AFSSAAE

Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering 2023 | Special Issue | 123-133
ISSN 2622-5921

ORIGINAL RESEARCH Open Access

Waste analysis of coated peanut production using *fuzzy* analytical hierarchy process (*Fuzzy* AHP)

Erika Ayu Yuanita, Panji Deoranto, Arif Hidayat, Riska Septifani, Wendra Gandhatyasri Rohmah

Department of Agro-Industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

KEYWORDS

Coated peanut

Fuzzy AHP

Seven waste

ABSTRACT

Production effectiveness is an essential aspect of industrial activities to obtain maximum profit with minimum expenditure. One of the companies currently focused on achieving high effectiveness in its production activities is PT XYZ. The purpose of the study was to determine the priority of waste in the coated peanut processing company using the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method. The Fuzzy AHP method combines AHP with a fuzzy system to cover the weaknesses of AHP, which has more personal properties. The Fuzzy AHP method helps in identifying the level of waste in PT XYZ, which is grouped into seven, namely defects (S1), waiting (S2), unnecessary inventory (S3), inappropriate processing (S4), unnecessary motion (S5), transportation (S6), and overproduction (S7). The results showed that the order of wastage criteria starting from the highest to the lowest are S4 with a weight vector value of 1.000; S5 with a weight vector value of 0.985; S1 with a weight vector value of 0.932; S2 with a weight vector value 0.702; S6 with weight vector value 0.678; S3 with a weight vector value 0.144; S7 with weight vector value 0.071. Based on this, it can be seen that the criteria for inappropriate processing have the highest priority as waste in production activities at PT XYZ. The results of the Fuzzy AHP method can be used as a basis for weighting the value stream analysis tools.

Introduction

Companies are encouraged to be able to retain business operations because of the increasingly strict industrial development now. Planning and calculations must be done with great care if the company continues to exist and compete with other manufacturers (Ghobakhloo., 2020). Many Factors affect the profitability of a company. One is waste in production (Ikatrinasari and Kosasih., 2021). Every company will try to achieve a production process that produces minimal waste. Lean production is a practice used to eliminate process waste in manufacturing. Lean eliminates all production activities without added value and will make the process flow more efficiently (Jasti and Kodali, 2015). Seven types of waste occur in manufacturing, namely defects, waiting, unnecessary inventory, inappropriate processing, unnecessary motion, transportation, and overproduction (Sahrupi et al., 2020)

PT XYZ is one of the companies that produce snacks in Tulungagung. The products produced are coated peanuts, egg nuts, and *bangkok* nuts. PT XYZ continues to increase the number of production targets to continuously increase the number of products on the market to become a product that dominates the market. Increasing the number of production targets carried out by PT XYZ at this time is very difficult to be realized quickly because there are several inhibiting factors in terms of manpower, machinery, equipment, and production premises. The waste weighting analysis method used in this research is the Fuzzy Analytical Hierarchy Process (Fuzzy AHP).

Fuzzy AHP is a combined weighting method between fuzzy and traditional AHP developed by Saaty (Sener et al., 2018). The alternative selection and weighting system use the fuzzy set theory concept and hierarchical structure analysis

*Corresponding author
E-mail address: erikaayuyuanita@student.ub.ac.id

(Tan et al., 2014). The fuzzy AHP method can cover the weaknesses of AHP, which have a higher subjective nature. The fuzzification process is carried out on the AHP method because, with the addition of fuzzy theory, it can correct inaccurate information in real situations (Basjir and Suhartini, 2019). The fuzzy AHP method has flexibility in determining the uncertainty of vague and subjective information in the assessment. The advantage of fuzzy AHP is that it can analyze several criteria, is easy to understand and use, and results are accurate (Boral et al., 2020). The purpose of the study was to determine the priority of waste at the coated peanuts processing company at PT XYZ using the fuzzy AHP method.

Research Methods

This study was carried out at PT XYZ Snacks & Food, Tulungagung, East Java. They are collecting data using a questionnaire to obtain primary data. Primary data is information gathered from the source without further processing to be used in a particular research project (Jihadudin et al., 2020). Questionnaires were distributed to expert respondents consisting of one production manager and two production supervisors. The criteria in the research include seven wastes consisting of defects, waiting, unnecessary inventory, inappropriate processing, unnecessary motion, transportation, and overproduction, as seen in Table 1.

