BI-OBJECTIVE FUNCTION OPTIMIZATION IN THE SUPPLY CHAIN MODEL USING THE PARETO APPROACH

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Abstract

Supply chain development is a system that includes a series of processes from production to product delivery to consumers. This study modifies the *supply chain* model by using multiobjective optimization. The model is constructed to maximize manufacturing profits and minimize carbon gas emission waste. The optimal solution produces a pareto solution and then a single solution is determined by the weighting method. Based on the application, the maximum profit was obtained at Rp 27524404.46 and the minimum carbon gas emission waste was 325.86 kg with 143 *crop blazer* products, 43 *basic blazer products*, and 341 bag products. Sensitivity analysis on the increase in distance results in reduced product profits and increased carbon gas emission waste, while the increase in the number of products per shipment makes product profits increase and carbon gas emission waste decrease.

Keywords: supply chain, multiobjective, pareto, weighting.

1 Introduction

Kumar and Kumar [6] state that the supply chain is a system that covers a series of processes from production to product delivery to consumers. This series of processes converts raw materials into a product which then sells the product to consumers or distributors at the right time and place. Each manufacturer has a different supply chain and it is important to determine the right supply chain to compete in the market (Birhanu et al. [1]). Rinaldi et al [8] explained that supply chains with simulations have been carried out to generate new behaviors of the players and compare different scenarios. Every manufacturer who conducts simulations with various scenarios must have the aim of obtaining optimal profits. Optimal profit can be obtained by minimizing costs.

Cost is the most commonly used criterion for supply chain performance. The influence of cost on overall performance is quite clear and the most significant type of direct measurement (Chan [2]). Gjerdrum et al [3] presented a mathematical programming model that can reduce operating costs by maintaining customer order fulfillment in the supply chain. All these aspects have an impact on the manufacturer's profit. The profit of a manufacturer can be increased by reducing waste disposal which has a detrimental impact on the surrounding environment. One of the production waste is carbon gas emission waste. The manufacturer has two problems, namely maximizing profits and minimizing carbon gas emission waste. Therefore, the two objective functions to be sought by a manufacturer can be mathematically modeled with multiobjective optimization.

Weber and Current [9] developed multiobjective optimization for the supply chain. The multiobjective optimization problem is an optimization problem that minimizes or maximizes an objective function that has more than one objective function with a set of constraints in the form of inequalities (Inayanti and Rahmawati [5]). Optimization problems can be linear or nonlinear. The optimization solution is often a collection of solutions called the Pareto optimal set. Then, the set of solutions can be determined by a single solution or global optimal solution, one of which is the weighted sum method. According to Yang [10], the weighted sum method is a method that converts multiobjective optimization into a single-objective with the order of preference of the weights of each objective so that a single optimal solution is obtained. Multiobjectives that have two objective functions can be called biobjectives.

This study modifies the research of Liu and Papageorgiou et al [7] with a supply chain model using bi-objective optimization by maximizing manufacturing profits and minimizing waste carbon gas emissions. Biobjective optimization uses the Pareto approach with a weighting method. The constructed model aims to maximize manufacturing profit and minimize carbon gas emission waste. The obtained model is applied and the applied results are analyzed.

2 Model Construction

The manufacturer produces three products denoted $\mathbf{x}$ where $\mathbf{x} = (x_1, x_2, x_3)$ with x_i as the number of products i which is the decision variable. The biobjective functions are total manufacturing profit denoted by $f_1(\mathbf{x})$ and total carbon gas emission waste denoted by $f_2(\mathbf{x})$. In this study, only a model for manufacturing actors was constructed. The manufacturer taken is a shirt manufacturer located in Sukoharjo Regency. The manufacturer produces three types of products, namely crop blazer products, and basic blazer products, and these products consist of four kinds of raw materials, namely linen fabric, furring fabric, sewing thread, and obras thread. The following is the construction of the total manufacturing profit model, total carbon gas emissions, and constraints.

