Alternative location determination of frozen tuna industry using analytical hierarchy process (AHP)

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Abstract. Tuna is a large pelagic fish that is widely found in Indonesian waters as one of the countries that have an important role in global tuna production. Moreover, tuna has the potential to be processed into frozen tuna. The added value as the result of the freezing process will increase the economic value of this product. Thus, it makes frozen tuna potential to be developed into an industry. One of the things that need to be considered in the establishment of an industry is location determination. The study was aimed to determine an alternative location for the frozen tuna industry in Banda Aceh city will be done. The method used in this research is the Analytical Hierarchy Process (AHP). The criteria used are Tuna Fish Production, Human Resources, Transportation Access, Institutional Support, and Availability of Infrastructure. The alternative location that will be determined is Kuta Alam Sub-district, Kuta Raja Sub-district, Meuraxa Sub-district, and Syiah Kuala Sub-district. The calculation result using the AHP method indicates that the most appropriate location for the establishment of the frozen tuna industry is Kuta Alam Sub-districts with a weight of 0.428, thus the district was chosen as the best location for the establishment of the frozen tuna industry.

1. Introduction
Tuna is a large pelagic fish widely found in Indonesian waters. Indonesia is one of the countries that have an important role in global tuna production. According to Firdaus [1], Indonesia produces about 16% of the total world’s tuna consumption because the volume of tuna production in Indonesia reaching about 362,639.2 tons [2]. It is presumed that the volume should be higher if the government contributes to preventing illegal trading [3]. This production volume varies in each region in Indonesia. One of many areas that has a large production of tuna is Aceh Province.

Aceh Province is the 6th largest tuna production in Indonesia or the highest tuna production volume in Sumatra. Aceh's tuna production volume reaches 22.291 tons per year [4]. The high volume of tuna production in Aceh must be in line with the ability to handle this commodity because tuna is a perishable product, so it requires handling to maintain the quality of the product. One of the treatments
that can be done is processing tuna into frozen tuna. The freezing process is expected to slow down the damage and decay in products because low temperatures can inhibit the growth of microorganisms, inhibit the rate of chemical reactions, and enzyme activity that is one of the causes of this occurrence. The freezing process carried out on tuna can also add value to the product.

The added value as the result of the freezing process will increase the economic value of this product. It makes frozen tuna potential to be developed into an industry. Industry takes a major role in regional economic development, public welfare, and national development. The establishment of the industry should take notice of several factors and having proper planning. One of the things that must be considered and planned is the location or area where the industry will be built. Yap et al. [5] said that location is the most important criterion in site determination.

Dewanti and Santoso [6] stated that several factors can affect the location determination of industries such as the availability of raw materials, labour, markets, accessibility, and electricity resources. While Fitrianingrum and Aulia [7] in their research on determining the location of corn-based industry use several criteria to determine it, such as basic physical conditions, accessibility, labour, raw materials, facilities, and infrastructure, agglomeration, institutional, and land suitability. Many factors can be the criteria to determine the location of an industry, therefore, a method that can help decision-making is needed to facilitate this process.

AHP method is a decision-making system that uses the perception of humans, who are experts to decide a problem. This decision-making system has been applied in various field such as economics, politics, and engineering [8]. In this decision-making process, the experts will assess pairwise comparisons between the criteria that have been set for the problem [9]. The usage of the AHP method in determining location has been carried out by Susilowati and Hidayatulloh [10] to determine the location of the home industry in Pringsewu District. Timisela [11] said that the AHP method is more efficient as it is based on the experiences and judgements of experts in the field. Therefore, in this study, the location of frozen tuna technology will be determined using the AHP method.

2. Materials and methods
This study used two types of data, primary data, and secondary data. Primary data was collected from observations, questionnaires, and discussions with experts. Three experts involved in this study came from academics, practitioners, and governments who have insight into the potential of tuna in Aceh, exports and imports of food commodities and fisheries, or those who have experience in similar businesses. Data obtained from the questionnaire filled by experts will be analysed using the Analytical Hierarchy Process (AHP) method. The stages involved in alternative selection using the AHP method are as follows [12]:

1) Determine problems and alternative solutions that can be done.
2) Organize a hierarchy that begins with goals, criteria, and alternatives
3) Make a paired comparison between criteria that will be assessed by experts. The geometric mean will be calculated from the result of the paired comparison from experts, using the following formula:

\[ GM = \sqrt[\text{n}]{X_1 X_2 \cdots X_n} \]  

Where:
- \( GM \) = Geometric Mean
- \( X_1 \) = First responder rating
- \( X_2 \) = Second respondent's assessment
- \( n \) = Number of Assessments

4) Calculate eigenvalues and logical consistency, data can be considered to be consistent or valid if the CR value ≤ 0.1 by using the following formula:

\[ CR = \frac{CI}{IR} \]  

Where:
- \( CR \) = Consistency Ratio
- \( CI \) = Consistency Index
- \( IR \) = Random Index

This consistency ratio (CR) will measures the uniformity of expert’s answers to the paired comparison or the AHP question [13].

