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Abstract. PG Krebet Baru is one of the companies that have not implemented green supply chain management (GSCM). The main problems currently faced by PG Krebet Baru's supply chain are low recycling process, fuel waste, and low raw material efficiency. The purpose of this research was to evaluate the performance of green supply chain management in PG Krebet Baru's supply chain. Thus, alternative improvement can be formulated and proposed to be implemented. The method used in this study was Supply Chain Operation Reference (SCOR) and to determine the alternative of supply chain DEMATEL method was employed. The result of this calculation was 56.12, indicating an average performance for GCSM application in PG Krebet Baru. Alternative improvements proposed were focused on reduction of hazardous material (GP2), worker and environmental sanitation (GM9), product handling (GD1), and reuse of packaging (RL3).

1. Introduction

Sugar is one of the strategic commodities in Indonesian economy. Indonesia as a sugar-producing country currently has 58 white sugar factories processing sugar cane with a capacity of 195,810 tons per day, covering an area of 380 thousand hectares [1]. One of the active sugar industries in Indonesia is PG Krebet Baru in Malang Regency.

Today, several companies have begun to implement supply chain performance with an environmental friendly approach called Green Supply Chain Management (GSCM). In general, the green supply chain is integrating the supply chain management (SCM) elements with the company's environmental management [2]. The addition of green or eco-friendly practices into SCM results in GSCM [3]. The GSCM concept is acknowledged as an important initiative to increase ecological advantages and promote organisational sustainability [4]. GSCM is the process of incorporating environmental factors into business activities. Companies must integrate all of the processing parts to get the biggest benefits from the environmental management [5]. The GSCM benefits include increasing efficiency, improving product quality and reducing the waste. The purpose of GSCM is to consider both the final and present impacts on the environment resulted from all products and processes, aiming to protect the natural environment [6]. The GSCM consists of 4 series of activities namely green procurement, green manufacturing, green distribution, and reversed logistics [7].

The core problems of supply chain in the PG Krebet Baru are lack of waste recycling process, wasting of fuel, and low raw material efficiency. Low recycling processes include directly disposed of waste emission into the atmosphere, as well as of *blotong* to the environment. Such practices can cause the environmental pollution. The wasting of fuel is caused by inadequate performance of engine and sugar factory equipment, which leading to lengthening the production time [8].

The purposes of this study were to identify and analyse the performance of the supply chain used by the PG Krebet Baru and to determine the proposed improvements. The method used to measure the supply chain performance is the Supply Chain Operation Reference (SCOR) with the GSCM approach. By using the SCOR model, the activities in the company's business process can be measured in detail from upstream to downstream [9]. The measurement of alternative improvements used the DEMATEL method. To identify the interactions among evaluation criteria of alternative systems, the Decision Making Trial and Evaluation Laboratory (DEMATEL) approach was used to construct a network structure with interdependent relationships [10]. In addition, DEMATEL can also be used to find and analyse the dominant criteria in a system. The results from DEMATEL can be employed to propose any measures or strategies to improve the supply chain performance with an environmentally friendly approach or GSCM [11].

2. Research Methods

The research was conducted at PG Krebet Baru. The data processing was carried out at Computation and System Analysis Laboratory, Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang. There were 4 variables used in this study include green procurement, green manufacturing, green distribution and reversed logistic. The variables determination was based on GSCM activities. There are four respondents were included, as follows: suppliers, production, warehousing and quality control staff.

The main research stages consisted of designing the Key Performance Indicator (KPI), measuring supply chain performance and determining alternatives for performance improvement.

2.1. KPI design

The KPI design was carried out following the stages of identifying supply chain models and supply chain mapping with green SCOR. From this step, the green objectives were produced. Furthermore, the validation test was conducted through in-depth interviews with stakeholders. Validation test using face validity was applied to find which KPI could be applied as an indicator for performance measurement. This test was to ensure that the measurement instruments or the research instruments are able to accurately measure the determined variables or indicators [12].

2.2. Supply chain performance measurement

The second step was GSCM performance measurement based on the selected KPI using the SCOR method. Performance attributes measured in the SCOR method included reliability, responsiveness, flexibility, cost, and asset management. In the process of performance measurement, a weighting of importance was needed for all factors that affect performance. In this measurement, the importance of weighting was done by using AHP based on hierarchy of levels, successive variables, green objective, and KPI. The AHP for decision-making is a theory of relative measurement based on paired comparisons used to derive normalized absolute scales of numbers, in which those elements are then used as priorities [12]. The result is in the form of a total score of each KPI, the actual performance value of the KPI was assessed to determine the performance of the supply chain. The actual performance value is the performance value achieved by the manufacturer. The actual performance value was normalized using Snorm de Boer so that each KPI has the same scale. Normalization is carried out with a formula that considers KPI indicators namely larger is better and lower is better [13].

