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FORMULATING KRI MARITIME SECURITY CAPABILITY USING FUZZY WEIGHTING

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ABSTRACT

KRI or Indonesian Navy warships has very significant role in maintain the maritime security and uphold the law on Indonesian waters. In order to deploy their KRI, TNI AL needs to measure their KRI Maritime Security (KAMLA) capability. This paper aim is to provide a formula that express KAMLA capability of a KRI out of 3 criterions (sensors, weaponry & Platforms) and 9 sub criterions. Fuzzy Weighting method has been used to derived 4 expert preference into formula of criterion weight. The result is KC = 0,45 S + 0,23 W + 0,32 P. Further work still need to do develop the formula into more detailed criterion.

Keywords: *KRI, Maritime Security, Fuzzy Weighting*

1. INTRODUCTION

KRI or Indonesian Navy warships become main instrument in maintaining the maritime security and uphold the law on Indonesian waters (Kasal, Buku Putih Kamla, 2004). Right now, Indonesian Navy (TNI AL) have more than 20 types of KRI. It spread to Escort , Amphibi , Submarine, Patrol, Survey, Support, and Fast Attack division. Each type has their own technical specifition and mission capabilities. Unfortunatelly, due to high maritime security missions demand and patrol ship technical readiness, TNI AL had been forced to deploy other type of ships to patrol mission. In order to deal with that, a formula of ships criterion combination is needed to calculate the ships Sea Security Patrol Mission (KAMLA) capability. Those formula can use by TNI AL Headquarter's operation staff to plan their KAMLA mission's unit accuratelly than just using intuitions.

In this research, the important criterion in determining ships KAMLA capability are Sensors, Weaponry and Platforms as in the following Figure 1

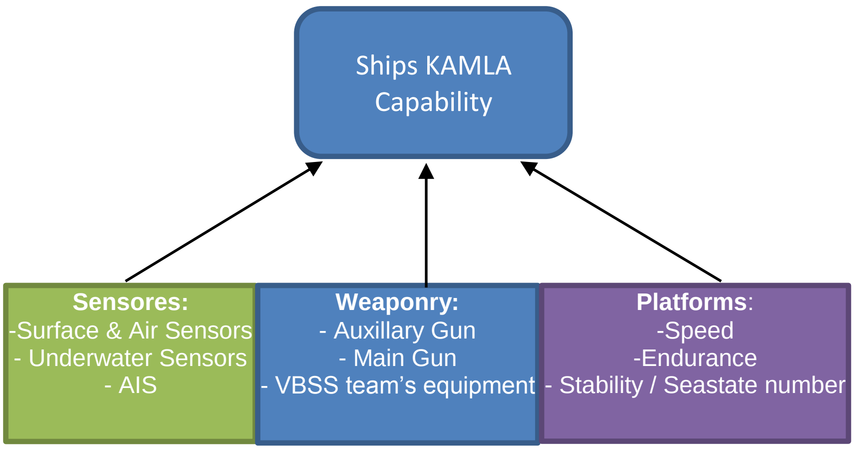

Figure 1 *The Important Criterion of Ships in KAMLA mission*

1.1 KRI

Indonesia should be able to control and secure the owned entire sea area in accordance with the provisions in the United Nations Convention on the Law of the Sea, UNCLOS'82. Efforts to control and safeguard the territorial sea are conducted through the maritime security patrol ships held by KRI and the Naval Bases as the supporting bases. As time being, TNI AL possesed 180 plus of KRI and deployed in several division such as Escort, Submarine, Amphibious, Fast Attack, minewarfare, Patrol, Support and Survey. In accordance with Maritime Security mission, Escort, Fast Attack and Patrol ships are considered appropriate and mostly deployed. Some technical specification of KRI shown in table 1 below.