5) Determine the priority of each paired comparison in each element of the hierarchy. Then, determine the global priorities that will be used for final ranking of the criteria, sub-criteria, and alternatives, and selection of the best one for each [14].

3. Results and discussion

The determination of industrial locations should be based on the criteria related to it. In the AHP method, criteria and alternative locations are needed to be able to determine the location. Criteria and alternative locations are determined from the results of discussions with experts and literature studies. Determination of criteria and alternatives using literature studies was also conducted by Mardesci et al. [15] on their research in determining prospective areas for the development of coconut agroindustry. In the AHP method, criteria and alternative locations determined will be arranged into a hierarchy due to their level.

Kusmindarti [16] stated that the hierarchy is functional because the arrangement is based on the parts that have the most important relationships. This hierarchy consists of several levels, namely goals, criteria, sub-criteria, and alternative decisions. In this study, the hierarchy consists of three
levels: Goals (level 1), criteria (level 2), and alternative location (level 3). The alternative location determination of frozen tuna industry hierarchy is as shown in Figure 2.

Susilowati and Hidayatulloh [10] stated that there are factors that should be considered in the determination of agro-industrial location such as raw material, labour, energy resources, transportation, markets, technology, and environmental conditions. Polyzos et al. [17] also said that there are many factors to be considered in determining the location of agro-industrial such as transportation cost, labour cost, raw material cost, and land cost. Kuswardhani et al. [18] in their research to determine the location of coffee agroindustry used nine factors, which are production processes, quality, human resources, institutions, capital, tools and technology, marketing, education and members farmer groups. However, in this study, only five criteria will be used to determine the location of the agroindustry, including tuna fish production, human resources, transportation access, Institutional support, and infrastructure availability. These selected criteria are considered to be the main factors in determining the location of the frozen tuna agroindustry. Moreover, Figure 2 also shows the alternative locations that have been determined to build the frozen tuna industry in Banda Aceh city. Four alternative sub-districts would be the option for industry locations. Alternative locations are selected based on proximity to raw material sources and land availability.

The criteria and alternative locations determined will be compared in pairs. The paired comparison will be done by the experts by providing a value on each of the paired criteria. The value scale used is 1-9, the best scale for representing opinions [19]. The scoring scale is as described in Table 1. After conducting a paired comparison, the data from three experts will be geometrically averaged (geometric mean). Geometric mean is a mathematical process that used to get a single value that represents all the respondent’s answer [20]. Then, the eigenvalue and logical consistency will be calculated. If the results are consistent (CR≤ 0.1), then the data can be used and the priority of the criteria and alternative locations can be determined.

| Intensity of Importance | Information                                    |
|------------------------|------------------------------------------------|
| 1                      | Equal importance                               |
| 3                      | Slightly more important (moderate importance)  |
| 5                      | More important (strong importance)             |
| 7                      | Very strong importance                         |
| 9                      | Absolutely more important (extreme importance) |
| 2, 4, 6, 8             | mid-score up and down grades                   |
| Opposite               | If for activity i gets one number compared to activity j, then j has the opposite value compared to i |

Based on the results of data processing, the data that has been consistent and has a certain weight will be the determinant for decision making of frozen tuna industry location. Figure 3 shows that tuna
production criteria have the highest weight value of 0.495. It makes this criterion a top priority in the
decision-making of determining the location of this frozen tuna industry. It is in line with the results
from Candy and Pamungkas [21] research that also used the AHP method to determine agroindustry
locations, where raw material criteria become priority criteria in the location determination. The raw
material criteria is a priority because it has the highest weight among others, about 0.311.

Figure 3. Weight of each location selection criteria.

Weighting is also done on alternative locations that have been determined. This weighting is
carried out between alternative locations to each criterion. The results of the weighting of alternative
locations based on tuna production criteria can be seen in Figure 4. Figure 4 shows that based on the
criteria of tuna production, the district that has the highest weight is Kuta Alam Sub-district (0.407)
and followed by Kuta Raja Sub-district (0.251), Meuraxa Sub-district (0.250), and Syiah Kuala Sub-
district (0.092). Commonly, raw material production and access to raw material are more considered
factors than other factors [17].