2.3. Determination of improvement alternatives

Alternatives were determined for each variable to find which criteria are alternatives for the related variables. The scoring result of improvement alternatives were then processed using DEMATEL to find the best criteria from the causal diagram. Recapitulation result from the pairwise comparison was obtained by building the pairwise comparison matrix. According to Nathan et al. [14] and Lin [23], there are 5 steps which is direct relation matrix (Z), the normalization matrix (X), the total relations matrix (T), making D and R value, and building causal diagram. The causal diagram analysis using BOCR matrix analysis is used to determine the best criteria. Based on BOCR analysis, positive cause factors, positive effect factors, negative cause factors, and negative effect factors can be determined.

3. Result and discussion

3.1. Supply chain performance measurement

3.1.1. Scoring 1st level

Scoring 1st level is carried out on each GSCM measurement variables. As a result, the inconsistency ratio is smaller than 0.1 meaning that the value is consistent. Hanson [15], the greater the ratio value, the more inconsistent the assessment. Inconsistency ratios 10% or less are considered consistent or acceptable. The results of first level can be seen in Table 1. Based on Table 1, the green manufacturing variable has the highest value compared to other variables of 0.49. It shows that green manufacturing has the highest level of importance or prioritized from all variables. Production process become a main aspect because it is related with consumer's demand and quality of sugar. Also, this aspect has and impact on eco-efficiency as it determine the amounts of (raw) material, energy, water, and fuel use, as well as the total amount of waste produced [16].

3.1.2. Scoring 2nd level

The results of 2nd level can be seen in Table 1. The highest value in green procurement is obtained by minimizing hazardous material by 1.00. The highest value in green manufacturing is obtained by minimizing source, energy, fuel, and others by 0.42. According to Thipparat [17], using the right amount of raw material will produce products that have good quality and reduce operational costs in the production process and minimize waste from the process. On green distribution, the highest value is obtained by packaging, storage and handling of products by 0.75. Green distribution includes green packaging and green logistics [18]. This activity serves to maintain product quality so that there is no damage on the product or packaging. In reversed logistic, highest value is obtained by maximizing the reuse and recycle by 1.00. This process can reduce the production cost and minimise the amount of waste disposed to the environment. Waste is not providing benefit to the process transformation from inputs into outputs [19].

3.1.3. Scoring 3th level

The scoring of KPIs was carried within the same objective, if added together the result of each objective is 1. Based on Table 1, KPI with the largest value shows priority for each objective. However, in second objective, the three KPIs have the same value of 0.33. It shows that the three KPIs that is efficiency material, minimizing water usage, and minimizing energy usage have the same level of importance. Thus, raw materials and energy costs can be reduced, low emission production can be designed, and the company's image can be improved, which can lead to higher product sales and a high societal acceptance [20]. After all values were obtained, the total value of each KPI is calculated.

3.1.4. Normalization actual performance value

This value is obtained from the condition of the company in 2017. Refer to Wahyuniardi et al. [21], the actual value calculation is carried out every period for 12 periods to get the best and worst value during the study period. This actual value is obtained from the average value. However, in this study, this calculation is carried out every month starting from May to November in 2017. This is adjusted

for the PG Krebet Baru milling season in 2017 starting from May to June. The results of normalization in Table 1 were calculated using the Snorm de Boer formula related to the KPI indicator.

Table 1. Result of scoring 1st level, 2nd level, 3th level.

