

Expert System for Selecting Product Packaging Materials as a Means to Achieve Sustainable Development Goals

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ABSTRACT

One of the aims of the Sustainable Development Goals (SDGs) that are closely related to the industry is SDGs number 12 which requires responsible consumption and production. Meanwhile, according to data from the Ministry of Environment and Maritime Affairs, the largest contributor to primary plastic production waste is from the packaging industry where 30 % plastic will be thrown out to sea and threaten waters. Some parties have provided various choices alternatives to plastic substitutes, but these alternatives may not be suitable to the wishes of customers and company capability. Therefore, research on the expert systems has conducted the selection of product packaging materials as a means of achieving SDGs. The purpose of this study helps companies to determine the best alternative packaging material to achieve SDGs. In designing the expert system, the study used the Fuzzy Analytical Hierarchy Process (FAHP). The result shows that the best expert system with Artificial Neural Network (ANN) obtained an accuracy of 70.83 %, MSE of 1.2063, and regression amounted to 0.9395. In addition, it was concluded that if the company decides to use paper as product packaging material will cost less than use environmentally friendly plastic.

Keywords: *expert system, SDGs, FAHP, ANN.*

1. INTRODUCTION

The definition of responsible consumption and production which is one of the goals of the Sustainable Development Goals (SDGs) is basically to separate economic growth from unsustainable use of resources and emissions and improve the management of hazardous substances and wastes [1]. This is related to the behavior of companies in choosing packaging to present the products they offer. Several companies become aware of the importance of SDGs and have begun to commit to realizing SDGs by reducing the use of plastic. Many foods and beverage companies have promoted the issue of SDGs and green manufacturing and it has succeeded in increasing the attractiveness of the community to survive to consume their products. The concept of sustainable manufacturing has three important aspects, namely economic aspects, environmental aspects, and social aspects [2]. Companies that adopt sustainable manufacturing can improve product quality, expand market share, and increase profits [3]. But on the other hand, there are a lot of alternative choices for plastic substitutes that are available but the alternatives are not necessarily suitable to the desires of consumers and the ability of the company. Therefore, research is needed on making decision support systems (DSS) in selecting product packaging materials used by food and beverage companies to achieve sustainable development goals.

Another goal is the company can effectively determine the feasibility of using substitute product packaging materials and assist in the selection of company suppliers so SDGs expected to be achieved. However, the process of selecting product packaging materials is complex, many data are difficult to obtain and ambiguous or vague to interpret. From several types of rating methods, this study uses Fuzzy Analytical Hierarchy Process (FAHP) because this method can be used to assess a number of alternatives in a limited amount and can reduce the subjective value obtained. Moreover, the resulting weight becomes the initial weight input and will be trained using Artificial Neural Network where the ANN method used is backpropagation. From ANN, a selection of materials is suggested and then followed by an analysis of the company's sustainability aspects the selection of these packaging materials.

2. MATERIALS AND METHODS

The purpose of this study is to design an expert system to assist stakeholders in determining the packaging materials for food or beverage products. Expert system or in further development can be referred to as Decision Support System (DSS) that was discovered by two professors from MIT (Anthony Gorry and Michael S. Morton) discovered the Decision Support Systems (DSS) [4]. In their opinion, DSS must be used to support management on semi-structured

problems, i.e. problems with information incomplete so managers doubt it makes decisions. DSS will give support or alternative settlement so that managers can test these alternatives to choose which one is the best [5]. Beside that, DSS is an interactive information system provide information, modeling and data manipulation [6].