Tabel 1. KRI Technical Specification Sample

No.	Spesifikasi Teknis	PKR 10514	LPD	KCR 60 M
1.	Radar	Thales SMART-S Mk2, Scout Mk2	2-I Band	Navigation
2.	Fire control	Thaler STIR 1.2 Mk2	N/A	N/A
3.	Sonar	Kingklip (hull mounted) CAPTAS 2/UMS (VDS)	N/A	N/A
4.	Main Gun	Rheinmetal, 76mm	2 x 20 mm	57 mm
5.	Rudal	4 x Exocet blok 2 atau 3, 12 x VL-MICA	N/A	2 x C-705
6.	Torpedo	6 tabung Eurotrop	N/A	N/A
7.	ECM & ESM	Scorpion 2 & Vigile 100	N/A	N/A
8.	Decoy / chaff	FFBNW	N/A	N/A
9.	SeaState	4-5	3-4	3-4
10.	Kecepatan	24 Kn	15 Kn	27 Kn
11.	Displacement	2365 Tonnes	7417 tonnes	460 tonnes
12.	Helly	1 Bell / Bo	2 Super Puma	N/A
13.	Personel	100	130	43

Source: Jane's Fighting Warship (Jane's, 2018)

1.2 Important Criterion of Ships

Each KRI has different characteristics under consideration of sensors, weaponry and platforms, which can be detailed as follows:

KRI Sensors

Ships ablity to comperhend their situation as well as detecting threat is dtermined by their sensores. In this paper, the sensores are:

a. Air and surface sensores. These are equipments to detect object on sea surface and or inthe air. This also main sensors of ships to help them navigate through waters.
b. Underwater sensor. This equipment help ship to detect underwater object such as submarines or torpedoes.
c. Automatic Identification Systems. A system that developed to display certain identifiction when detected. It make opther ship easier to differ one from another.

KRI Weaponry

KRI as a warships naturaly will has several type of weaponry installed or carried. Those are :

a. Auxilliary Gun. A "small" caliber gun that vary from 12,7 mm to 30 mm. It installed in sideward of ships.
b. Main Gun. A medium range gun that vary from 40 mm to 120 mm and installed on bow or astern side of ships.
c. VBSS team's equipment. This equipmnet mostly consist of handcarried firearm, combat helmet, bulletproff vest and armed water vessel. This team role is essential when KRI need to do physical inspection onboard target ships .

KRI Platforms

KRI's Platform has significant role in KRI success on patrol mission as well as other missions. Platforms in this paper will refered to :

a. Speed. It is determine how fast a KRI can go and presumably how quick it can get to a trouble spot. It also detemine the number of covered area of patrol mission in certain time.
b. Endurance. This feature determine how long a KRI can operate before resupply. The higher it number, the longer a KRI can operate between supllies.
c. Stability (Seastate number). It expresed the limit of KRI to operate under bad condition. the number are 1 to 5 and the higher number means more capable a KRI to operate in bad water and weather conditions.

2. MATERIAL AND METODHOLOGY

2.1 Fuzzy Multiple Criteria Decision Making (MCDM)

The Fuzzy Multi-Criteria Decision Making (FMCDM) is a decision making method intoduced by Liang & Wang (1994). FMCDM which consists of theories, processes, and analytical methods for decision making that involves uncertainty, dynamics, and aspects of the multi-criteria decision. Multi Criteria Decision Making (MCDM) is the terminology used in solving problems whose existence MCDM approach is expected to get the best alternative.

I their paper, Liang & Wang stated that" The first level is to evaluate fuzzy importance and continue wtih second level is to assign ratings to the candidates (Liang & Wang, 1994)". Using this algorithm, the decision-maker's fuzzy assessments will taken into account in the aggregation process to make sure a more convincing and accurate choice.

Fuzzy theory was proposed by Lotfi Zadeh (1974) with his paper "Fuzzy sets and their applications to cognitive and decision processes". With fuzzy theory, it shown that concept of fuzzy can be applied on all theories or continues membership function (Suharyo, Manfaat, & Armono, 2015).

Fuzzy Multiple Criteria Decision Making (FMCDM) used for banking performance evaluation on a Balanced Scorecard (BSC), It shows that it performance using the BSC framework can be useful and effective tool (Wu, Tzeng, & Chen, 2009). FMCDM also used to select an environmental watershed in China (Chen, et al., 2011), manpower selection (Ashari, 2015), find weight location routing problem (Torfi, Farahani, & Mahdavi, 2016) and prioritizing renewable energy alternatives (Çolak & Kayab., 2017) .

The Proposed Methodology in this research can be shown in the following figure 2.

