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Research paperr

Optimization Manufacturing System Model with Recycling Oriented

Abdurrozzaq Hasibuan[1*], Susi Ekalestari[2], Abdul Rahman Suleman[3], Adek Khadijatul Z Harahap[3], Masnilam Hasibuan[3], Janner Simarmata[4], Desi Novita[5], Eko Sumartono[6], Achmad Daengs GS[7], Syifa Saputra[8], Mas Intan Purba[9], Khoirul Hidayat[10]

[1]Faculty of Engineering, Universitas Islam Sumatera Utara, Medan, Indonesia
[2]Faculty of Literature, Universitas Islam Sumatera Utara, Medan, Indonesia
[3]Faculty of Economic, Universitas Graha Nusantara Padangsidimpuan, Indonesia
[4]Universitas Negeri Medan, Medan, Indonesia
[5]Faculty of Agriculture, Universitas Islam Sumatera Utara, Medan, Indonesia
[6]Agribussines Programme, Department Agricultural Socio – Economic, Agricultural Faculty, Universitas Bengkulu, Indonesia
[7]Faculty of Economic, Universitas 45 Surabaya, Surabaya, Indonesia
[8]Faculty of Teaching and Education, Universitas Almuslim Bireuen Aceh, Indonesia
[9]Faculty of Economic, Universitas Prima Indonesia, Medan, Indonesia
[10]Faculty of Agriculture, Trunojoyo University Bangkalan, Indonesia
**Corresponding author E-mail: rozzaq@uisu.ac.id*

Abstract

To reuse of used or damaged products is known as recycle. Recycling will reduce the exploitation of natural resources and the accumulation of waste in the environment. This research shows that there is an opposite relationship between profits and recycling level. The higher the profit obtained, the lower the recycling rate achieved. On the contrary, the higher the level of recycling achieved, the lower the profits earned. The result of this research also shows that the collection of efficient recycling level planning for the system is within the target range of a certain value. To get better understanding of the characteristics of the system, additional research is needed on the extreme conditions of the system. First, a condition that describes that the system is only oriented towards recycling (internally and externally), and secondly, profit-oriented (does not recycle at all).

Keywords: *Manufacturing, Recycling, Optimization Systems*

1. Introduction

Nowadays, a large number of products have been made, consumed and disposed. These products have very convincingly improved our lives on the one hand, but on the other hand, these products also greatly affect all kinds of ecological aspects on earth. Thus, large amounts of natural resources are consumed for production and their products are piled into the environment after use[1].
The solution to avoid these conditions is to build a 'closed type production system' which prevents the use of 'negative' or 'general damage', or by recycling the materials used to produce after the product has been consumed. This method not only reduces the taking of natural resources but also reduces landfill. A short way should be made to make environmental contamination can be reduced to an acceptable level[2][3].
Two kinds of investigations have been carried out in recycling-oriented societies. The first group, builds a conceptual model that takes into account all material flows in the community, composes a recycling strategy, but does not provide clarification of definitive recycling procedures for a company. Whereas, others pay more attention to research and development practical recycling technologies for a company, but, they do not cover extensive recycling technology from industrial/manufacturing systems as well[4].

1.1 Objectives of the Research

The purpose of this study was to analyze the recycling of the total manufacturing system for a company. The optimization model is built for recycling-oriented manufacturing systems, taking into account the role of the company in a recycling-oriented environment. Then, the model was analyzed using the goal programming method with the aim of enhancing recycling by optimizing company profits[5].

2. Recycled Oriented Manufacturing Form Today’s Society vs. Recycling Oriented Society

Figure 1 shows the difference between the flow of material in today's society and a recycling-oriented society. In today’s society, the flow starts from taking natural resources from the earth, which is followed by production and consumption, and finally all waste is discharged into the environment. In contrast, in a recycling-oriented society has a stream called 'recycling', which, in particular, reduces the environmental burden to a decent level.[1]
In building a recycling-oriented society, the following are very important factors to be considered:

a. Consider recycling recycled materials from the design stage: product design is made not only from a function/quality point of view, but also from consideration of the efficiency of recycling and the lack of danger posed by waste.
b. Increase re-production and part reuse: after consumption of the product, parts/materials that can be re-produced or reused are collected. This is very important in building a manufacturing system for this purpose.
c. Analyze the cost effectiveness of recycling activities: it is very important that recycling activities are also economically supportive. From this point of view, an analysis of the effectiveness of costs is made, so that the expenditure needed for recycling is divided into communities or covered with the price of a viable product.