In the process of designing an expert system, this study uses the Artificial Neural Network algorithm as an approaching method to help the alternative selection process. In the first step, multi-criteria identification was carried out using the Fuzzy Analytical Hierarchy Process (FAHP) to determine the characteristics of selecting product packaging materials. Fuzzy Analytical Hierarchy Process (FAHP) is the development of the AHP method. Analytical Hierarchy Process (AHP) itself is a decision support models that outline multi-factor or multi-criteria problems complex becomes a hierarchy [7]. The FAHP steps are as follows:

- a) Change the AHP scale to triangular fuzzy number,
- b) Determine fuzzy synthetic extent,

$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1}$$

where:

S_i : value of fuzzy synthetic extent

M_{g_i} : value fuzzy AHP

- c) Determine the degree of likelihood
- d) Normalization

In the multi-criteria identification process, there are three groups of respondents involved in this study. The first group is consumers who care about and implement a sustainable lifestyle for more than one year. The second group consists of a material expert which are professionals who work as environmental observers and have a good understanding of environmentally friendly material properties. The third group consists of procurement experts who are accustomed to working in the field of procurement and interacting with suppliers, they must also be committed to implementing the SDGs and be responsible for production waste in the company being managed.

After the multi-criteria weights have been identified, these values are used as the initial weighting of the ANN (Artificial Neural Network). ANN is inspired by brain neuron structures [8], mathematical models that are known as a neural network has been developed as an approach to providing structure algorithmic that can interact with the environment in the same way as the brain human. This interaction includes aspects of intelligence artificial, for example, learning from experience, generalize from examples, and abstract the essence of data input that might contain irrelevant factors. ANN algorithm steps backpropagation in the learning process is as follows [9]

- a) Forward propagation
- b) Backpropagation
- c) Weight update

2.1. Object and Data

The object of this research is the food company and drinks that have been committed in the movement SDGs are always dynamic and innovate to reduce waste and realize SDGs number 12. Additionally, votes are considered consumers at the company and suppliers environmentally friendly products.

In this study, primary data obtained with interviewed 2 respondents customer and 1 material expert related to the criteria affect the selection of material use packaging, then give a questionnaire AHP pairwise weighting ratio. In addition, interviews were conducted with 1 person procurement experts to get the criteria and weighting of supplier selection. Other primary data what is taken is the assessment of each criterion if an alternative is provided packaging material for a case. This data is taken with a questionnaire filled out by 2 respondents and 1 material expert.

The criteria are determined based on the results of the interview to customers and material experts and experts procurement where the results obtained to be considered in determining the use of product packaging materials and determination supplier. Respondents were asked to weight the criteria of the results of the interview by filling out the AHP pairwise comparison questionnaire. Respondents were asked to compare accordingly pair level relative importance criteria which influence the election or the use of a product packaging material because of the most appropriate weighting criteria based on the level of importance. As a case study, this research uses four packaging materials that have different characteristics as an alternative choice, including: bamboo, paper, plastic, and stainless. The alternative choice will then be decided by a decision support system which designed in this study.

3. RESULTS AND DISCUSSION

3.1. Results of Calculation of Weight using FAHP Method

3.1.1. Results of Respondent Consideration Criteria

Based on the respondents' assessment, several criteria for selecting raw materials are sorted from the highest preference to the lowest preference. The weighting assessment is carried out using a questionnaire instrument filled with environmentally friendly products customers. Weighting is done to determine customer preferences in choosing product packaging. The weighting results can be seen in Fig. 1 below.

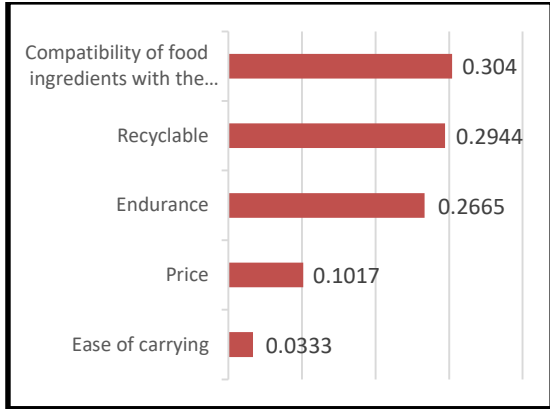


Figure 1 Respondent Weighting Questionnaire Results

From Figure 1 it can be seen that the criteria for compatibility packaging material with the product have a weight the biggest is 0.304. This weight is the value slightly different from the criteria weights can be recycled reset which has a weight of 0.2944. Criteria others like endurance have weights of 0.2665 and at underneath, there are criteria for price weights and ease of carrying with each weighing 0.1017 and 0.0333.