Sequence of data processing using fuzzy MCDM algorithm will be detailed in 12 steps. (Suharyo, Manfaat, & Armono, 2015). In this paper not all steps is necessary, instead of 12, it only needs 6 steps to determine the weight of criteria. The steps will be:

Step 1. Processed the questionnaire results to table of level assessment qualitative criterion and sub criterion.

Step 2. Processed the assessment results of criterion and sub criterion to get aggregate value.

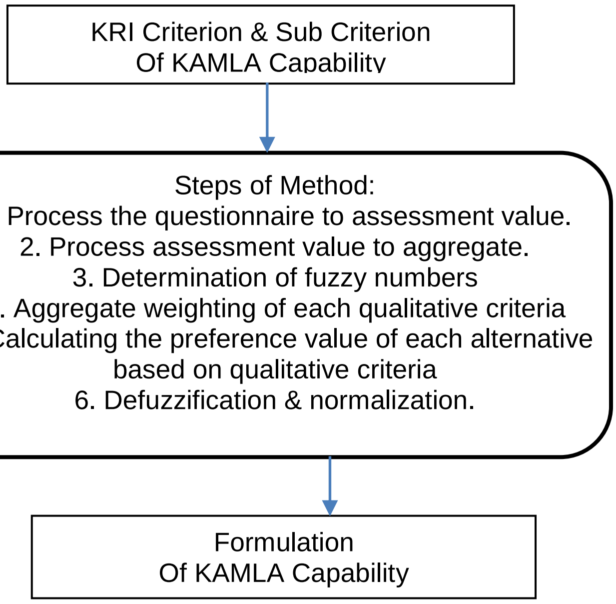

Figure 2 *The Proposed Methodology Diagram*

Step 3. Determining the mean fuzzy numbers, by adding the value that appears in aggregate tables and then dividing the sum by the number of criteria that value into the inside of the linguistic assessment level. The mathematical notation is as follows

$$a_t = \frac{\sum_{i=1}^{k}\sum_j T_{ij}}{\sum_{i=1}^{k} n_{ij}}$$

a_t = median fuzzy numbers to levels
T = the level of assessment is very low, low, medium, high and very high.
N = number of scale linguistic scale factor for an alternative to T-1 of the i-th factor
T_{ij} = numerical value of the scale for an alternative to linguistic T-1 of the j-th factor.

Step 4. Determining the value of the lower limit and upper limit value fuzzy numbers, where the lower limit value (ct = b (i - 1)) is equal to the mean level down, while the upper limit value (bt = b (i - 1)) is the same as the mean level on it.

Step 5. Determining the aggregate weight of each qualitative criteria, by searching for the aggregate value of the respective lower limit value (ct), the mean (at) and the upper limit value (bt), which can be modeled as follows:

$$c_t = \frac{\sum_{j=1}^{n} c_{tj}}{n} \qquad a_t = \frac{\sum_{j=1}^{n} a_{tj}}{n} \qquad b_t = \frac{\sum_{j=1}^{n} b_{tj}}{n}$$

c_{tj} = lower limit value of qualitative criteria to-t by decision makers to-j
a_{tj} = median qualitative criteria to-t by decision makers to-j
b_{tj} = the value of the upper limit to the qualitative criteria-t by decision makers to-j
n = number of assessors (decision maker)

Aggregate value is $N = (c_j, a_j, b_j)$
where
Nt = Value aggregation weights for qualitative criteria to-t

Step 6. Defuzzy the value to finish the Fuzzy weight steps following with normalisation of defuzzy number of each criterion and sub criterion. The result of normalisation will be the criterion and sub criterion weight. Those weights can be combined to create a formula of KAMLA capability of KRI.

2.2 Analysis and Data Processing

The next step in this research is to determine weighted of criterion and sub criterion of KRI KAMLA capability. Questionnaire has been done by 4 expert assesor or decision makers (X1-X4) who are competent in Naval Operation and Maritime Security. Scale of questionnaire is divided into two linguistic scale and a numerical scale. The examples of linguistic scale is "very low", "low", "medium", "high" and "very high", while numerical scale interval of values take 1-10.