1st level		2nd level		3th level		
Variable	Value	Objective	Value	KPI	Value	Total
Green Procurement	0.19	Minimizing the dangerous materials	1.00*	Percentage of dangerous materials in inventory[a]	0.75*	0.146*
				Percentage of biodegradable materials[b]	0.250	0.049
Green Manufacturing	0.49*	Minimizing the usage of resources, energies, fuels, and others	0.42*	Usage of energy[a]	0.333	0.069
				Usage of water[a]	0.333	0.069
				Material usage efficiency[b]	0.333	0.069
		Minimizing the emission handling	0.26	Air emission[a]	0.444*	0.056
				Water emission[a]	0.444*	0.056
				Ground emission[a]	0.111	0.014
		Training improvement for Green Operation	0.13	Percentage of trained workers[b]	1.000*	0.066
		Minimizing the waste management	0.19	Percentage of waste product. (solid, liquid, gas)[a]	0.558*	0.053
				Percentage of dangerous waste[a]	0.320	0.030
				Percentage of total byproducts[a]	0.122	0.012
Green Distribution	0.19	Customers satisfaction of product refers to environment aspect	0.25	Percentage of customers' complaint[a]	1.000*	0.049
		Packaging, storage, and product handling	0.75*	Percentage of broken product during storage[a]	0.75*	0.109
				Percentage of non-feasible packaging[a]	0.25	0.036
Reversed Logistic	0.12	Maximizing the reuse and recycle	1.00*	Percentage of materials that can be recycled/reused[b]	0.75*	0.088
				Percentage of reusable waste[b]	0.25	0.029

Note: [a]lower is better; [b]larger is better; *largest value

3.1.5. Scoring supply chain performance

To get the scoring value of the supply chain performance, the results of normalization were multiplied with the total value of each KPI. Table 2 shows that the total supply chain performance reaches 56.12. Refer to the supply chain performance indicator [9], this value is at an average level which shows that the application of GSCM in the PG Krebet Baru has not been fully implemented.

Table 2. Result of scoring supply chain performance.

Variable	Variable Score
Green Procurement	9.77
Green Manufacturing	28.29
Green Distribution	15.89
Reversed Logistic	2.17
Total	56.12

3.2. Alternative supply chain performance improvement

The improvement recomendation are based on each variable. The criterias are from the KPI that is used to measure the performance or fraction of the KPI. Improvement criteria can be seen in Table 3.

Table 3. Alternatives improvement criteria

Variable	Criteria	Code	D+R	D-R
Green Procurement (GP)	Minimizing damage material[e]	GP_1	0.961	-0.086
	Minimizing dangerous material[c]	GP_2	0.699	0.176
	Green transportation[c]	GP_3	0.868	0.007
	Material handling[e]	GP_4	0.971	-0.096
Green Manufacturing (GM)	Material usage efficiency[e]	GM_1	15.409	-0.289
	Energy usage efficiency[e]	GM_2	14.313	-0.715
	Water usage efficiency[e]	GM_3	14.377	-0.971
	Minimizing the emision[e]	GM_4	15.181	-0.164
	Waste handling[e]	GM_5	14.300	-0.701
	Sertificate of environmental management[c]	GM_6	15.665	0.816
	Labor training[c]	GM_7	15.382	0.845
	Green packaging[c]	GM_8	15.391	0.847
	Environment and worker sanitation[c]	GM_9	15.702	8.426
Green Distribution (GD)	Product Handling[c]	GD_1	0.891	0.162
	Green Transportation[c]	GD_2	0.370	0.000
	Brand image improvement[e]	GD_3	0.781	-0.166
	Quality Control of product[c]	GD_4	0.838	0.004
Reverse Logistic (RL)	Recycle[e]	RL_1	-4.500	-0.100
	Material reuse[e]	RL_2	-4.409	-0.009
	Packaging reuse[c]	RL_3	-4.291	0.109

Note: [c]cause, [e]effect

3.3. Causal diagram

Causal diagram can be constructed by mapping the data set (D+R, D-R) where the horizontal axis (D+R) is obtained by summing D and R. The vertical axis is obtained by reducing D and R. Causal diagrams can provide information on which factors are the most dominating and influencing and factors that are influenced. The results of making causal diagrams for each variable are presented successively in Figure 1 to Figure 4.

In Figure 1, the highest value obtained by GP_4 is 0.971. In cause group was obtained by GP_2 of 0.176 followed by GP_3. This shows that GP_3 has a very large influence in the green procurement system followed by GP_2. The lowest value is obtained by GP_4 followed by GP_1. This shows that GP_4 is a criteria that receives the maximum impact from the system. Gandhi et al [22], the cause group factors are very vital due to their direct impact on the overall system. Thus, it would be significant to focus on the cause group factors. The axis (D+R) in Figure 2, the highest value obtained by GM_9 is 15.72. It shows that GM_9 criteria has the highest degree of importance and provides greater benefits than other criteria. In the positive cause group, the highest value was obtained by GM_9 with a value 8.426. In the effect group, the lowest value was obtained by GM_3 with a value -0.971.