2.1 Total Manufacturing Profit Model Construction. The first objective function is the total profit of the manufacturer $f_1(x)$ which is divided into three components, namely revenue, product transportation costs, and costs. Product revenue is the number of products x_i multiplied by the product selling price per product i by P_i so that it can be written $x_i P_i$. Transportation cost is the total number of products divided by the number of products per shipment denoted by m_t multiplied by the transportation cost denoted C_t and the distance from the manufacturer to the distributor is L and according to the 2nd to 4th assumptions, the transportation cost is written as $\frac{x_i}{m_t} C_t L$. The production cost is obtained from the production cost of manufacturing and the cost incurred for the use of electrical power required per unit of product. Production cost per product i amounting to C_i^p multiplied by many products is written $x_i C_i^p$. The cost of electrical power is the number of products multiplied by the electrical power required for one product. i which is denoted T_i multiplied again by the cost of electric power per kWh of C_l so that the production cost is $x_i T_i C_l$. The total cost of production (TCP) is the sum of production costs and electricity costs, namely $BTP = x_i C_i^p + x_i T_i C_l$. So, total profit is product revenue minus the sum of transportation costs and total production costs.

$$f_1(\mathbf{x}) = \sum_{i=1}^{3} x_i P_i - \left(\sum_{i=1}^{3} \frac{x_i C_t L}{m_t} + \sum_{i=1}^{3} x_i \left(C_i^p + T_i C_l \right) \right) \tag{2.1}$$

2.2 Model Construction Total Manufacturing Profit. The second objective function is the amount of carbon gas emission waste $f_2(\mathbf{x})$ generated from product transportation and production processes. The amount of carbon gas emission waste from many products in one shipment multiplied by the carbon gas emission waste from the vehicle for transportation is denoted as E_t multiplied again by the distance so that the transportation carbon gas emission waste is $\frac{x_i}{m_t} E_t L$. Waste carbon gas emissions in the production process based on the use of electric power are obtained by the total number of products multiplied by the electric power of each product and the waste carbon gas emissions released per unit of kWh of electric power is denoted as E_l so that the production carbon gas emission waste is $x_i T_i E_l$. So, the total carbon emission waste is obtained by adding up the carbon emission waste from the transportation process and the production process.

$$f_2(\mathbf{x}) = \sum_{i=1}^{3} \frac{x_i E_t L}{m_t} + \sum_{i=1}^{3} x_i T_i E_l \qquad (2.2)$$

2.3 Constraints. Constraints are limitations on the amount of raw materials used, which are divided into four, namely linen fabric constraints, furring fabric constraints, sewing thread constraints, and obras thread constraints.

2.3.1 Linen fabric constraints. The amount of linen fabric raw materials required for the product i by b_i^l multiplied by the number of products each i. The amount of linen fabric raw materials for production needs do not exceed the available linen fabric limit by b_{max}^l so it can be written.

$$\sum_{i=1}^{3} b_i^l x_i \leq b_{max}^l \qquad (2.3)$$

2.3.2 Furring fabric constraints. The number of raw materials for furring fabrics is limited by the number of furring fabrics available by b_i^f. The amount of furring fabric required for the product i is b_i^f multiplied by each product i. The raw material constraint of furring fabric is written as

$$\sum_{i=1}^{3} b_i^f x_i \leq b_{max}^f \qquad (2.4)$$

2.3.3 Sewing Thread Constraints. Sewing thread is the raw material to hold linen and furring fabrics together and is used to create motifs and hold accessories together. The amount of regular thread required for the product i by b_i^b multiplied by the number of each product i. The amount of raw material for sewing thread for production needs does not exceed the available sewing thread limit of b_{max}^b so it can be written

$$\sum_{i=1}^{3} b_i^b x_i \leq b_{max}^b \qquad (2.5)$$

2.3.4 Obstacle of Obrasion Thread. Obras thread is used to tidy up the edges of each product made. The amount of raw material for the production needs does not exceed the limit of available obras thread b_{max}^o . Many raw materials of obras thread are required for the production of i by b_i^o multiplied by the number of each product i so that it can be written

$$\sum_{i=1}^{3} b_i^o x_i \leq b_{max}^o. \tag{2.6}$$

3 Bi-Objective Model

The bi-objective model is obtained by maximizing the profit function $f_1(\mathbf{x})$ function in equation (2.1) and minimizing the carbon gas emission waste function in equation (2.2) and the constraints are then presented as follows $f_2(\mathbf{x})$ in equation (2.2) and the constraints are then presented as

$$\text{maximize} \quad f_1(\mathbf{x}) = \sum_{i=1}^{3} x_i P_i - \left(\sum_{i=1}^{3} \frac{x_i C_t L}{m_t} + \sum_{i=1}^{3} x_i \left(C_i^p + T_i C_l \right) \right) \tag{3.1}$$

$$\text{minimize} \quad f_2(\mathbf{x}) = \sum_{i=1}^{3} \frac{x_i E_t L}{m_t} + \sum_{i=1}^{3} x_i T_i E_l \tag{3.2}$$