The method used to weigh the seven wastes is fuzzy AHP. There are several versions of the fuzzy AHP method, namely the Buckley Fuzzy AHP Method, Van Laarhoven and Pedrycz Fuzzy AHP Method, and Chang's Extended Analysis Method (Koulinas et al., 2019). This study uses the fuzzy AHP method version of Chang's Extended Analysis Method. This is because it is the simplest and most common method for multicriteria triangular fuzzy analysis and pairwise comparison (Saffarian et al., 2020). According to Chang, D.Y. (1996), if two fuzzy triangular numbers M_1 and M_2 where $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. Then the mathematical operation rules for fuzzy triangular numbers are:

a. $(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2 , m_1\ m_2 , u_1\ u_2)$
b. $(\lambda, \lambda, \lambda) \otimes (l_1, m_1, u_1) = (\lambda\ l_1, \lambda\ m_1, \lambda\ u_1)$ where $\lambda > 0, \lambda \in R$
c. $(l_1, m_1, u_1)^{-1} = (\frac{1}{U1}, \frac{1}{m2}, \frac{1}{l1})$

Where l is lower, m is medium, and u is upper.

The steps of Fuzzy AHP in this research are as follows (Chang, 1996):

1. Calculating fuzzy synthetic extents (S_x) from the pairwise comparison (TFN) matrix between criteria or sub-criteria on the x criteria/sub-criteria with the equation:

$$S_x = \sum_{y=1}^{n} C_{xy} \otimes [\sum_{k=1}^{n} . \sum_{y=1}^{n} . C_{ky}]^{-1} ; x = 1, 2, \ldots, n \quad (1)$$

Where n is the size of the pairwise comparison matrix between criteria/sub-criteria, k is a combination of criteria from row i where i=1 to n.

$$\sum_{y=1}^{n} . C_{xy} = (\sum_{y=1}^{n} . l_{xy} , \sum_{y=1}^{n} . m_{xy} , \sum_{y=1}^{n} . u_{xy}) ; x = 1, 2, \ldots, n \quad (2)$$

Where l is the lower limit, m is the middle limit, u is the upper limit.

$$[\sum_{k=1}^{n} . \sum_{y=1}^{n} . C_{ky}]^{-1} = [\frac{1}{\sum_{k=1}^{n} . \sum_{y=1}^{n} uky.} , \frac{1}{\sum_{k=1}^{n} . \sum_{y=1}^{n} mky.} , \frac{1}{\sum_{k=1}^{n} . \sum_{y=1}^{n} lky.}] \quad (3)$$

$$\sum_{k=1}^{n} . \sum_{y=1}^{n} . C_{ky} = (\sum_{k=1}^{n} . \sum_{y=1}^{n} . l_{ky} , \sum_{k=1}^{n} . \sum_{y=1}^{n} . m_{ky} , \sum_{k=1}^{n} . \sum_{y=1}^{n} . u_{ky}) = [(\sum_{y=1}^{n} . l_{1y} , \sum_{y=1}^{n} . m_{1y} , \sum_{y=1}^{n} . u_{1y}) + \ldots + (\sum_{y=1}^{n} . l_{ny} , \sum_{y=1}^{n} . m_{ny} , \sum_{y=1}^{n} . u_{ny})] \quad (4)$$

2. Comparing the value of the fuzzy synthetic extent (S_x) of one criteria/sub-criteria with the fuzzy synthetic extent (S_x) of another criteria/sub-criteria, which is called the degree of possibility with the equation:

$$V(Sx \geq Sy) = \begin{cases} 0, if\ mx \geq my \\ 1, if\ lx \geq ux \\ \frac{ly-ux}{(mx-ux)-(my-ly)} \end{cases} \quad (5)$$

$$ly - ux\ (other\ terms: mx \geq my\ dan\ ly \geq\ ux)$$

where V (Sx >= | Sy y = 1, …, n; y ≠ x) and the number of possibilities (n-1)

3. Determine the minimum degree of possibility of V (Sx >= Sy)
4. Determine the normalized importance weight vector W = (w_1, w_2, …, w_n) from :

$$Wx = \frac{V\ (Sx >= |\ Sy \quad y = 1,\ldots,n;\ y \neq x)}{\sum_{k=1}^{n} . V\ (Sx >= |\ Sy \quad y = 1,\ldots,n;\ y \neq x} ; x = l, \ldots, n \ldots (6)$$

Where: Wx is nonfuzzy number.

Table 1. Seven Waste Criteria

No	Waste Criteria	Definition
1.	Defect	There is reworked on the product, or if the product is defective, it must be minimization
2.	Waiting	Waste occurs when the operator's hand is idle or waiting for the process
3.	Unnecessary Inventory	Purchasing too many materials so that inventory piles up in the warehouse
4.	Inappropriate Processing	Inappropriate technology or poor product design. This process wastage occurs in many cases, such as those caused by failure to synchronize processes
5.	Unnecessary Motion	The movement of workers is not directly related to value-added
6.	Transportation	Excessive movement activities and excessive handling can cause damage and possibly cause product quality to decline
7	Overproduction	Produce products or goods that are more than what customers need

Source: El-Namrouty and Shaaban (2013).