3.1.2. Results of Material Expert Consideration Criteria

Based on the manufacturer's point of view, there are important criteria to consider in selecting environmentally friendly product packaging materials to minimize the risk of damage during product delivery and also to maintain the quality of food products while they are in packaging. The identification of criteria and weighting is done by providing a questionnaire which is assessed by material experts who are accustomed to being involved in product development and packaging. The results of weighted material criteria based on experts are shown in Figure 2.

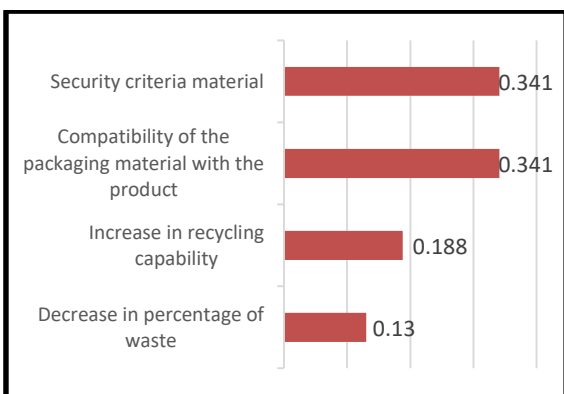


Figure 2. Material Expert Weighting Questionnaire Results

Figure 2 shows the security criteria material and the suitability of the packaging material with the product has the same and greatest weight, i.e. amounted to 0.341. This

weight value is quite significant compared to other criteria. Security and compatibility of packaging materials is a factor very important in determining the packaging material according to material expert as it relates to dangerous or not when the product is consumed.

3.1.3. Results of Procurement Expert Consideration Criteria

Several criteria related to procurement are needed to determine the manufacturer's point of view where the price, quality, and timing of procurement of packaging materials are important variables in decision making. The identification of criteria and weighting related to procurement materials is carried out by providing a questionnaire which is assessed by procurement experts who are accustomed to being involved in the procurement of packaged goods. The results of weighted material criteria based on procurement experts are shown in Fig. 3 below.

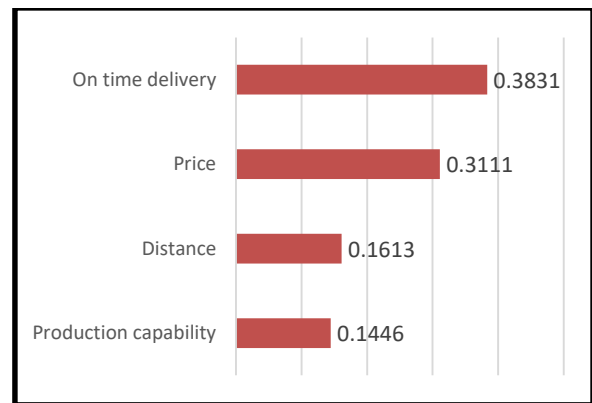


Figure 3. Procurement Expert Weighting Questionnaire Results

From Figure 3 it appears that the criteria for accuracy shipping have the biggest weight, that is, equal to 0.3831. This weight value is quite significant compared to other criteria because of its accuracy shipping can affect product performance and the use of fees. Tardiness shipping can cause shortages to inventory, but vice versa if shipping is done earlier then space is needed addition to the storage of goods, which can be transferred to additional costs. Other than that, on-time delivery also includes shipping the number of parts matches the number listed purchase order.