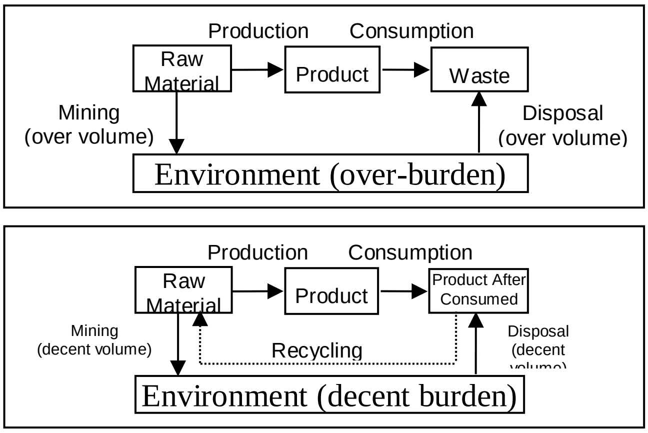

Figure 1. Material flow in today's society (a) and recycling oriented society (b)

3. Recycling Oriented Manufacturing System

A manufacturing system with recycling activities is called a "Recycled Oriented Manufacturing System".
Figure 2 shows the main structure of a manufacturing system which has two divisions, namely the production division and the disposal division.[6][7]
a. Production division: manufacturing systems purchase raw materials from external suppliers, make certain products, and sell products to consumers. The production division plays an important role in producing products.
b. Disposal Division: This division activity is very crucial in recycling-oriented manufacturing systems. Products that have been used are collected from consumers. Then, these products are classified into three groups - namely materials that can be recycled inside the factory, materials that can be recycled outside the factory, and waste disposal.

The two divisions are linked to three external sectors (raw material suppliers, consumers, and the environment). Material flow is indicated by the six arrows, as explained below:
a. Purchasing raw materials. Raw materials used for production are purchased from raw material suppliers.
b. Product sales. Products made by the production division are sold to consumers.
c. Collection of products after consumption. Products after consumption are collected for recycling.
d. Recycling in the factory. Recyclable materials are reused in the factory to produce products in the production division.
e. The sale of materials that can be reproduced. Some of the batches collected are sold to suppliers of raw materials for reproduction of raw materials at an adequate price.
f. Landfill, material that has been used that cannot be recycled is buried into the environment. This amount will be minimized.

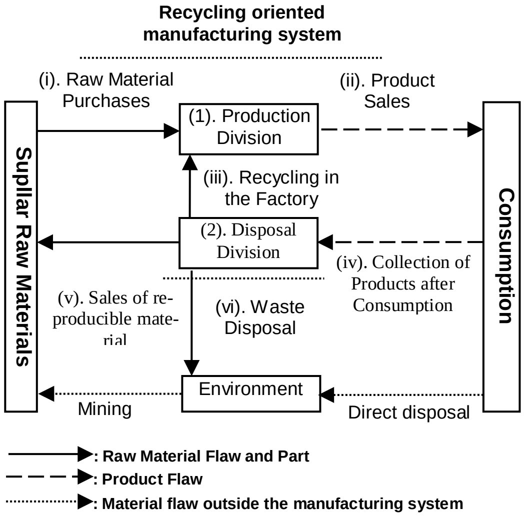

Figure 2. The framework of recycling oriented system

4. Recycling Oriented Manufacturing System Model Form of the Model

A model is constructed for a company with a recycling-oriented manufacturing system, which buys important parts from raw material suppliers, and assembles products from these parts together with recyclable parts which are then processed in the company's factory. The company sells parts that can be reproduced to raw material suppliers, while the others are poured out.
Then we classify three types of parts that have different recycling capabilities, namely:
a. Part that can be re-usable: this type of part can be reused in the factory (this part is stated with attribute 1).
b. Part that cannot be reused but re-producible: this type of part cannot be reused in the factory, but is reproduced by a raw material supplier (attribute 2).
c. Part that can be reproduced/reused: this type of part cannot be recycled inside or outside the factory (attribute 3).

The evaluation criteria set for the company are total profit and recycling speed. Recycling speed for each type of part is defined as the ratio of the quantity of part recycling to the quantity of part use for production.