Results and Discussion

Seven Waste

The research criteria are seven wastes in the production process of coated peanuts at PT XYZ, which include defects (S1), waiting (S2), unnecessary inventory (S3), inappropriate processing (S4), unnecessary motion (S5), transportation (S6), overproduction (S7). Seven waste on PT XYZ include:

1. Inappropriate processing at PT XYZ is the lack of employee integrity regarding the standard of ability in the production process, so the resulting product quality is not optimal. The over-production results in a loss of profit on unsold goods and a reduction in available storage space. On-demand adjustments must be made to the production schedule (Paul-Eric et al., 2020).
2. Unnecessary motion at PT XYZ is the many activities of chatting between employees and sitting and relaxing while waiting for the coated peanuts to be cooked in the frying pan. The motion of a human or an individual (operator, foreman, and the people directly involved in production) or equipment that is unnecessary, ineffective, and adds no value to the manufacturing process is referred to as unnecessary motion. Unnecessary motion can disturb the production process, waste time, and lengthen the lead time for the product (Syahputri et al., 2017).
3. The defect in PT XYZ is the presence of peanut and flour dough that is not shaped according to a predetermined standard, specifically in the form of small peanut crumbs that do not completely attach to the flour and huge, sticky lumps of flour. There is a mistaken waste when the product does not meet the requirements for selling. This wastes money and puts the cost of repairs at risk of going over budget. This may be brought on by subpar tools, staff with minimal qualifications, or outdated tools (Paul-Eric et al., 2020).
4. Waiting at PT XYZ is waiting for the bean and flour kneading process to finish so that the frying area is idle, and vice versa, with the accumulation of peanut and flour dough because the frying area is slow. A queue in front of the production station results in lost time from waiting, which is the amount of time wasted between one step and the following steps (products to be finalized). The root reason for this can be significant time gaps between procedures. However, this might be resolved by looking at each process and creating a balance (Paul-Eric et al., 2020).
5. Transportation at PT XYZ is disrupting the transportation process using a trolley because of the floor where the product is damaged. When the movement of the examined workpiece, labor, or equipment occurs outside of an activity, an event occurs. However, a movement occurs as a result of or is brought on by a worker at the place of employment during a procedure or inspection (Syahputri et al., 2017).
6. Unnecessary inventory at PT XYZ is scarce because the circulation of raw materials is good, and the stock of finished products in the warehouse is always very well-regulated. Waste happens due to surplus inventory, which is the buildup of finished items, works in progress (semi-finished goods), and too many raw materials at all stages of production, necessitating storage (Pailin et al., 2020).
7. Overproduction at PT XYZ is very rare due to frequent shortages of stock. There is a mistaken waste when the product does not meet the requirements for selling. This wastes money and puts the cost of repairs at risk of going over budget. Subpar tools may bring this on staff

with minimal qualifications or tools not up to code (Paul-Eric et al., 2020).

Calculation of Geometric Mean

After knowing the questionnaire results from the three respondents, the geometric mean is calculated by converting it into a fuzzy number on each respondent's assessment first, as seen in Table 2. The fuzzy number has three values: lower, medium, and upper. The next step is calculating the average expert assessment of the three respondents to obtain the geometric mean, which can be seen in Table 3. The geometric mean is a method of smoothing participants' answers to perform pairwise comparisons. To get one particular value from all these values, each value must be multiplied by the other. Then the multiplication result is raised to the power of 1/n (Krejci and Stoklasa, 2018). Before looking for the consistency value on the criteria, the geometric mean is calculated because the number of respondents taken is more than one (Azari et al., 2020).

Calculation of Consistency Value

The next step is to calculate the consistency value of the criteria. The calculation results will be considered consistent if they have a CR value of 0.1 or 10%; otherwise, data verification will be carried out (Putra et al., 2018). The following are the steps for calculating the consistency value on the seven waste criteria:

1. The first step is to convert the questionnaire into a matrix.
2. Second, calculate the geometric mean can be seen in Table 4.
3. Normalization
   At the normalization stage, the results can be seen in Table 5.
4. Vector Weight
   The next step is to determine the weight vector for each criterion, as seen in Table 6, and the λ max, CI, CR, and RI values can be seen in Table 7. Based on Table 6, it can be seen that the obtained CR value of 0.057 means less than 0.1, so the calculation is considered consistent and can be continued in the weight calculation using fuzzy AHP (Kutlu et al., 2021).

