Benefit-cost for selecting technology in salt production

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Abstract. This paper discusses the costs of choosing the technology for the salt production process using the Analytical Hierarchy Process (AHP) technique. The strength of the strategy to the selection of production process technology based on the benefit-cost ratio by several criteria. The choice of salt production technology is traditional techniques, tunnelling techniques, prism techniques, and FDS (Flow down system) techniques. The AHP structures are the criteria and sub-criteria. AHP criteria give impacts such as production process technology, salt quality, production costs, and human resources. From these criteria, the cost of investment modal and maintenance have the highest weight — the quality of salt determined by the colour, NaCl content, and size of the salt granules. The criteria for production costs consist of sub-criteria for raw material costs, capital investment costs, and indirect costs. The level of technology is conventional technology, semi-modern technology, and modern technology. Human resources are the experience of farmers in processing salt production. The production costs needed for the salt production process greatly determine the farmer decision to obtain the optimal quality and quantity of salt. The second priority is the ease of production process technology and successively the following criteria as human resources and the quality of the salt produced. The recommended technology for production process based on AHP by using B/C ratio and consideration as indicators are tunnel and prism techniques.

1. Introduction
Salt is one of the strategic commodities that cannot be replaced by other products. The stability of the fulfillment of salt needs must be maintained. The need for salt divided into two, namely consumption salt and industrial salt. Consumption salt has a minimum NaCl of 94,7% and used for raw material iodized salt, various foods. Industrial salt has minimum NaCl level of 97% used raw material industry [1].

Factors that affect salt production are sea water, soil, climate/weather, capital, technology, and labour. Seawater is the primary raw material for salt. Land topography affects the quality of salt. A functional topography is sloping and has a tide of less than 1 meter to facilitate obtaining sea water. Also, the texture of ponds is a determinant of the influence of the production factors of people's salt products. While this produces salt in a traditional way that is poor in technology so that the climate dramatically affects the quality and amount of salt provided. Technology improvement cannot make because of limited capital [2]. The weakness of salt production technology carried out by farmers is using conventional technology. The traditional technique is highly dependent on the relatively short dry season, 4 to 5 months and a relatively high humidity level of 60-70% so that it can overtake the salt evaporation process. The worker who processes salt are labourers from low education so that
difficulties in providing guidance. And a land area of ponds owned by farmers is classified narrow (0.5 hectares per farmer) making it challenging to increase salt productivity.

The indicator of salt quality based on SNI 04-3556–2012 for consumption salt and SNI 04-3556–2016 for industrial salt can be considered from the colour, NaCl content, and size of the salt. In the WO 2007/036949 patent, it was stated that approximately 60% of the world's production salt used for industrial applications based on chlor-alkali and caustic soda industries [3]. The problem most often found in salt consumption with the direct method of crystallisation with sunlight resulting the salt with a very high impurity so that the purity of the salt has not reached its maximum. The existence of component MgCl$_2$, MgSO$_4$, CaSO$_4$ and KBr in seawater which also crystallises in the salt production process causes low salt quality (NaCl content between 75-80%) and tends to be dirty.

Several alternatives can be done to increase salt productivity. The increased productivity is not only in quantity but in quality. Technologies that can use include tunnel technology, prism, and FDS (Flow down system). The three techniques are not dependent on sunlight, can be done throughout the year and can produce better quality than conventional methods [4].

The choice of salt production technology carries risks, especially for farmers. Farmers have become accustomed to using conventional technology. The main factors that are considered by farmers are the costs, benefits, and risks that will be faced. To determine the right choice of technology that will be used to increase salt productivity can be made using the AHP (Analytical Hierarchy Process) approach. AHP is a decision-making method that involves many criteria and alternatives that are selected based on consideration of all related criteria [5]. Criteria have different degrees of importance; likewise, choices have different preferences according to each existing rule. The AHP method has contributed to measuring standards that have different dimensions/scales.