Having obtained the data from the questionnaire, the next step is to recapitulate the results of the questionnaire and data processing. Sequence of data processing using fuzzy MCDM algorithm above is as follows

Step 1. Processed the questionnaire results to table of level assessment qualitative criterion and sub criterion.

Table 2. Criterion Score

Criteria	X1	X2	X3	X4
Sensors	8	8	9	10
Weaponry	6	7	7	7
Platform	7	8	8	8

Table 3. Sub Criterion Scores

Criterion	Subcrit	Expert			
		X1	X2	X3	X4
Sensors	Surf & Air	7	10	9	10
	AIS	9	9	9	9
	SubSurf	7	9	9	7
Weaponry	Aux Gun	7	8	8	10
	VBSS	8	9	9	8
	Main Gun	4	9	8	7
Platform	Speed	9	9	8	9
	Endurance	9	8	8	8
	Seastate	9	8	8	8

Step 2. Processed the questionnaire results of criterion and sub criterion to get aggregate value.

Table 4. Aggregate of Criterion

Linguistic	X1	X2	X3	X4
Very low				
Low				
Middle	6			
High	7,5	7,666667	7,5	7,5
Very High			9	10

Table 5. Aggregate of Sub Criterion

Linguistic	X1	X2	X3	X4
Very Low				
Low				
Middle	5			
High	7,25	8	8	7,6
Very High	9	9,166667	9	9,5

Step 3. Determining the mean fuzzy numbers, by adding the value that appears in aggregate tables and then dividing the sum by the number of criteria that value into the inside of the linguistic assessment level.

Step 4. Determining the value of the lower limit and upper limit value fuzzy numbers, where the lower limit value (ct = b (i - 1)) is equal to the mean level down, while the upper limit value (bt = b (i - 1)) is the same as the mean level on it.

Step 5. Determining the aggregate weight of each qualitative criteria, by searching for the aggregate value of the respective lower limit value (ct), the mean (at) and the upper limit value (bt). Result of step 3 to 5 will be shown in table below:

Table 6. Fuzzy Number of Criterion

	X1			X2			X3			X4		
Lingustik	ct	at	bt	ct	at	bt	ct	at	bt	ct	at	bt
Very low												
Low												
Middle	1	6	7,5									
High	6	7,5	10	1	7,667	10	1	7,5	9	1	7,5	10
Very High							7,5	9	10	7,5	10	10

Table 7. Fuzzy Number of Sub Criterion

Linguistik	ct	at	bt	ct	at	bt	ct	at	bt	ct	at	bt
Very low												
Low												
Middle	1	5	7,25									
High	5	7,25	9	1	8	9,167	1	8	9	1	7,6	9,5
Very High	7,25	9	10	8	9,167	10	8	9	10	7,6	9,5	10

Step 6. Defuzzy the value to finish the Fuzzy weight steps following with normalisation of defuzzy number of each criterion and sub criterion. The result of normalisation will be the criterion and sub criterion weight. Those weights can be combined to create a formula of KAMLA capability of KRI.

Table 8. Final Weight of Criterion

Criterion	ct	at	bt	Defuzzy	Weight
Sensors	5,5	8,542	10	7,773831	0,449551
Weaponry	1	7,167	9,125	4,028871	0,232985
Platform	2,25	7,542	9,75	5,489736	0,317465

Table 9. Final Weight of sub Criterion of Sensors

Subcrit	ct	at	bt	Defuzzy	Weight
Surf & Air	7,15	8,729	9,75	8,474117	0,33936
AIS	7,713	9,167	10	8,908451	0,356753
Subsurf	5,5	8,254	9,625	7,588319	0,303887

Table 10. Final Weight of Sub Criterion of Weaponry

Subcrit	ct	at	bt	Defuzzy	Weight
Aux Gun	3,65	8,188	9,292	6,52398	0,329682
VBSS	5,5	8,254	9,625	7,588319	0,383467
Main Gun	2,75	7,442	8,938	5,6764	0,286851

Table 11. Final Weight of Sub Criterion of Platform

Subcrit	ct	at	bt	Defuzzy	Weight
Speed	5,963	8,917	9,75	8,033014	0,408521
Endurance	2,563	8,15	9,417	5,81531	0,295739
Seastate	2,563	8,15	9,417	5,81531	0,295739