Weighting Using Fuzzy AHP

1. The first step is to create a fuzzy pairwise comparison matrix on each criterion, as shown in Table 8. In the fuzzy pairwise comparison matrix, there are values of l (lower), m (medium), and u (upper) (Kaganski et al., 2018).
2. The next step is to add up each triangular fuzzy number in each row and all fuzzy numbers, as shown in Table 9.
3. Calculate the fuzzy synthetic extent, which can be seen in Table 10.
4. Comparing the probability level between fuzzy synthetic extents and the minimum value can be seen in Table 11. The fuzzy synthetic extent value is used to obtain the expansion of an object. So that it can be obtained the value of extent analysis m which can be shown as $M1\ gi$, $M2\ gi$, …, $Mm\ gi$,i = 1, 2, …, n , where $Mj\ gi$ (j = 1,2, …, m) is a triangular fuzzy number (Singh et al., 2018).
5. Perform weight calculations and normalize weight vectors, as seen in Table 12. Weight vectors are carried out to facilitate interpretation. Normalization of this weight will be carried out so that the values in the vector weights are allowed to be analogous to weights and consist of non-fuzzy numbers (Watrobski et al., 2022).

Seven Waste Weighting Analysis Using Fuzzy AHP Method

Based on the data processing results, the priority weight of each of the seven wastes is known. Then the questionnaire results were tested for consistency and obtained a consistency value of 0.057 which means less than 0.1, so it is considered consistent. The next stage is a data processing to get the weight of each waste. From the research results, it can be seen that the order of wastage criteria starting from the highest to the lowest weight vector is S4 (Inappropriate processing), S5 (Unnecessary Motion), S1 (Defect), S2 (Waiting), S6 (Transportation), S3 (Unnecessary inventory) and S7 (Overproduction).

The criteria S4 (Inappropriate processing) has the highest vector value (1.000). The higher frequency of criteria impacts the company (Yilidz et al., 2022). Inappropriate processing at PT XYZ is the lack of employee integrity regarding the standard of ability to carry out the production process so that the resulting product is not optimal. Employee integrity is essential in production activities because with a high commitment in employees to produce the best products, the resulting product quality will also be maximized (Peng and Wei, 2018).

Table 2. Questionnaire Results from the Three Respondents

Criteria	S1: S2	S1: S3	S1: S4	S1: S5	S1: S6	S1: S7	S2: S3	S2: S4	S2: S5	S2: S6	S2: S7	S3: S4	S3: S5	S3: S6	S3: S7	S4: S5	S4: S6	S4: S7	S5: S6	S5: S7	S6: S7
R 1	3	1	0.2	0.14	0.33	3	1	0.14	0.2	0.33	3	0.2	0.14	0.33	1	0.33	1	7	3	3	3
R 2	3	5	5	5	5	3	1	0.2	3	5	5	3	1	0.2	1	0.2	1	5	1	3	3
R 3	3	3	0.33	1	5	5	3	1	1	5	5	0.2	0.2	1	3	0.33	1	3	0.33	3	7

Table 3. Fuzzy Numbers on Respondents' Assessment and Geometric Mean

	Respondents													**Defuzzification**
	R1			**R2**			**R3**				**Geometric Mean**			
	l	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***		***l***	***m***	***u***	
S1	1	1.5	2	1	1.5	2	1	1.5	2	S2	1.000	1.500	2.000	1.500
S1	1	1	1	2	2.5	3	1	1.5	2	S3	1.260	1.554	1.817	1.544
S1	0.333	0.4	0.5	2	2.5	3	0.5	0.667	1	S4	0.693	0.874	1.145	0.904
S1	0.25	0.286	0.333	2	2.5	3	1	1	1	S5	0.794	0.894	1.000	0.896
S1	0.5	0.667	1	2	2.5	3	2	2.5	3	S6	1.260	1.609	2.080	1.650
S1	1	1.5	2	1	1.5	2	2	2.5	3	S7	1.260	1.778	2.289	1.776
S2	1	1	1	1	1	1	1	1.5	2	S3	1.000	1.145	1.260	1.135
S2	0.25	0.286	0.333	0.333	0.4	0.5	1	1	1	S4	0.437	0.485	0.550	0.491
S2	0.333	0.4	0.5	1	1.5	2	1	1	1	S5	0.693	0.843	1.000	0.846
S2	0.5	0.667	1	2	2.5	3	2	2.5	3	S6	1.260	1.609	2.080	1.650
S2	1	1.5	2	2	2.5	3	2	2.5	3	S7	1.587	2.109	2.621	2.106
S3	0.333	0.4	0.5	1	1.5	2	0.333	0.4	0.5	S4	0.480	0.621	0.794	0.632
S3	0.25	0.286	0.333	1	1	1	0.333	0.4	0.5	S5	0.437	0.485	0.550	0.491
S3	0.5	0.667	1	0.333	0.4	0.5	1	1	1	S6	0.550	0.644	0.794	0.663
S3	1	1	1	1	1	1	1	1.5	2	S7	1.000	1.145	1.260	1.135
S4	0.5	0.667	1	0.333	0.4	0.5	0.5	0.667	1	S5	0.437	0.562	0.794	0.598
S4	1	1	1	1	1	1	1	1	1	S6	1.000	1.000	1.000	1.000
S4	3	3.5	4	2	2.5	3	1	1.5	2	S7	1.817	2.359	2.884	2.353
S5	1	1.5	2	1	1	1	0.5	0.667	1	S6	0.794	1.000	1.260	1.018
S5	1	1.5	2	1	1.5	2	1	1.5	2	S7	1.000	1.500	2.000	1.500
S6	1	1.5	2	1	1.5	2	3	3.5	4	S7	1.442	1.990	2.520	1.984