Formulation
Assumption
a. The company produces a single product, which has different parts.
b. After the product has been consumed, the company collects products that have been used by consumers and determines which parts are recycled. The speed of collecting products from consumers for recycling is given.
c. Each part has one of three defined attributes. Companies can use each part for production.
d. Important parts for production are purchased from raw material suppliers except parts that can be recycled in the factory.
e. Cost of part-purchase, stockpiling, and recycling with three attributes, as well as income obtained by selling parts that can be produced is supplied and constant.
f. Fixed costs for production/disposal activities, as well as variable costs for production and disposal activities, are given.
g. The planning period is T (period).
h. Production quantities in each period are equated with accepted requests.
i. The company's goal is to maximize the speed of repetition and maximize total profits.

Barriers

a. Part that is needed to produce is obtained by supplying: from assumption (8), the production quantity in period $t(t=1,2,\ldots,T)$ is the same with the demands $q(t)$. from assumption (1) part quantity type m $(m=1,2,\ldots,M)$ that is needed to make the quantity same with $q(t)$. determine the purchase quantity part m with attribute n $(n=1,2,3)$ as $x_{mn}(t)$ and re-using part m with attribute 1 as $u_m(t)$. then,

$$\sum_{n=1}^{3} x_{mn}(t) + u_m(t) = q(t) \quad (m=1,2,\ldots M; t=1,2,\ldots,T) \ldots (1)$$

b. The relationship between the quantity of parts used for production and the quantity of parts collected from consumers: set the speed of collecting r^{th} as the ratio of the quantity collected in period t to the number of products made in the period t-h. Therefore, the quantity of product collected at period t is given as,

$$y(t) = \sum_{h=1}^{H} r_{th} . q(t-h) \quad (t=1,2,\ldots,T)$$

where H represents the longest time of the product that is used by consumers.

c. The products collected from the consumers as soon as possible are separated into partial items. Every part is classified into reusale parts, re-producible parts, and waste. Determine $v_m(t)$ as part quantity that can be re-used in the factory, $z_{mn}(t)$, as part quantity that can be re-produced with attribute $n(n=1,2)$, dan $z_{m3}(t)$, and as part quantity that is disposed, with attribute 3. then,

$$\sum_{h=1}^{H} r_{th}\{x_{m1}(t-h) + u_m(t-h)\} = z_{m1}(t) + v_m(t) \quad (m=1,2,\ldots,M; t=1,2,\ldots,T)$$

$$\sum_{h=1}^{H} r_{th} x_{mn}(t-h) = z_{mn}(t) \quad (m=1,2,\ldots,M; n=2,3; t=1,2,\ldots,T)$$

d. The inventory of the re-usable part will determine the inventory of re-using part period t by $I_m(t)$,

$$I_{mn}(t+1) = I_m(t) + v_m(t) - u_m(t) \quad (m=1,2,\ldots M; t=1,2,\ldots,T)$$

e. Non-negative condition of the variable is: $x_{mn}(t)$, $u_m(t)$, $z_{mn}(t)$, $v_m(t)$, dan $I_m(t)$

f. The ability of part re-using: parts with attribute 1 that is obtained from decomposition of the collected products is not now replaced (re-use), because some parts may be damaged. Reusable (reusable level) α_m is defined as the ratio of the number of parts for actual reuse to the total number of parts. Therefore, the part that can be reused in the period t is:

$$v_m(t) \le \alpha_m \sum_{h=1}^{H} r_{th}\{x_{m1}(t-h) + u_m(t-h)\} \quad (m=1,2,\ldots,M; t=1,2,\ldots,T)$$

substitution Calculation (3) into this calculation,

$$v_m(t) \le \alpha_m\{z_{m1}(t) + v_m(t)\} \quad (m=1,2,\ldots,M; t=1,2,\ldots T)$$