The criteria should use in the selection of salt production technology are benefits, costs, and risks. Interests related to the quality standards of salt receipts by consumers. The quality of salt determined by colour, NaCl content, and grain size. Cost criteria include the components of costs incurred starting from the investment process of technological change, processing of raw materials, production processes, and post-salt production. The cost and profit criteria will illustrate the value of the benefit cost. The benefit-cost amount will determine the decision of farmers and policy makers in implementing the salt production process technology. In addition to the value of the benefit-cost ratio, the risk criteria are no less important than the decision makers. The risk experienced is the risk of using technology from the conventional production process to semi-modern or modern.

The purpose of this study was to determine the best choice for the application of salt production technology based on the value of the benefit-cost ratio and risk using the AHP technique. Alternative production processes to be used are conventional techniques, tunnelling, prisms, and FDS techniques.

2. Research Methods
The approach used in determining the salt production process uses the AHP approach. AHP will analyse a complex and unstructured problem by decomposing and synthesising human perception, which is considered an expert to determine decision making. The problem hierarchy will divide into 3 or more levels, namely Goal (Criteria), Criteria (which may still develop in sub-criteria), and Alternative decisions [6]. The stages of the AHP approach are as follows:

1. Define the problem and determine the desired solution.
2. Creating a hierarchical structure that begins with a general goal, followed by sub-objectives, criteria, and possible alternatives at the lowest criteria level.
3. Making pairwise comparison matrices from several criteria (Table 1).
4. Perform pairwise comparisons so that judgment is obtained as much as n x [(n-1) / 2], with n is the number of elements compared. Calculate the eigenvalue and test its consistency, if it is not consistent, then the data retrieval is repeated.
5. Repeat steps 3, 4, and 5 for all levels of the hierarchy.
6. Calculate the eigenvectors of each paired comparison matrix. The value of the eigenvector is the weight of each element. This step is to synthesize judgment in determining the priority of the items at the lowest hierarchy level until the goal reached.

7. Check hierarchical consistency. If the value is more than 10 percent, the assessment of data judgment must be corrected.

Table 1. The Pairwise comparison scale [6]

| Intensity of Importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two elements contribute equally to the property |
| 3                       | Moderate importance | Experience and judgment one over another slightly favor one element over another |
| 5                       | Essential or strong | Experience and judgment importance strongly favor one element over another |
| 7                       | Very strong | An element is strongly in importance favored and its dominance is demonstrated in practice |
| 9                       | Extreme | The evidence favoring one importance element over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Intermediate values | Compromise is needed between the two judgment adjacent judgment |

3. Results and Discussion
3.1. Decomposing problem into a hierarchy goal, criteria, sub criteria and alternatives
The decision, the hierarchy of decision structures, was constructed from the elements of each level formulated. In the selection of technology, the salt production process employed four levels, namely objectives, criteria, sub-criteria, and alternatives. Level 1 (goal) was the selection of salt production process technology, while level 2 (criteria) consisted of benefits, costs, and risks. The sub-criteria benefit related to the quality of the salt produced, including colour, NaCl level, and the size of the salt grain. Sub-criteria for cost included the cost used during the preparation until the post-harvest salt process. The cost included objectives for capital investment costs, raw material processing costs, indirect costs, maintenance costs, and post-harvest costs. Level 4 constituted an alternative technology for the salt production process, covering four alternatives: conventional techniques, tunnel techniques, prism techniques, and FDS techniques. The method of extracting information was carried out by using opinions based on essential factors to consider in the selection. The hierarchy of the AHP model is illustrated in Figure 1.

![Figure 1. Structure of AHP hierarchy selection of salt production process](image-url)
3.2. Factor priority of calculating weight and significant test of inter factor

Table 2 described the pairwise comparison matrix as well as the use of Eigen value for determining weight of each category.

| Category        | Colour  | Nacl Content | Granule size |
|-----------------|---------|--------------|--------------|
| Colour          | 1.00    | 5.00         | 0.20         |
| Nacl Content    | 0.20    | 1.00         | 0.14         |
| Granule size    | 3.00    | 7.00         | 1.00         |
| Normalised Colour | 0.158  | 0.789        | 0.053        |
| Normalised Nacl Content | 0.149 | 0.745 | 0.106 |
| Normalised Granule size | 0.273 | 0.636 | 0.091 |
| Weight (Wi)     | 0.188   | 0.731        | 0.081        |
| Eigen Value     | 3.076   | 2.971        | 3.087        |
| CI              | 0.044   |              |              |
| RI              | 0.58    |              |              |
| CR (%)          | 7.5     |              |              |