Table 4. Geometric Mean

Criteria	S1	S2	S3	S4	S5	S6	S7
S1	1.000	3.000	2.466	0.693	0.894	2.027	3.557
S2	0.333	1.000	1.442	0.306	0.843	2.027	4.217
S3	0.405	0.693	1.000	0.493	0.306	0.405	1.442
S4	1.442	3.271	1.709	1.000	0.281	1.000	4.718
S5	1.119	1.185	2.759	3.557	1.000	1.000	3.000
S6	0.493	0.493	2.466	1.000	1.000	1.000	3.979
S7	0.212	0.212	0.342	0.189	0.281	0.251	1.000
Total	5.005	9.855	12.185	7.238	4.605	7.711	21.913

Table 5. Normalization

Criteria	S1	S2	S3	S4	S5	S6	S7
S1	0.200	0.304	0.202	0.096	0.194	0.263	0.162
S2	0.067	0.101	0.118	0.042	0.183	0.263	0.192
S3	0.081	0.070	0.082	0.068	0.066	0.053	0.066
S4	0.288	0.332	0.140	0.138	0.061	0.130	0.215
S5	0.224	0.120	0.226	0.491	0.217	0.130	0.137
S6	0.099	0.050	0.202	0.138	0.217	0.130	0.182
S7	0.042	0.022	0.028	0.026	0.061	0.033	0.046
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 6. Vector Wight

Criteria	S1	S2	S3	S4	S5	S6	S7	Total	Vector Weight (VW)
S1	0.200	0.304	0.202	0.096	0.194	0.263	0.162	1.422	0.203
S2	0.067	0.101	0.118	0.042	0.183	0.263	0.192	0.967	0.138
S3	0.081	0.070	0.082	0.068	0.066	0.053	0.066	0.486	0.069
S4	0.288	0.332	0.140	0.138	0.061	0.130	0.215	1.305	0.186
S5	0.224	0.120	0.226	0.491	0.217	0.130	0.137	1.545	0.221
S6	0.099	0.050	0.202	0.138	0.217	0.130	0.182	1.018	0.145
S7	0.042	0.022	0.028	0.026	0.061	0.033	0.046	0.257	0.037
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	7.000	1.000

Table 7. λ Max, CI, CR, dan RI

	S1	S2	S3	S4	S5	S6	S7	VW	Multi plication Criteri (MC)	VW/MC	λ max	CL	RI	CR
S1	1.000	3.000	2.466	0.693	0.894	2.027	3.557	0.203	1.541	7.587	7.452	0.075	1.320	0.057
S2	0.333	1.000	1.442	0.306	0.843	2.027	4.217	0.138	0.999	7.230				
S3	0.405	0.693	1.000	0.493	0.306	0.405	1.442	0.069	0.519	7.470				
S4	1.442	3.271	1.709	1.000	0.281	1.000	4.718	0.186	1.431	7.678				
S5	1.119	1.185	2.759	3.557	1.000	1.000	3.000	0.221	1.722	7.800				
S6	0.493	0.493	2.466	1.000	1.000	1.000	3.979	0.145	1.038	7.144				
S7	0.212	0.212	0.342	0.189	0.281	0.251	1.000	0.037	0.267	7.256				