3.2. Results of Decision Support System

This study uses several functions to design ANN, including *trainlm* (Levenberg-Marquardt) to update weight and bias values based on the Levenberg-Marquardt Backpropagation optimization, adaptation learning *learn_gdm* (Gradient Descent Momentum) with transfer the *tansig* (Tan-Sigmoid) function to update weights. in a Neural Network by minimizing the loss function. The weight for each

criterion becomes the initial weight in designing ANN in MATLAB and trial and error for the network created as shown in Table 1 below

Table 1. ANN Result

Neuron Input	Neuron Hidden Layer	Neuron Output	Momentum Update	MSE	R
9	9	1	0.01	1.20630	0.93950
			0.03	1.55270	-0.98440
			0.05	1.06340	0.56487
			0.07	1.69420	0.75445
9	10	1	0.01	1.30340	0.19997
			0.03	1.59770	-0.61950
			0.05	0.61809	0.34625
			0.07	1.56620	0.88644
9	15	1	0.01	0.16018	0.33095
			0.03	1.69660	0.01717
			0.05	0.28869	0.71651
			0.07	3.38990	0.91630
9	20	1	0.01	1.28770	0.41808
			0.03	0.44540	-0.80420
			0.05	2.31220	-0.08640
			0.07	2.07080	-0.27000

From Table 1, it can be seen by using training function *trainlm* and adaptation learning *learngdm* with transfer the *tansig* function and the MSE performance function followed by 1000 epochs training parameters with a minimum gradient of $1e-10$, maximum fail 1000, mu decrease 0.1, mu increase 10 and maximum 1000000000, then the model has obtained the best ANN with a 9-9-1 pattern with momentum update 0.01. 9-9-1 networks produce performance values best as seen in Fig. 4 below.

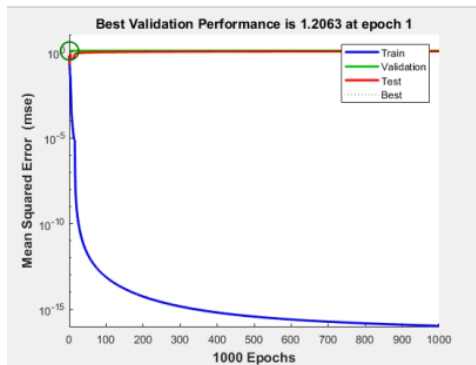


Figure 4. MATLAB Performance Graph

Based on Figure 4, the value the performance is represented by the Mean Square Error (MSE) indicates a value of 1.2063 on epoch one. This shows that the best error difference obtained is 1.2063. When seen in the picture, the

lines appear in green which represents validation and lines red color representing the test almost coincide. This indicates that this happened a slight difference in both data. Apart from that, the MATLAB software to produce a regression graph for each component as shown in Figure 5 below.

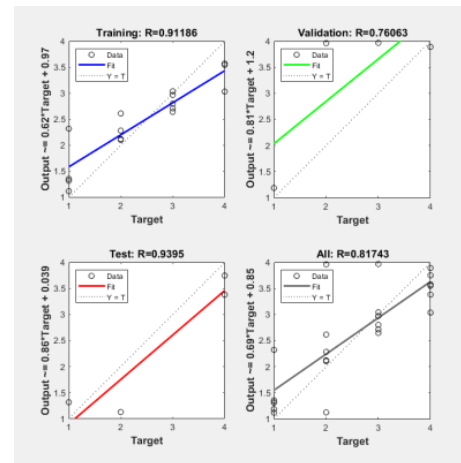


Figure 5. MATLAB Regression Graph

If seen from the regression graph in Figure 5 above, it can be concluded that the value of the test is close to number 1 which means the output from the system that is built near

the target ought to or can be said to reach the target and small system output. As for the value of system accuracy

decision support in the selection of materials product packaging can be seen in Table 2 the following,