In Figure 3, GD_1 has the highest value 0.891. In cause group, the highest value is obtained GD_1 with a value 0.162. In effect group, the lowest value is obtained by GD_3 with a value of -0.166. In Figure 4, the highest value obtained by RL_3 is -4.291. In the cause group, the highest value was obtained by RL_3 with a value of 0.109 which showed that RL_3 had the greatest influence in reversed logistics. In the result group, the lowest value was obtained by RL_1 with value -0.100 followed by RL_2.

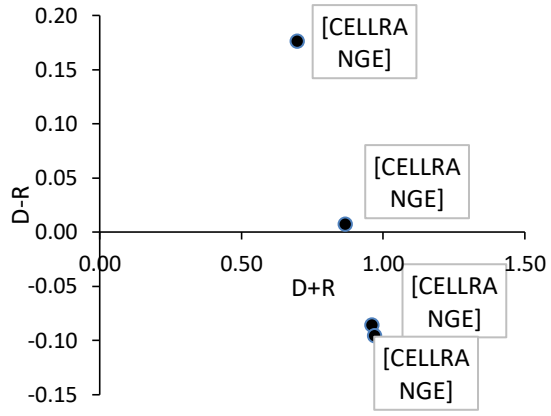

Figure 1. Green procurement.

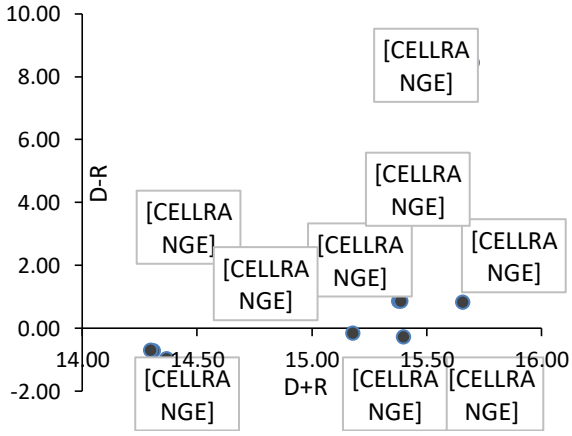

Figure 2. Green manufacturing.

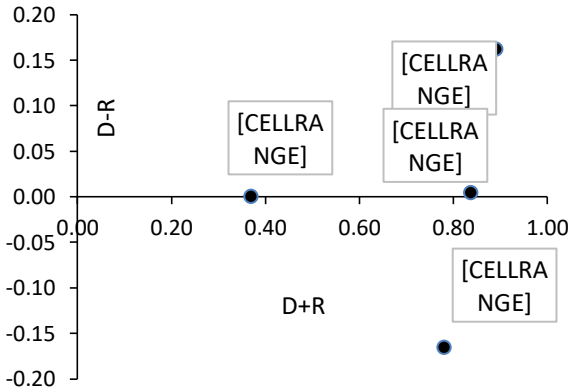

Figure 3. Green distribution.

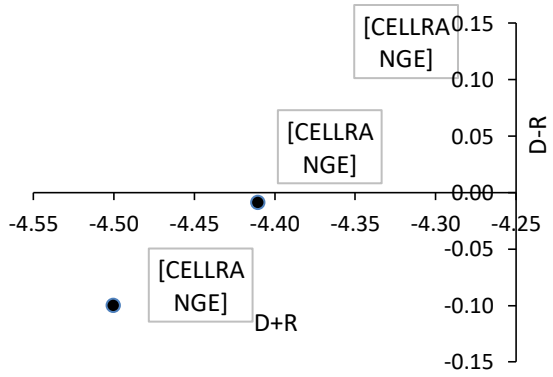

Figure 4. Reversed logistic.

4. Conclusion

The final result of supply chain performance measurement based on 4 variables is 56.12 which is show the application of green supply chain in PG Krebet Baru at the level of average performance. Recommendations for alternative improvements are focused on cause factors for green procurement, green manufacturing, green distribution, and reverse logistics variables. The criteria classified as cause factors that have the highest influence are reduction of hazardous material (GP2), worker and environmental sanitation (GM9), product handling (GD1), and reuse of packaging (RL3). These criteria are priorities as an alternative to improving supply chain performance. Overall GM9 is the criterion that gives the most influence, and becomes the top priority for improving system performance.

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