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Analysis of Green Manufacturing and Its Implementation to Overcome Pollution from Economic, Social, and Environmental Perspectives Using The Fuzzy Topsis Method

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ABSTRACT

CV. XYZ is a company engaged in agribusiness as a fertilizer producer. CV manufacturing process. XYZ has not fully paid attention to the environment with the discovery of pollution due to waste. Based on observations, the percentage of B3 and non-B3 waste that has been managed is 36% and that which has not been managed is 64%. In addition to environmental pollution, this problem will also affect the economy and society if there is environmental damage and workers' health problems. This research was conducted to identify factors that support companies to implement environmentally friendly practices and provide recommendations so that companies know the steps in implementing these practices. The method used is fuzzy to tolerate inappropriate data from the questionnaire and TOPSIS to rank supporting factors based on economic, social, and environmental perspectives. The results showed that the priority supporting factors in the economic sector were market trends (0.629), social sectors were worker demand (0.594), and environmental sectors were regulatory compliance (0.629). Based on these factors, the recommendation given based on an economic perspective is to implement the 3R, namely reduce, reuse, and recycle. Recommendations based on a social perspective are the existence of ISO 14001 training programs and AMDAL training. Recommendations based on an environmental perspective are the establishment of waste limits for each department, a zero waste culture, the provision of a storage place for all waste, and working with third parties to manage all waste.

INTRODUCTION

The manufacturing industry sector continues to progress every year, which has an impact on increasing competition in the business world, especially in the economic sector. Therefore, every country is required to continue to develop to ensure the equitable distribution of the welfare of its population. In the context of the business world, the growth of a company will trigger increasingly intense competition between one company and another.Industry is an activity that processes raw or semi-finished materials into finished goods [1]. In industrial activities, there are often violations such

as disposing of industrial waste without proper management processes that cause pollution. If the company does not make efforts to improve the impact, then in the future this condition can be detrimental to the community and the company.This not only has an impact on the environment but also brings economic and social consequences, potentially causing environmental damage.

Based on the results of observations, the manufacturing process in CV.XYZ has not fully paid attention to the company's environment with pollution still being found. Pollution arises due to waste produced from manufacturing with toxic and hazardous material waste (B3) and non-B3 waste. B3 waste has properties that can pollute and even damage the environment, human health and other creatures [2]. The waste has increased every year in line with the amount of fertilizer produced by the company. Fertilizer production and waste stockpiles from 2020 to 2022 can be seen in figure 1 and table 1.

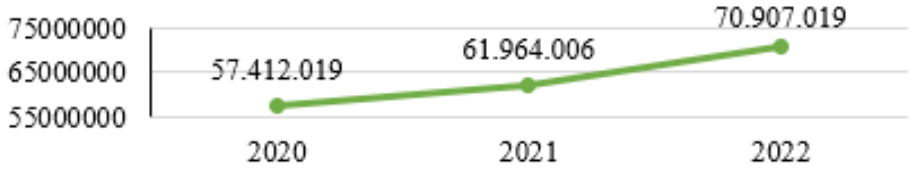

Figure 1. CV Fertilizer Production Graph. XYZ

Based on figure 1, it can be concluded that the collection of B3 and non-B3 waste continues to increase every year. This condition occurs due to an increase in fertilizer production and the company has not managed waste properly. The increase in fertilizer production from 2020 to 2021 was 5% and the increase in fertilizer production from 2021 to 2022 was 11%. The increase in landfills from 2020 to 2021 was 8% and the increase in landfills from 2021 to 2022 was 16%.

Table 1. Recapitulation of B3 and Non B3 Waste Landfills

	2020 (kg)	**2021 (kg)**	**2022 (kg)**
B3 Waste	52.043	81.506	134.832
***Non* B3 Waste**	534.792	537.222	549.048
Total	586.835	618.728	683.880

From the results of the observation, it is known that the percentage of B3 and non-B3 waste that has been managed is 36% and those that have not been managed is 64% (source: company data). In addition to environmental pollution, the impact of this problem will also affect the economy and society if there is environmental damage and disturbances to workers' health due to pollution. Environmentally friendly continuous improvement, namely the concept of green manufacturing, is very important for companies to implement to minimize pollution due to increasing waste deposits.