3. RESULT AND DISCUSSION

3.1. Formulation

Using technical specification as criterion and sub criterion, an Indonesian Naval Warship's / KRI KAMLA capability can be formulized as follow:

a. KC = 0,45 S + 0,23 W + 0,32 P , which : KC : KAMLA Capability, S : Sensor onboard, W : Weaponry On Board, P : Platform of KRI
b. S = 0,34 SA + 0,36 AI + 0,30 SS , which S = Sensors, SA : Surface & Air, AI : Automatic Identification System, SS : Sub Surface sensor.
c. W = 0,33 AG + 0, 38 VB + 0,29 MG , which W = Weaponry, AG : Auxiliary Gun, VB : VBSS weapon & equipment, MG : Main Gun.
d. P = 0,4 SP + 0,3 EN + 0,3 SS , which P = Platform, SP: Speed, EN: Endurance, SS: Seastate capability number

3.2. Sensitivity Analysis

a. Sensors is the most significant variable on KRI KAMLA Capability. It has weight of 0,45 and dominated the other 2 variables. The fluctuation of sensor's value will affect KRI KAMLA capability greatly.
b. Among the sensors onboard KRI, Automatic Identification System (AIS) has the biggest effect in determining the success of KRI KAMLA mission. AIS has weight of 0,36 while the other 2 not so far from it. Overall those sensors have equal number in determining KRI sensor value.
c. VBSS has weight of 0,38 and become the most important part in weaponry of KRI when performing KAMLA mission.
d. Speed considered most important features of a ship in performing KAMLA. Speed has weight of 0,4 and dominating influence on KRI Platform.

4. CONCLUSION

This Paper proposed a formula of KAMLA (Maritime Security) mission Capability of KRI by processing expert preference on 3 criterions and 9 sub criterion using Fuzzy Weighting method.

The formula is: KC = 0,45 S + 0,23 W + 0,32 P, which : KC : KAMLA Capability, S : Sensor onboard, W : Weaponry On Board, P : Platform of KRI

This formula can be developed with more criterion (such as communication and personnel) and more number of expert to provide a robust result.

TNI AL Integrated Weapon Fleet System (SSAT) has 4 elements (Kasal, DOKTRIN Jalesveva Jayamahe, 2018) . To perform a KAMLA operation SSAT capability still need to be formulated following figure 3, where KRI KAMLA capability become one of the element. Along with Maritime Security Level and TNI AL development policy, SSAT build a loop of dynamic KAMLA capability cycle.

Author Statement. This paper is the result of the author research for the purposes of education only and development of operations research and modeling science, not a result of the policy of the TNI AL institution, because the data used is confidential, and is used for educational purposes only without reducing the substance of modeling and study interests.

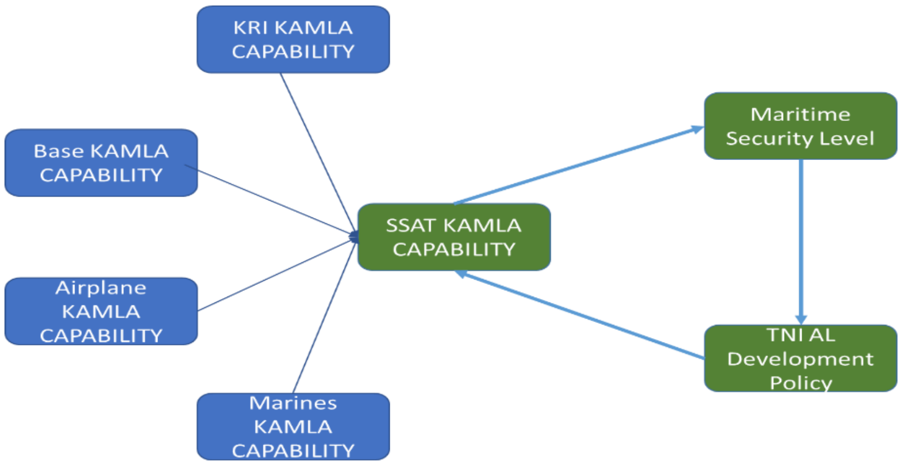

Figure 3. *Diagram of KAMLA capability Development in the Next Research*

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