Table 2 Comparison of System Outputs with Experts

Case 1	Respondent 1	ANN Output	Result
Alternative 1	Bamboo	Plastic	Different
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Paper	Different
Alternative 4	Stainless	Stainless	Same
Case 2	Respondent 1	ANN Output	Result
Alternative 1	Bamboo	Paper	Different
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Paper	Different
Alternative 4	Stainless	Stainless	Same
Case 1	Respondent 2	ANN Output	Result
Alternative 1	Bamboo	Bamboo	Same
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Plastic	Same
Alternative 4	Stainless	Plastic	Different
Case 2	Respondent 2	ANN Output	Result
Alternative 1	Bamboo	Bamboo	Same
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Plastic	Same
Alternative 4	Stainless	Plastic	Different
Case 1	Material Expert	ANN Output	Result
Alternative 1	Bamboo	Bamboo	Same
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Plastic	Same
Alternative 4	Stainless	Stainless	Same
Case 2	Material Expert	ANN Output	Result
Alternative 1	Bamboo	Paper	Different
Alternative 2	Paper	Paper	Same
Alternative 3	Plastic	Plastic	Same
Alternative 4	Stainless	Stainless	Same

Based on Table 2, from 2 cases provided based on alternative choices selected consisting of 24 system outputs decision support found that the ANN model was made for the support system the decision has an accuracy rate of 70.83% seen from the match the output with the choice respondent and material expert.

3.3. Results of DSS Design

Based on calculations and the process that has been done in this research, the design of the decision support system for packaging material selection is shown in Fig. 6 below.



Figure 6. Design of DSS

As the DSS design shown on Fig.6, it appears that there are 3 main components, namely input, process, and output. Therefore the DSS design obtained with input entered by a manager on the packaging material selection decision support system is the type of product i.e. food/beverage, then the form of the product namely liquid/solid, and the characteristic of the product to be packaged is hot/cold. Furthermore, the manager will select and enter the packaging material criteria from the choices consisting of (a) the suitability of the material with the product based on the consumer, (b) the compatibility of the material with the product based on the expert ingredients, (c) ease of carrying, (d) durability, (e) price, (f) recyclable, (g) material safety, (h) decreasing the percentage of waste, and (i) increasing the ability to recycle and choosing several alternatives consisting of (a) bamboo, (b) paper, (c) plastic, (d) stainless

(can also check all available alternatives). Next, the data entered will be processed in the system using the FAHP method which will produce criteria weights that will be input in the ANN process in the decision support system. So that the system will produce output in the form of materials and explanations for the evaluation of criteria based on cases in the system.

3.4. Analysis of Sustainability Aspects

On the other hand, a decision support system can help companies in assessing the sustainability of the company in terms of product packaging material selection as shown in Table 3 below.

Table 3. Comparison of Experts Procurement

Criteria	Bamboo	Paper	Plastic	Stainless
Cost (IDR per year)	511,000,000	52,195,000	52,049,000	1,138,800,900
	2,190,900,000	93,075,000	142,350,000	2,727,500,900
On time delivery (rating on scale of 1-5)	4	4.5	4.5	4
Location	Jakarta, Singapore, Philippines, China	Bali, Yogyakarta, China, Jakarta	Bali, Yogyakarta, China, Singapore	Jakarta, Hongkong, Singapore
Minimum order	1000 cups and packs	25-50 cups and packs	100 cups and packs	500 cups and packs

Table 4 Comparison of Environmentally Friendly Packaging Material

Criteria	Bamboo	Paper	Plastic	Stainless
Durability	<18 months, reuse	Disposable	Disposable, reuse >1 year	>1 year, reuse
Price	IDR 10,000/unit	IDR 850/unit	IDR 1,000/unit	IDR 18,700/unit
Compatibility material and product	Cold, hot, solid, liquid, dry, wet product	Cold, hot, solid, dry product	Cold, hot, solid, liquid, dry, wet product	Cold, hot, solid, liquid, dry, wet product
Recycling options	Bamboo crafts	Recycled paper, crafts	Recycled plastic, plant's pot	None
Safety (scale of rating 1-4)	4	3	3	4
Portability (scale of rating 1-4)	3	2	2	3
Availability	Easy to get, abroad	Easy to get, domestic	Difficult to get, abroad	Easy to get, abroad