Research by [3] has identified related factors that support industries in India in implementing green manufacturing practices. This is due to the lack of awareness of industry players in maintaining environmental health during production.In addition to knowing the factors for the industry to implement green manufacturing, steps or ways to achieve green manufacturing also need to be discussed. However, this has not been conveyed in previous research. Research by [4] studies the processes associated with the application of Green Manufacturing in industrial environments and highlights the influential factors. It is known that the application of the concept of Green Manufacturing in companies is still limited. Many company leaders see the implementation of Green Manufacturing as an obstacle to profitability rather than as an opportunity to advance.

Therefore, in addition to knowing the practices in handling waste and knowing the factors that support companies to want to implement practices related to the concept of green manufacturing, this study also discusses what steps must be taken in implementing environmentally friendly practices. These supporting factors are determined by ranking from several known supporting factors. Before conducting the ranking, an assessment of several supporting factors was carried out through the distribution of questionnaires. The questionnaire is prepared with easy-to-understand language and an assessment system that has tolerance for inappropriate data so that data that is able to represent the data needed is obtained.

The determination of the supporting factors of the green manufacturing concept is carried out by considering economic, social and environmental perspectives. The economic perspective includes activities to gain profit through the production process and utilization of natural resources. The social perspective includes relationships in society. The environmental perspective is based on a combination of physical conditions that include natural elements such as soil, water, air, and energy, and affects human development. These three perspectives are used in determining supporting factors so that the company continues to develop and survive in competition without causing a negative impact on the environment. After knowing the supporting factors, the researcher provides recommendations so that companies know what steps to take in implementing environmentally friendly practices.

MATERIALS AND METHODS

This research began with observations on CV. XYZ and literature studies by looking for various sources that are relevant to the problem being researched. The questionnaire made was 2 questionnaires. Questionnaire 1 is a questionnaire on the level of influence of criteria on the concept of green manufacturing and is filled out by respondents who are in accordance with their fields. Questionnaire 2 is a questionnaire on the level of importance of factors that make companies willing/willing to implement the concept of green manufacturing and filled out by respondents who are in accordance with their fields. The results of questionnaire assessment I and II will later be processed using the fuzzy method as a reference in determining supporting factors and will be ranked based on the TOPSIS method.

A. Environmental Health

According to the Regulation of the Minister of Health Number 70 of 2016 concerning Industrial Work Environment Health Standards and Requirements, environmental health is an environmental condition whose quality is maintained so that it avoids diseases or health problems caused by work environmental factors. Environmental health problems can be formed by several factors, workers' actions, mindsets and behaviors [5].

B. *Green Manufacturing*

Green Manufacturing (GM) is an approach that is carried out to improve sustainable environmental health in the industrial sector and its products, aiming to reduce or prevent air, water, and soil pollution, minimize waste, and reduce risks to humans and other species [4].

C. Industrial Waste Company

Waste is the residue of a business and/or activity [6]. The waste produced can be in the form of toxic and hazardous material waste (B3) and non-B3 waste . B3 waste is waste with harmful and toxic substances. B3 waste has properties that can pollute and

even damage the environment, health, and survival of humans and other creatures. Non-B3 waste can be interpreted as the residue of harmless and toxic activities.

D. Fuzzy Logic

Fuzzy logic is a decision support system that has a high tolerance for unclear data. Fuzzy logic works using the degree of membership of a value which is then used to determine the desired outcome based on a predetermined specification. This membership degree or membership function is an indicator curve mapping data input points into its membership value that has an interval between 0 to 1 [7]. Before converting the assessment into a membership function, the questionnaire was filled out using a likert scale of 1-5 to make it easier for respondents to fill out the questionnaire. Furthermore, the assessment is processed by converting it into a membership function. The description and value of the likert scale can be seen in table 2.

Table 2.Description of Assessment with Likert Scale

Information		Value
Criterion	**Alternative**	
Not Influential	Not Important	1
Less Influential	Less Important	2
Quite Influential	Quite Important	3
Influential	Important	4
Highly Influential	Very Important	5

Tabel 3. Variabel Linguistik Kriteria dan Alternatif

Variabel Linguistik		Membership Functions
Criterion	**Alternative**	
Not Influential	Not Important	(1,1,3)
Less Influential	Less Important	(1,3,5)
Quite Influential	Quite Important	(3,5,7)
Influential	Important	(5,7,9)
Highly Influential	Very Important	(7,9,9)

E. *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS)

The TOPSIS method is used to rank and provide weighting criteria to determine the best solution from the available options. This method assumes that each criterion in the study will be maximized or minimized so that a positive ideal solution and a negative ideal solution from each criterion are obtained [8].