Figure 4. Location alternative weights based on tuna production.

Weighting carried out on alternative locations based on Human Resources, Transportation Access,
Institutional Support, and Infrastructure Availability also shows that Kuta Alam district has the highest
weight on each weighting. On weighting based on Human Resources, Kuta Alam Sub-district weights
0.497 and followed by Meuraxa Sub-district with 0.198 (Figure 5). The same thing happened to the
weighting based on Transportation Access (Figure 6), Institutional Support (Figure 7), and
Infrastructure Availability (Figure 8), where Kuta Alam Sub-district became the priority and Meuraxa
Sub-district became the second priority for the selection of the industrial locations.
Kuta Alam Sub-district becomes the location with the highest weight value based on human resources (Figure 5) because the sub-district has the largest population of 53,000 people when compared to other sub-districts [22]. Besides quantity, the quality of human resources is also must be considered in the selection of locations based on human resources. The qualities of human resources that need to be considered are physical and non-physical qualities. The physical qualities in question are in the form of posture, strength, endurance and health. Non-physical qualities that need to be considered are the ability to think, work, and have skills. HR is intended as workers who can be in the form of human resources in government institutions, human resources who act as entrepreneurs who will play a direct role in determining the quality of workers, and also experts who play a role in observing and improving quality [23].

Transportation accessibility is the ease of access to reach a location. The main transportation access to be considered is the road. Transportation access is important to note in choosing the location of industry because it determines the sustainability of economic activities, and can also help improve the economy of an area [24]. Road infrastructure or transportation access has a very significant role in accelerating agricultural production and also agroindustry development [25]. On the weighting of alternative locations based on transportation access; it is known that the Kuta Alam Sub-district has the highest weight (Figure 6). Kuta Alam Sub-district has a road length of 72.51 km, consisting of 68.56 km of city roads and 3.95 km of village roads [24].
Figure 7. Location alternative weights based on institutional support.

Institutional support is a rule or value regulated by an institution, usually by the government, and it will affect an industry. Figure 7 shows that Kuta Alam Sub-district is a location that has the highest weight value based on institutional support because there are Lampulo Fishing Port and Lampulo Fish Auction Place in the sub-district which became the centre of fish trade in Banda Aceh City. Therefore, Aceh Government gives full support to the plans for industrial establishment in the area.

Figure 8. Location alternative weights based on infrastructure availability.

Infrastructure is a basic facility of public interest, which includes river lines, railway lines, sea routes, building construction, sewer facilities, electricity, and bridges. Based on the availability of infrastructure, Kuta Alam Sub-district was chosen to be an alternative location for the establishment of the frozen tuna industry in Banda Aceh City (Figure 8). Kuta Alam Sub-district already has a good infrastructure system, such as highways, electricity availability, fibre optic network, telephone network, and also has fishing port infrastructure.

Table 2 shows that Kuta Alam Sub-district as a whole is the Sub-district that has the highest value weight of 0.428. It makes Kuta Alam Sub-district the chosen location in the establishment of the frozen tuna industry in Banda Aceh City. Kuta Alam Sub-district has an area of 1004.70 ha and 11 villages. This district is the second-largest district in Banda Aceh city. According to Robin et al. [24], the sub-district is dominated by residential areas and trading areas. The areas are also planned to be the centre for trade services in the city of Banda Aceh.
Table 2. Priority ranking determining the location of frozen tuna industry in Banda Aceh City.

| Location                  | Tuna Production | Human Resources | Transportation Access | Institutional Support | Infrastructure Availability | Priority Ranking |
|---------------------------|-----------------|-----------------|-----------------------|-----------------------|-----------------------------|------------------|
| Kuta Alam Sub-Districts   | 0.407           | 0.497           | 0.385                 | 0.392                 | 0.498                       | 0.428            |
| Kuta Raja Sub-Districts   | 0.251           | 0.183           | 0.186                 | 0.217                 | 0.150                       | 0.214            |
| Meuraxa Sub-Districts     | 0.250           | 0.198           | 0.251                 | 0.239                 | 0.224                       | 0.238            |
| Syiah Kuala Sub-Districts | 0.092           | 0.122           | 0.179                 | 0.152                 | 0.128                       | 0.119            |

4. Conclusions
The criteria that have the largest to the smallest value weight in a row are Tuna Production (0.495), Transportation Access (0.162), Infrastructure Availability (0.150), Human Resources (0.137), and Institutional Support (0.057). Furthermore, the results of location alternative priorities determination show that Kuta Alam Sub-district has the highest weight of 0.428, thus the district was chosen as the best location for the establishment of the frozen tuna industry.

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