The stages for the pairwise comparison matrix and the consistency of the cost and risk ratio, as well as the benefits matrix, can be seen in Table 3.

| Wi              | Cost                   | CI     | RI    | CR (%) |
|-----------------|------------------------|--------|-------|--------|
| Capital investment | 0.302                  | 5.414  | 1.06  | 9.5%   |
| The raw material processing cost | 0.052                  | 5.424  |       |        |
| Indirect cost    | 0.164                  | 5.336  | 1.11  |        |
| Maintenance cost | 0.406                  | 5.267  |       |        |
| Post-harvest cost | 0.076                  | 5.369  |       |        |
| Risk             | Traditional Technology | 0.081  | 3.087 | 0.044  | 5.8%  |
| Semi Modern technology | 0.188                | 3.076  |       |        |
| Modern technology | 0.731                  | 2.971  |       |        |

3.3. Alternative priority weights (Wi)

Benefits, Costs, and Risks level hierarchy have all the same alternatives of technology: conventional, tunnel, prism, and FDS. Pairwise comparison matrices built around each defined criterion (benefits, costs, and risks).

On the benefit and risk criteria (Table 4), the highest weight is the choice of technology using FDS, which are 0.323 and 0.306. While the cost criteria, the highest weight is conventional technology, which is 0.315.

The benefit is a profit derived from a production process. The benefits of the salt production process are related to the quality of salt. According Rusiyanto and Jumaeri [7], Setyaningrum et al. [8], the quality of salt with conventional technology is not by SNI 01-3556-2000, which says that NaCl level of 94.7%, maximum moisture content 7% and pure white. While the quality of conventional salt is 82.5% NaCl, 9.19% moisture content is dull and coarse grain. Different from prism technology produces salt with NaCl content of 87.56%, Mg content of 2.15%, Ca content of 3.45% and water content of 5.86% the quality of prism salt included in the medium quality category Sumada and Dewati [9], Kurnawan et al.[10]. The content of NaCl in salt from the production process
with the tunnel technique not only meets the standards of consumption salt and can even meet industrial salt standards. The content of sodium chloride (NaCl) salt produced on average still meets the needs of the industry. To note, the industry needs salt with the content of NaCl 97-99 percent [9, 10]. The quality of salt with the FDS technique is that the NaCl level is more than 99% so that it can use for consumption salt or industrial salt [11]. The amount of production with the FDS technique can increase production volume by up to 78% and increase production time by 50 - 57% [12].

| Main Category | Conventional Technology | Prism Technology | Tunnel Technology | FDS Technology |
|---------------|-------------------------|------------------|------------------|---------------|
| Benefit Colour | 0.172                   | 0.276            | 0.276            | 0.276         |
| NACL Content  | 0.167                   | 0.250            | 0.250            | 0.333         |
| Granule size  | 0.167                   | 0.250            | 0.250            | 0.333         |
| Weight Rating | **0.168**               | **0.255**        | **0.255**        | **0.323**     |
| Costs Capital investment | 0.333               | 0.250            | 0.250            | 0.167         |
| The raw material processing cost | 0.348               | 0.217            | 0.261            | 0.174         |
| Indirect cost  | 0.333                   | 0.250            | 0.250            | 0.167         |
| Maintenance cost | 0.280               | 0.240            | 0.160            | 0.320         |
| Post-harvest cost | 0.364               | 0.273            | 0.227            | 0.136         |
| Weight Rating | **0.315**               | **0.246**        | **0.212**        | **0.227**     |
| Risk Traditional Technology | 0.182               | 0.227            | 0.227            | 0.364         |
| Semi Modern technology | 0.174               | 0.261            | 0.261            | 0.304         |
| Modern technology  | 0.364                 | 0.227            | 0.227            | 0.182         |
| Weight Rating | **0.191**               | **0.252**        | **0.252**        | **0.306**     |