The data that exists in this solution making is inadequate for real-life problems due to the lack of clear preferences of human judgment and the inability to estimate his preferences with precise numerical values [9]. herefore, TOPSIS needs another method that can overcome this problem, namely fuzzy theory that overcomes the problem of measuring the ambiguity of subjective human judgment.

RESULTS AND DISCUSSION

Result

A. Identification of Green Manufacturing Practices

In this study, green manufacturing practices were identified to overcome the problem of pollution due to waste that has not been handled by the company. After knowing the green manufacturing practices , then the determination of factors that support the company to implement these practices will be determined.

Table 4. Practices that companies can do to handle waste

No	Types of Waste	Green Manufacturing Practices	Source
1	Majun Fabric	Reduce the use of advanced fabrics by using wood sawdust to clean up oil spills. This is more effective because wood sawdust has better absorption against spilled or leaking oil and is more environmentally friendly. The wood powder is then handed over to a third party for management.	[10]
2	Fly Ash	- Addition of a wet scrubber system to control fly ash. Wet scrubbers work by absorbing pollutants with liquids. Inside the system, the contaminated gas will enter the bottom of the system, then it will be drained or sprayed upwards. - Collecting fly ash and bottom ash and working with third parties to process fly ash and bottom ash into bricks. Ash from combustion is used as a mixture of concrete and brick because of its very fine particle size so that it can function as a cavity filler and as an aggregate binding agent..	[11], [12], [13], [14], [15]
3	Bottom Ash		
4	Used Filters	Placing the used filter and used lubricating oil into the drum and then stored in a temporary storage area at the B3 waste landfill which is then transported by a third party.	[16], [17], [18]
5	Used Lubricating Oil		
6	Zak	Collecting zak waste is then sold to a third party who processes zak waste.	[19]
7	Charcoal	Collecting wood charcoal and cooperating with third parties to process wood charcoal as a mixture material for making light concrete.	[20]

B. Identification of Green Manufacturing Criteria

In this study, the identification of green manufacturing criteria was carried out because these criteria will help in determining factors that support the company to realize the GM concept. The criteria used are perspectives from the economic, social, and environmental fields. This is because the three fields are interconnected and have an impact on each other. An explanation of the perspective used as a criterion in determining the supporting factors of the GM concept can be seen in table 5.

Tabel 5. Green Manufacturing Criteria

No	Criteria	Explanation	Source
1	Economic Perspective	Includes activities to gain profits through the production process and utilization of natural resources.	[21], [22], [23]
2	Social Perspective	Includes the company's relationship to the company's human resources.	
3	Environmental Perspective	combination of physical conditions that include natural conditions that affect the state of the environment and human health.	

C. Identification of GM Supporting Factors

In this study, factors that support companies to implement green manufacturing are identified because the availability of companies has an important role in realizing GM practices in the company. Based on the results of the literature review that has been conducted, several relevant supporting factors were obtained to be used in this study. The supporting factors can be seen in table 6.

Table 6. Factors Supporting the GM Concept

No	Factor	Symbol	Source
1	Financial Advantages	A1	[3]
2	Competitors	A2	[3]
3	Market trends	A3	[3]
4	Supply Chain Needs	A4	[22]
5	Company image	A5	[22], [3]
6	Customers	A6	[22], [3]
7	Internal motivation	A7	[3]
8	Employee Deman	A8	[22], [3]
9	Regulatory Compliance	A9	[22], [3], [23]
10	Eco-friendly innovation	A10	[3], [24]
11	Environmental Conservation	A11	[5]
12	Environmental Management	A12	[4]

D. Data Processing Results

After obtaining a preference value or Closeness Coefficient (Cci) from data processing using the TOPSIS fuzzy method, a ranking of supporting factors for the implementation of green manufacturing in the company can be done based on economic, social, and environmental perspectives. The ranking of supporting factors in the economic, social, and environmental fields can be seen in tables 7, 8, and 9

Table 7. Ranking of Supporting Factors in the Economic Sector

Symbol	Factor	CCi	Ranking
A3	Market trends	0,629	1
A1	Financial Advantages	0,591	2
A2	Competitors	0,591	3
A4	Supply Chain Needs	0,520	4

Table 8. Ranking of Social Factors

Symbol	Factor	CCi	Ranking
A8	Employee Demand	0,594	1
A5	Company image	0,569	2
A7	Internal motivation	0,569	3
A6	Customers	0,521	4