Table 8. Fuzzy Pairwise Comparison Matrix

	S1			S2			S3			S4			S5			S6			S7		
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
S1	1.0	1.0	1.0	1.0	1.5	2.0	1.3	1.6	1.8	0.7	0.9	1.1	0.8	0.9	1.0	1.3	1.6	2.1	1.3	1.8	2.3
S2	0.5	0.7	1.0	1.0	1.0	1.0	1.0	1.1	1.3	0.4	0.5	0.6	0.7	0.8	1.0	1.3	1.6	2.1	1.6	2.1	2.6
S3	0.6	0.6	0.8	0.8	0.9	1.0	1.0	1.0	1.0	0.5	0.6	0.8	0.4	0.5	0.6	0.6	0.6	0.8	1.0	1.1	1.3
S4	0.9	1.1	1.4	1.8	2.1	2.3	1.3	1.6	2.1	1.0	1.0	1.0	0.4	0.6	0.8	1.0	1.0	1.0	1.8	2.4	2.9
S5	1.0	1.1	1.3	1.0	1.2	1.4	1.8	2.1	2.3	1.3	1.8	2.3	1.0	1.0	1.0	0.8	1.0	1.3	1.0	1.5	2.0
S6	0.5	0.6	0.8	0.5	0.6	0.8	1.3	1.6	1.8	1.0	1.0	1.0	0.8	1.0	1.3	1.0	1.0	1.0	1.4	2.0	2.5
S7	0.4	0.6	0.8	0.4	0.5	0.6	0.8	0.9	1.0	0.3	0.4	0.6	0.5	0.7	1.0	0.4	0.5	0.7	1.0	1.0	1.0

Table 9. The Sum of Fuzzy Number Comparison Matrix

	l	*m*	*u*
S1	7.267	9.209	11.331
S2	6.477	7.859	9.511
S3	4.811	5.413	6.191
S4	8.204	9.736	11.490
S5	7.870	9.644	11.541
S6	6.457	7.786	9.184
S7	3.855	4.505	5.667
Total	44.941	54.152	64.915

Table 10. Calculation of Fuzzy Synthetic Extent

	l	*m*	*u*
S1	0.112	0.170	0.252
S2	0.100	0.145	0.212
S3	0.074	0.100	0.138
S4	0.126	0.180	0.256
S5	0.121	0.178	0.257
S6	0.099	0.144	0.204
S7	0.059	0.083	0.126

Table 11. Probability of Fuzzy Synthetic Extent

Criteria	S1 ≥	S2 ≥	S3 ≥	S4 ≥	S5 ≥	S6 ≥	S7 ≥	Total
S1	1.000	0.780	0.260	1.000	1.000	0.763	0.186	
S2	1.000	1.000	0.465	1.000	1.000	1.000	0.375	
S3	1.000	1.000	1.000	1.000	1.000	1.000	0.864	
S4	0.932	0.702	0.144	1.000	0.985	0.678	0.071	
S5	0.948	0.722	0.182	1.000	1.000	0.701	0.109	
S6	1.000	1.000	0.466	1.000	1.000	1.000	0.375	
S7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Min	0.932	0.702	0.144	1.000	0.985	0.678	0.071	4.512

Table 12. Vector Weight and Normalization

Criteria	Vector Wight	Normalization
S1 (Defcet)	0.932	0.207
S2 (Waiting)	0.702	0.156
S3 (Unnecessary Inventory)	0.144	0.032
S4 (Inappropriate Processing)	1.000	0.222
S5 (Unnecessary Motion)	0.985	0.218
S6 (Transportation)	0.678	0.150
S7 (Overproduction)	0.071	0.016
Total	4.512	1.000

The second is S5 (Unnecessary motion) with a weight vector value of 0.985. An unnecessary motion in PT XYZ is the number of employee movements outside the production movement. Many employees chatted with each other during the production process in the flour mixing section with peanuts and the frying section. Some employees sit back while waiting for the beans to reach optimum maturity during the frying process, wasting time. The effectiveness of employee production time is significant (Diamantidis and Chatzoglou, 2018).

The third is S1 (Defect), with a weight vector value of 0.932. The wastage of defects at PT XYZ was in the process of coating the peanuts using imperfect flour and seasonings so that there were still parts of the peanuts visible from the outside. The flour layer was broken before frying due to the lack of seasoning coating. Based on this, it is necessary to rework to produce products following the company's quality standards. Wasteful defects include failures or defects in production activities. Defects to quality require rework which will incur additional costs. Costs include inventory, re-examination, and rescheduling (Hines and Rich, 1997).

The fourth is S2 (Waiting), with a weight vector value of 0.702. Waiting in the coated peanuts production process at PT XYZ occurs while waiting for results from the inter-station to be transported to the frying section, waiting to be put into the frying machine, and waiting to be put into the spinner machine. This condition is caused by poor materials, slow production, and large distances between work centers (Hines and Rich, 1997). This waiting activity will require a lot of lead time. Waiting waste includes waiting for the following process or operators waiting for the next job.