Constraints

$$\begin{aligned} &\sum_{i=1}^{3} b_i^l x_i \leq b_{max}^l \\ &\sum_{i=1}^{3} b_i^f x_i \leq b_{max}^f \\ &\sum_{i=1}^{3} b_i^b x_i \leq b_{max}^b \\ &\sum_{i=1}^{3} b_i^o x_i \leq b_{max}^o. \end{aligned} \tag{3.3}$$

4 Application

Given the application of bi-objectives to the supply chain model is to maximize the total manufacturing profit and minimize the total carbon gas emission waste. The parameters obtained are based on data obtained from clothing manufacturers in Sukoharjo Regency. The products consist of three types, namely crop blazer products, basic blazer products, and bag products. The selling price of the products is Rp. 155000, Rp. 140000, and Rp. 30000, respectively. Production costs for crop blazer products amounted to Rp. 50000, basic blazer products Rp. 50000, and bag products Rp. 3000. The cost of electricity is 1444.70 per kWh, the waste of carbon gas emissions produced per one kWh is 0.716 kg, and the use of electric power for the production of three products is 0.988 kWh, 0.866 kWh, and 0.478 kWh respectively. The transportation process yields 0.24116 per km, the number of products per shipment is 100 units, and the transportation cost is 220 per km. The required raw materials in kilograms and the limit of available raw materials are presented in Table 1 as follows.

Table 1. Product raw material requirements

Raw material	Product crop blazer	Product basic blazer	Product bag	Product available
linen fabric (b_i^l)	0.2	0.1	0.05	50
furring fabric (b_i^f)	0.1	0.2	0.05	40
regular thread (b_i^b)	0.05	0.05	0.05	30
embroidery thread (b_i^o)	0.025	0.025	0.001	5

Then nine feasible points are obtained as follows

Many products	Eligible point								
	o_1	o_2	o_3	o_4	o_5	o_6	o_7	o_8	o_9
x_1	0	200	0	0	133	200	0	125	143
x_2	0	0	200	0	0	0	66	25	43
x_3	0	0	0	600	466	200	533	450	341

Based on the application parameters, nine feasible points are obtained with points o_1, o_8, and o_9 being the Pareto optimal solution then with the weighting method, the global optimal point is obtained, namely point o_9. The maximum optimal value of manufacturing profits is Rp. 27524404.46 and the minimum carbon gas emission waste is 325.86 kg. After obtaining the optimal solution of the model, a sensitivity analysis is carried out to determine the effect of changes in parameter values.

5 Sensitivity Analysis

The parameter values that were changed were the distance from the manufacturer to the distributor (L), and many products in one shipment (m_t) by using the global optimal point, namely point i. Sensitivity analysis for distance parameters L the sensitivity analysis for the distance parameter starts at 36 km with an interval increase of 7 and 8 simulation points are taken. In addition, the sensitivity analysis for the parameter change in the number of products per mt delivery starts at 100 km with an interval increase of 50, and 9 simulation points are used. The following table shows the effect of changes in distance and number of products per shipment.

L	Point i		m_t	Point i	
	f_1	f_2		f_1	f_2
36	27556867.66	290.28	100	27524404.46	325.86
43	27548751.86	299.17	150	27549138.32	298.75
50	27540636.06	308.07	200	27561505.26	285.19
57	27532520.26	316.97	250	27568925.42	277.06
64	27524404.46	325.86	300	27573872.19	271.64
71	27516288.66	334.76	350	27577405.6	267.76
78	27508172.86	343.65	400	27580055.66	264.86
85	27500057.06	352.55	450	27582116.81	262.60
			500	27583765.74	260.76

Based on Table 3, changes in distance increase result in reduced product profits and carbon gas emission waste increases constantly with a profit reduction value of Rp. 8115.8 and waste carbon gas emissions increase by 8.89 kg. In addition, many products per shipment increase profit and reduce waste carbon gas emissions quickly so that the greater the value of the distance, the less the exact difference between the two previous points until it approaches zero. mt results in the exact difference between the previous two points decreasing to near zero.

6 Conclusion

Based on the results and discussion, the following conclusions are drawn.

(1) The bi-objective supply chain model considering product profit and waste carbon gas emission is equation (3.1), equation (3.2), and inequality (3.3).

(2) The bi-objective supply chain model solution using the pareto approach and weighting method obtained a maximum profit of Rp. 27524404.46 and minimum

carbon gas emission waste of 325.86 kg with 143 crop blazer products, 43 basic blazer products, and 341 bag products.

(3) The bi-objective model was subjected to sensitivity analysis of changes in distance and changes in the number of products per shipment. Analysis of changes in distance increases resulted in diminishing product profits and constantly increasing carbon gas emission waste. In addition, many products per shipment increase profit and reduce waste carbon gas emissions rapidly.

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