Table 9. Ranking of Supporting Factors in the Environmental Sector

Symbol	Factor	CCi	Ranking
A9	Regulatory Compliance	0,629	1
A11	Environmental Conservation	0,591	2
A12	Environmental Management	0,591	3
A10	Eco-friendly innovation	0,520	4

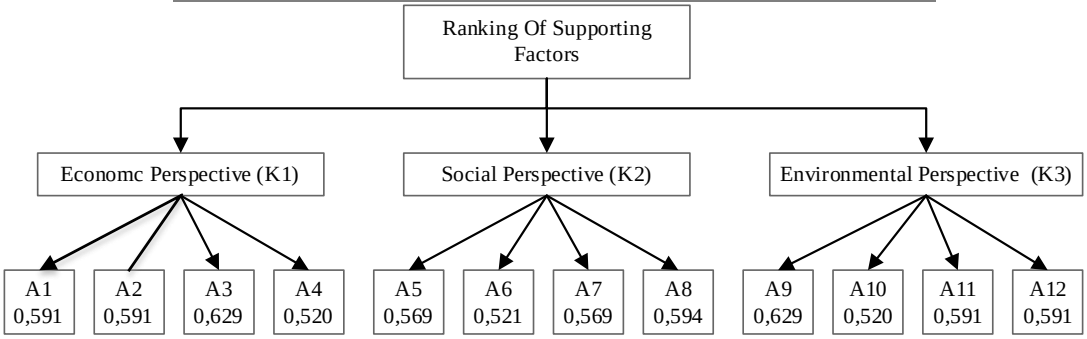

Figure 2. Structure Hierarki Beserta Nilai Cci

Discussion

Based on an economic perspective, it is obtained that market trends are the first order or factors that support companies to be willing to implement green manufacturing because they have the highest CCI value of 0.629. It is known that at this time the trend of green manufacturing is supported by all external parties. In this case, the trend puts pressure on manufacturers to produce products through environmentally friendly manufacturing activities. The second order of supporting factors based on the economic perspective is financial advantage and competitors with a Cci value of 0.591. The last order of supporting factors based on an economic perspective is supply chain needs with a Cci value of 0.520.

Based on a social perspective, it is obtained that the demand for workers is the first order or priority factor that supports companies to be willing to implement green manufacturing because it has the highest Cci value of 0.594. It is known that at this time some operations produce hazardous and toxic waste that can pollute the environment and pose a risk to worker safety. Therefore, there are demands from workers for companies to implement the concept of green manufacturing. The second order of supporting factors based on social perspective is company image and internal motivation with a Cci value of 0.569. The last order of supporting factors based on social perspective is customers with a Cci value of 0.521.

Based on an environmental perspective, it is found that compliance with regulations is the first order or priority factor that supports companies to be willing to implement green manufacturing because it has the highest Cci value of 0.629. The company's obligation to comply with the regulation of the minister of environment and forestry which contains the operation of the field of environmental pollution control. Therefore, existing regulations are able to support companies to implement the concept of green manufacturing. The second order of supporting factors based on the environmental perspective is environmental conservation and environmental management with a Cci value of 0.591. The last order of supporting factors based on an environmental perspective is environmentally friendly innovation with a Cci value of 0.520.

CONCLUSION

The research on green manufacturing analysis and its implementation to overcome pollution from economic, social, and environmental perspectives using the fuzzy topsis method can solve the problems that exist in the company because in this study it is determined that green manufacturing practices are appropriate to overcome the problem of pollution due to company waste and to know the factors that support the company to be willing to implement environmentally friendly practices. The use of the Fuzzy TOPSIS method in this study is a method that is able to determine the supporting factors of the green manufacturing concept. Fuzzy was used to complete the assessment with tolerance for inappropriate data from the questionnaire, while TOPSIS was used to rank supporting factors based on economic, social, and environmental perspectives. Priority supporting factors based on economic, social, and environmental perspectives in supporting companies to be willing to implement green manufacturing have been known, including market trends with a Cci value of 0.629 based on an economic perspective, worker demand with a Cci value of 0.594 based on a social perspective, and compliance with regulations with a Cci value of 0.629 based on an environmental perspective. With the knowledge of the priority supporting factors, recommendations can be determined, namely implementing the 3R, namely reduce, reuse, and recycle. involve employees in carrying out green manufacturing practices through ISO 14001 training programs and EIA

training, establish company policies in the form of setting waste limits for each department, zero waste culture, providing storage facilities for all types of waste, collaborating with third parties to manage all types of waste.

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