The fifth is S6 (Transportation), with a weight vector value of 0.678. Transportation waste at PT XYZ occurred due to the transfer of raw materials to inter stations. This was disrupted due to a damaged production floor so that the trolleys carrying raw materials could not experience smooth mobility. There is a temporary placement of raw peanuts at the station, thereby reducing the effectiveness of the production process. Excessive displacement will cause damage and loss of quality. Transportation waste includes unnecessary transfers such as temporary placement, re-stocking, and material movement (Hines and Rich, 1997).

The sixth is S3 (Unnecessary inventory) with a weight vector value of 0.144. Waste of unnecessary stock at PT XYZ is rare. This is because the production process of coated peanuts at PT XYZ is carried out continuously and uses a make-to-stock system. PT XYZ also continues to consider demand forecasting so as not to cause excessive storage conditions. Accuracy in forecasting is important so as not to waste unnecessary inventory (Rusmanan, 2020).

The last is S7 (Overproduction) with a weight vector value of 0.071. Overproduction is a waste that is not a major problem at PT XYZ. In producing coated peanuts, PT XYZ always pays attention to demand forecasting and production processes using a make-to-stock system. This avoids product accumulation in warehouses, which can increase product handling and storage space costs if stored for a long time. Overproduction occurs because there are more production activities of a product than customer demand or production earlier than the schedule that has been made (Pradana et al., 2018). According to Rachman (2018), companies must implement a demand forecasting system based on analysis and aspects of consumer demand. The results of the weighting of seven wastes using fuzzy AHP in this study will be used for weighting the Value Stream Analysis Tools (VALSAT) so that they can map the process flow on the value stream mapping. The VALSAT tools are selected based on the multiplication between the weighting of each type of waste and the multiplier factor in the VALSAT matrix.

Conclusion

The criteria for inappropriate processing have the highest priority as waste in production activities at PT XYZ, whereas the last priority of criteria is overproduction. Waste with the highest weight should receive more attention as improvement efforts are made. The results of the Fuzzy AHP method can be used as a basis for weighting the Value Stream Analysis Tools (VALSAT).

Declarations

Conflict of interests The authors declare no competing interests.

References

Azari, A., Nabizadeh, R., Mahvi, A. H., and Nasseri, S. (2020) 'Integrated Fuzzy AHP-TOPSIS for selecting the best color removal process using carbon-based adsorbent materials: multi-criteria decision making vs. systematic review approaches and modeling of textile wastewater treatment in real conditions', *International Journal of* Environmental *Analytical Chemistry*, 202(18), pp. 7329-7344

Boral, S., Howard, I., Chaturvedi, S.K., McKee, K., and Naikan, V.N.A. (2020) 'An integrated approach for fuzzy failure modes and effects analysis using fuzzy AHP and fuzzy MAIRCA', *Engineering Failure Analysis*, 108, pp. 104195

Chang, D. Y. (1996) 'Applications of the extent analysis method on fuzzy AHP', *European Journal of Operational Research*, 95(3), pp. 649-655

Diamantidis, A. D., and Chatzoglou, P. (2018) 'Factors affecting employee performance: an empirical approach', *International Journal of Productivity and Performance Management*, 68(1), pp. 171-193

Ghobakhloo, M. (2020) 'Corporate survival in Industry 4.0 era: the enabling role of lean-digitized manufacturing', *Journal of Manufacturing Technology Management*, 31(1), pp. 1-7

Hines P., and Rich N. (1997). 'The seven value stream mapping tools', *International Journal of Operations and Production Management*, 17(1), pp. 46-64

Ikatrinasari, Z.F., and Kosasih, S. (2021) ' Waste elimination to increase productivity in small, medium industries Kembangan West Jakarta', *Community Empowerment In Tourism & Creative Economy*, 3(1), pp. 308-311

Jasti, N.V.K., and Kodali, R. (2015) 'Lean production: literature review and trends', *International Journal of Production Research*, 53(3), pp. 867-885

Jihadudin, Sartika, N.S., Subroto, D. E., Mauladaniyati, R., Rosdianwinata, E., Rifa'I, R., Sujana, A., Abidin, Z., Priadi, M. D., Setiawan, E., Yanti, D., Purwanto, A. (2020) 'Effect of pedagogic, professional competency, and work motivation toward indonesian primary school teachers performance', *Systematic Reviews in Pharmacy*, 11(9), pp. 617-626

Kaganski, S., Majak, J., and Karjustm, K. (2018) 'Fuzzy AHP as a tool for prioritization of key performance indicators', *Procedia CIRP*, 72, pp. 1227-1232