Cost is the amount of expenditure made in salt production. Cost compensation used is investment costs, raw material processing costs, indirect costs (labour), maintenance costs, and costs of post-harvest salt care. The investment made in the conventional production process is relatively low because the technology used is simple by using windmills and water pumps using personal capital. Whereas the workforce involved is workers as owners and tenants of land for the production process assisted by their relatives. The labour costs needed are relatively high because each stage of the process uses labour-intensive techniques [13,14] Labour costs for tunnel and prism techniques are not much different from conventional techniques. The cost of handling salt after harvest in traditional methods is relatively high because salt yields high impurity compared to tunnel and prism techniques. The investment used in tunnel production techniques and prisms is the initial capital investment. In tunnelling techniques, the costs used to make the tunnel while the prism technique is to use the tarp as a base and geothermal plastic for the roof of the prism house. The most significant cost component in the FDS technique is an initial investment while the labour cost is relatively low because it does not involve many workers. The initial investment costs include raw water pool pump, separation, and seawater purification tanks, liner (geomembrane) for drying beds, pipes for fogging processes, filtering tools for suspension separators and colloids from seawater, and tools harvesting. Similarly, maintenance and post-harvest costs are also low due to the quality of the salt produced is white, and the impurity is small.

Risk is a result or consequence that can occur as a result of an ongoing process or future event. Risks to this criterion are associated with farmers’ acceptance of technological changes used when farmers faced with the choice of making changes to the production process to improve production performance. The consequence of farmers is that farmers must practice each different production stage
with activities that are usually carried out for years. Traditional technology is used for conventional production processes, namely using direct sunlight evaporation. The tunnel and prism technology are using evaporation techniques but is not dependent on sunlight so that they can do throughout the year. Unlike the FDS technique, the salt production process uses sea water, which is flowed through pipes and equipped with filtration. The principle of FDS technology is a vacuum evaporation system so that it can accelerate the rate of evaporation of sea water into salt. Treated water is put into a vacuum and will be heated using sunlight through solar lighter technology.

Changes in salt-making technology from conventional technology to tunnel, prism, and FDS technology have indicated increased salt production costs, increased production costs by the quality of salt to be produced [15].

3.4. Calculating benefit-cost ratio at risk
The weighted ratings of Benefits, Costs, and Risks for each level was calculated to obtain category and alternative level. The appraised benefits, costs, and risks was quantitatively calculated using AHP, enabling to determine the benefit-cost ratio more quickly. Table 5 shows the results of the analysis.

| Technology          | Benefit | Cost  | B/C ratio | Risk |
|---------------------|---------|-------|-----------|------|
| Conventional Tech.  | 0.168   | 0.315 | 0.533     | 0.191| low  |
| Prism Tech.         | 0.255   | 0.246 | 1.036     | 0.252| medium |
| TFDS Tech.          | 0.255   | 0.212 | 1.201     | 0.252| medium |
| FDS Tech.           | 0.323   | 0.227 | 1.420     | 0.306| high |

Based on AHP calculations using expert opinion, it is recommended to use prism technology or tunnel technology. It is because the B/C ratio is more than 1, which indicates that this process is profitable, and the level of risk of the medium. The factors most considered in selecting this production process are capital investment costs and maintenance costs. This risk is caused by farmers if using tunnel technology or prism is relatively low because farmers do not need to change the usual production technology used. The quality produced from tunnel, prism, and FDS technology is the same both in terms of colour, NaCl level, and grain size of salt. However, if the selection of FDS technology is carried out, the risks experienced by farmers are very high. It is because farmers must improve their capabilities.

4. Conclusions
Technology options that can be used by farmers to improve salt production performance based on the value of B/C tunnel technology ratio (1.201) and prism technology (1.036) and the risks experienced by farmers to make changes are medium. Future research is needed to calculate the cost of each salt production technology and social impact on farmers.

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