	0	0	0	0.103073	0.09586	0	0	0	0.0935	0.1057	0.0947	0.0916	0.0935	0	0.1014	0.0964	0.125	0	0	0
C8	0	0	0	0.094628	0.09272	0	0	0	0.0988	0.111	0.0975	0.0946	0.0965	0	0.1006	0.1009	0.1216	0	0	0
C9	0.095648	0.101837	0.111242	0.114871	0.11537	0	0.103549	0.1045	0	0.1182	0.122	0.115	0.113	0	0.1069	0.1065	0.159	0	0.1017	0.1201
C10	0.128017	0.123821	0.130445	0.112077	0.10964	0	0.100142	0.1011	0.1217	0	0.1389	0.1209	0.1281	0	0.1182	0.117	0.1642	0	0.1051	0.1343
C11	0.096407	0.094743	0.097957	0.10041	0.0935	0	0	0	0	0.1066	0	0	0	0	0	0	0.15	0.0883	0.0921	0.1165
C12	0.088291	0	0.089837	0	0	0	0	0	0.0883	0.1081	0.1037	0	0.0968	0	0	0	0.106	0	0	0
C13	0	0	0	0	0	0	0	0	0.0953	0	0	0.0949	0	0	0	0	0.1005	0	0	0
C14	0	0	0	0	0	0.0906	0	0	0	0	0	0	0	0	0	0	0.0999	0	0	0
C15	0.10446	0.104708	0.108739	0.133548	0.12651	0	0	0	0	0.1294	0.1035	0	0	0	0	0.1189	0.1622	0.0961	0.1211	0.1179
C16	0	0	0	0.093249	0.09219	0	0	0	0	0	0	0	0	0	0.0901	0	0.1216	0	0.0955	0
C17	0.113129	0.110692	0.115428	0.145918	0.14392	0	0.096068	0.0972	0.1317	0.1536	0.1437	0.1132	0.0961	0.0913	0.1241	0.1284	0	0.1183	0.1217	0.131
C18	0	0	0	0.111742	0.10993	0	0	0	0	0.1062	0.0983	0	0	0	0.1493	0.1474	0.1805	0	0.1497	0.1537
C19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1019	0.1034	0.1235	0.0951	0	0.1044
C20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1209	0.0977	0	0

Figure 2. Network Relationship Map (NRM)

Figure 2 is a Network Relationship Map (NRM). To describe NRM, the threshold value of the total relationship matrix (Tc) is first calculated. The threshold value is the average value of all values from the total relationship matrix (Tc). In this study, the threshold value was 0.088. Values lower than the threshold value of 0.088 in the Tc matrix are treated as if there is no relationship, so that data can be deleted (replaced with zeros).

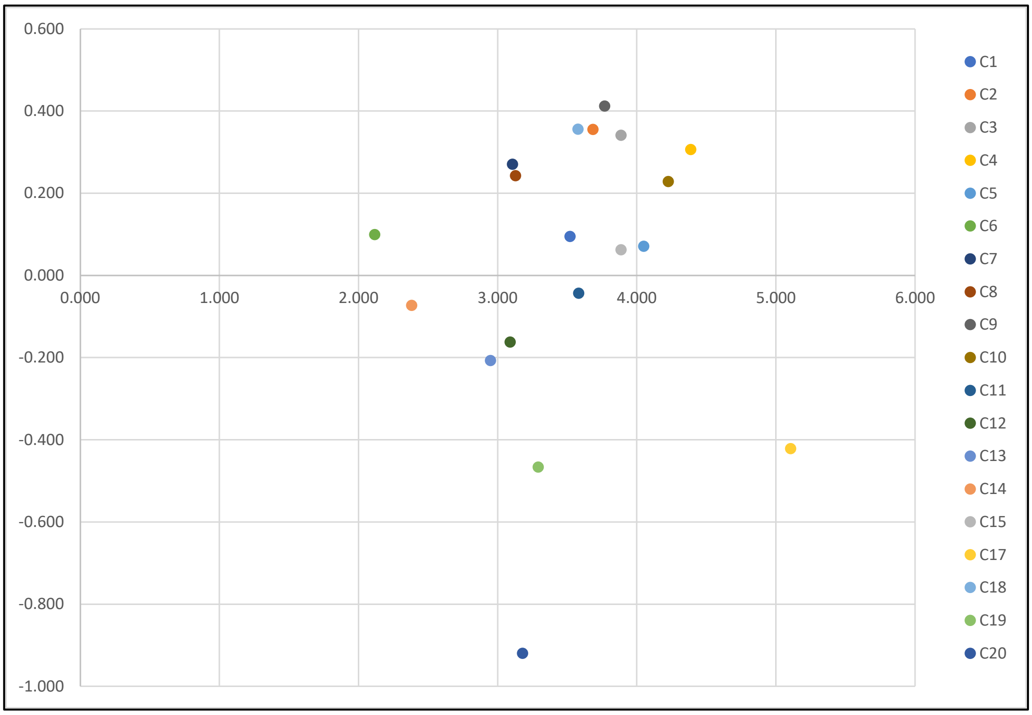

Figure 3. Impact Digraph Map

Figure 3 shows the overall distribution of criteria based on importance and relationship. The results (Di+Ri) of all criteria have a positive value on the X axis (horizontal), so all criteria can be said to have importance. In the causal matrix, the criterion that has the greatest relationship and is the first priority is the payload criterion (C9), which has a very large level of influence because it is also offset by a strong and positive value relationship. This payload criterion (C9) is referred to as a dispatcher and is a criterion with a high degree of interaction influence and a driving force for other criteria. This also applies to the criteria Altitude (C1), Endurance (C2), Range (C3), Sensor System (C4), Communication System (C5), Number of Operators (C6), Length (C7), Wingspan (C8), Engine Power (C10), Spare Parts (C15), and Political (C18). The criteria for cruise speed (C11), fuel capacity (C12), maximum takeoff weight (C13), GCS size (C14), maintenance tools (C16), price (C17), transfer of technology (C19), and strategic (C20) are called receivers because they have a negative level of influence, but the level of relationship is still relatively strong because they have a positive value.

1. CONCLUSION.

In this research, identification and mapping of interrelationships between criteria have been carried out in the decision-making process for selecting an unmanned aircraft. In this case, the study or case study is an unmanned aircraft that will be selected for military purposes (TNI AU). Criteria Altitude (C1), Endurance (C2), Range (C3), Sensor System (C4), Communication System (C5), Number of Operators (C6), Length (C7), Wingspan (C8), Payload (C9), Engine Power (C10), Spare Parts (C15), and Political (C18) are dispatchers, namely the level of influence is very large because it is also offset by a strong and positive value relationship level. While receivers are other criteria. The findings of this study show that, out of the 20 criteria, four were found to be the most important in the decision-making process for choosing an unmanned aircraft. The payload criteria was found to be the most important, with a value of 0.412, followed by the political criteria in second place with a value of 0.356, and the endurance criteria and range in third and fourth place on the list of the four factors that most influence the decision-making process. The DEMATEL approach should be used in conjunction with a quantitative validation process, according to suggestions or recommendations for additional study.

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