Koulinas, G.K., Marhavilas, P.K., Demesouka, O.E., Vavatsikos, A.P., Koulouriotis, D.E. (2019) 'Risk analysis and assessment in the worksites using the fuzzy-analytical hierarchy process and a quantitative technique – A case study for the Greek construction sector', *Safety Science*, 112, pp. 96-104

Krejci, J. and Stoklasa, J. (2018) 'Aggregation in the analytic hierarchy process: Why weighted geometric mean should be used instead of weighted arithmetic mean', *Expert Systems With Applications*, 114, pp. 97-106

Kutlu, G.F., Duleba, S., Moslem, S., and Aydın, S. (2021) 'Evaluating public transport service quality using picture fuzzy analytic hierarchy process and linear assignment model', *Applied Soft Computing*, 100, pp. 106920

Pailin, D. B., Camerling, B. J., Nasarany, C. (2020) 'Lean distribution to minimize waste of time in the stripping process at PT. Pelabuhan Indonesia IV Ambon Branch', *Journal of Engineering and Applied Technology*, 1(2), pp. 74-84

Paul-Eric, D., Rafael, P., Cristiane, S., Joao, C.J. (2020) 'How to use lean manufacturing for improving a Healthcare logistics Performance', *Procedia Manufacturing*,51, pp. 1657-1664

Peng, H., and Wei, F. (2018) 'Trickle-down effects of perceived leader integrity on employee creativity: A moderated mediation model', *Journal of Business Ethics*, 150, pp. 837–851

Pradana, A.P., Mochammad, C., and Shodiq, A.K. (2018) 'Implementasi konsep lean manufacturing guna mengurangi pemborosan di lantai produksi (Implementation of the concept of lean manufacturing to reduce waste on the production floor)', *Jurnal Optimasi Sistem Industri*, 11(1), pp. 14-18 [In Indonesian]

Putra, M. S. D., Andyana, S., Fauziah., and Gunaryati, A. (2018) 'Fuzzy analytical hierarchy process method to determine the quality of gemstones', *Hindawi Advances in Fuzzy Systems*, 2018, pp. 1-6

Rachman, R. (2018) 'Penerapan metode moving average dan exponential smoothing pada peramalan produksi industri garment (Application of the moving average and exponential smoothing methods in garment industry production forecasting)', *Jurnal Informatika*, 5(2), pp. 211-220 [In Indonesian]

Rusmawan, H. (2020) 'Perancangan lean manufacturing dengan Metode Value Stream Mapping (VSM) di PT. Tjokro Bersaudara (PRIOK) (Lean manufacturing design using Value Stream Mapping (VSM) Method at PT. The Tjokro Brothers (PRIOK))', *Jurnal Optimasi Teknik Industri*, 2(1), pp. 30-35 [In Indonesian]

Saffarian, S., Mahmoudi, A., Shafiee, M., Jasemi, M., and Hashemi, L. (2020) 'Measuring the effectiveness of AHP and fuzzy AHP models in environmental risk assessment of a gas power plant', *Human and Ecological Risk Assessment: An International Journal*, 27, pp. 1227-1241

Sahrupi., Dwiputra, G.A., and Chasanah, U. (2020) 'Implementation of lean manufacturing to enhance the efficiency of acrylic resins production process', *Jurnal Sistem dan Manajemen Industri*, 4(1), pp. 50-60

Sener, E., Sener S., and Davraz A. (2018) 'Groundwater potential mapping by combining fuzzy-analytic hierarchy process and GIS in Beyşehir Lake Basin, Turkey', *Arabian Journal of Geosciences*, 11(187), pp. 1-21

Singh, R. K., Chaundhary, N., and Saxena, N. (2018) 'Selection of warehouse location for a global supply chain: A case study', *IMB Management Review*, 30, pp. 343-356

Syahputri, K., Sari, R. M., Siregar, I. (2017) 'Identification and waste reduction on rubber industry', IOP Conf. Series: Materials Science and Engineering, 180, pp. 1-8

Tan, R.R., Aviso, K.B., Huelgas, A.P., and Promentilla, M.A.B. (2014) 'Fuzzy AHP approach to selection problems in process engineering involving quantitative and qualitative aspects', *Process Safety and Environmental Protection*, 92(5), pp. 467-475

Watrobski, J., Baczkiewicz, A., and Salabun, W. (2022) 'Pyrepo-mcda — Reference objects based MCDA software package', *SoftwareX*, 19, pp. 1-10

Yilidz, A., Guneri, A. F., Ozkan, C., Ayyildiz, E., and Taskin, A. (2022) 'An integrated interval-valued intuitionistic fuzzy AHP-TOPSIS methodology to determine the safest route for cash in transit operations: a real case in Istanbul', *Neural Computing and Applications*, 34(18), pp. 15673–15688