Based on Table 3 and Table 4, if the company chooses to use bamboo packaging materials, the company must collaborate with suppliers from abroad because most bamboo packaging suppliers are abroad. That is because the production capabilities of other countries are more advanced in terms of technology, availability of quality materials and people. So that it causes the profit aspect (cost) to swell where using bamboo as a packaging material for products will cost a very large amount of IDR 511,000,000 to IDR 2,190,900,000 per year. If the company can make a big profit then it will not experience obstacles, but to make a large profit of course the company must reduce other costs or increase profits. If the company chooses to increase profits, there is a challenge in price competition in a market that is ready to become a threat. For the planetary aspect, based on the opinion of experts, when using bamboo packaging materials, the company can save the use of packaging around 18 months. This can be done if

the consumer stores the packaging for later use or the company pulls it back and uses it again so that it will not add waste or other environmental impacts because it is natural. As for the aspect of people, by using bamboo, of course, someone is not threatened by dangerous chemicals or other health threats.

Whereas if the company chooses to use paper packaging materials, it can be seen that the company will save the cost of product purchases of IDR 458,805,000 annually when compared to if the company chooses to use bamboo. That certainly becomes its own advantage for the profit aspect. For the planetary aspect, the paper is known to be more environmentally friendly than plastic because it has a relatively shorter time to disintegrate and blend with nature. In addition, the ease of recycling into a variety of products makes paper the right choice when used as packaging material. For the aspect of people, it is not so affected

because the paper is considered safe for use in various packaging.

If the company chooses to use plastic, then the company will need a cost of IDR 52,049,000 to IDR 142,350,000 per year, not so far away if the company uses paper as packaging material. Plastic here is plastic that meets environmental friendly standards and can be destroyed in nature in a short time even with only a small temperature the plastic will melt or can be consumed. For the aspect of the planet, of course, this will add plastic waste, but in a certain period of time, it remains harmless because it will soon be one with nature. In addition, there is also the type of plastic chosen that can be used more than once, so that it will solve the problem of adding waste. If a company uses plastic packaging materials that are environmentally friendly, it will cost more and produce continuously, but if the company decides to use plastic packaging materials that can be used more than once with the system saved by consumers as souvenirs and hold promotions using certain provisions or if the system is withdrawn by the company and used again, it will solve the problem of plastic waste being dumped at sea so that aspects of planetary sustainability are met. For the aspect of people, plastics certainly contain certain chemicals so there is a need for certain choices and standards to be considered.

If the company chooses to use stainless, then the company requires a very large procurement cost. But many companies like Starbuck use this packaging material because it is run with a special promotional strategy so that it does not cause harm. Stainless itself is well-known for its durability and is suitable for food/drinks both hot and cold and can be enhanced in various ways so as to create its own charm. By using stainless, companies can save on packaging expenses by implementing a souvenir or discount system for consumers who have their products. This will be beneficial for both profit and planetary aspects. While the aspect of people can be seen with the safety of the use of stainless.

4. CONCLUSION

Decision support system for product packaging material selection to achieve SDGs formed by input in the form of product type, product form, product properties, selection criteria, and alternative packaging which then produces weights and calls the ANN process so as to produce recommendations for packaging materials that must be used the company.

Based on the results of the DSS system output, it is obtained that packaging material recommendations can be used for the supplier selection process which can then estimate aspects of the company's sustainability. As in the case of drinks, DSS will produce paper packaging materials that generate a small ordering fee so that it generates profits for companies with periodic bookings because it is not durable but it certainly has a good impact for the planet because, in addition to being easily integrated with nature (destroyed), the waste paper also has many options for recycling so that

it does not pollute the environment and endanger people (aspects of people).

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