Purpose

The main purpose of a recycling-oriented manufacturing system is to maximize recycling speed. However, any plan that does not generate profit is not acceptable to companies in capitalist society. Therefore two types of targets are determined

a. Maximizing the recycling speed for each part refers to the desired level of desire: We make R_m the recycling rate, it is the ratio of part m recycled quantity towards the quantity of the part for production. Recycled quantity is the total quantity of parts for re-use and re-production. The quantity re-using part is u_m (t). To estimate the quantity of parts re-produced, the re-producible rate of α_{mn} (m = 1,2, ..., M; n = 1,2) is used from the parts that can be reproduced against the part. the re-producible is shown. Then the recycling rate of R_m is,

$$R_m = \left(\frac{\sum_{t=1}^{T}\{u_m(t) + \beta_{m1} z_{m1}(t) + \beta_{m2} z_{m2}(t)\}}{\sum_{t=1}^{T} q(t)} \right) \ge R_{m0} \quad (m=1,2,\ldots,M)$$

where R_{m0} is a certain level of part recycling speed m

b. Maximization of total profit: Determine P_p (t) as the total cost needed to buy parts and adopt parts for re-use; P_m (t), the total cost of production, collection, and disposition; B_s (t), total revenue derived from product sales; P_I (t), the cost of storing parts for re-use; Br (t), the total income derived from the sale of parts that can be re-produced; and P_r (t), the cost of removing parts. From the assumptions (5) and (6), the amount is expressed as follows.

$$P_p(t) = \sum_{m=1}^{M}\left\{\sum_{n=1}^{3} c_{mn} x_{mn}(t) + d_m u_m(t)\right\} \quad (t=1,2,\ldots,T)$$

$$P_m(t) = a_m + b_m q(t) + b_d y(t) \quad (t=1,2,\ldots,T)$$

$$B_s(t) = b_s q(t) \quad (t=1,2,\ldots,T)$$

$$P_I(t) = \sum_{m=1}^{M} \frac{1}{2} b_{\mathrm{Im}}\{I_m(t) + I_m(t+1)\} \quad (t=1,2,\ldots,T)$$

$$B_r(t) = \sum_{m=1}^{M}\{e_{m1} z_{m1}(t) + e_{m2} z_{m2}(t)\} \quad (t=1,2,\ldots,T)$$

$$P_r(t) = \sum_{m=1}^{M} w_m z_{m3}(t) \quad (t=1,2,\ldots,T)$$

where c_{mn} is the cost of purchasing part m with attribute n; d_m, the cost to take each part for re-use; a_m, fixed costs of production, collection and disposition; b_m, the cost of the production variable; b_d, the cost of the collection and disposition variables; b_s, product prices; b_{Im}, saving fees; e_{mn}, the income obtained through the sale of each part that can be re-produced (reproducible); and, wm, disposal fees.

By using calculations (10) ~ (15) and interest r, the total profit is,

$$B_T(t) = \sum_{t=1}^{T}\{B_s(t) + B_r(t) - P_p(t) - P_m(t) - P_r(t) - P_I(t)\}(1+r)^{-1}$$

Optimization Analysis

To rank the two types of objectives above, namely maximizing the recycling speed of each part and maximizing the total profit, two types of linear goal programming issues can be used as follows:

[Issue 1]

Goal 1: Fill out all the barriers

Goal 2: Maximize the speed of recycling the types of parts while maintaining the speed towards a certain level of desire.

Goal 3: Maximize total profit.

[Issue 2]

Goal 1: Fill out all the barriers

Goal 2: Maximize total profit.

Goal 3: Maximize the recycling speed of types of parts, while maintaining that speed towards a certain level of desire

The solutions to the above problems are alternatives to recycling planning, but none can provide solutions to the following situations:

- It is often difficult to set the desired level sufficiently for the speed of recycling parts.

Therefore, an acceptable procedure for dealing with both cases is carried out to generate a set of efficient solutions and choose one of the best solutions from the whole set. The set can be made by answering the following problem:

[Issue 3]

Goal 1: Fill out all the barriers

Goal 2: Equalize all recycling rates of part types against targets that are changed from 0% to the maximum value obtained by answering Problem 1.

Goal 3: Maximize total profit.

Numerical Example

A numerical example is shown to show the effectiveness of the model that has been built. We specify the planning period T = 10 (period) and the longest period of product utilization, H = 4 (period). Collectable rate, r_{th}, is given in Table 1; 10% of the products sold that cannot be collected from consumers. The product has two parts; the data for part 1 and 2 is given in table 2. The cost is still a_m at 100 (x 103 \$); product prices, b_s, 70 (\$); the variable cost of production, b_m, 11 (\$); and the cost of the collection and disposition variables, b_d, 15 (\$). The interest rate r is 0.1, and the demand q (t) is given in table 3.

Table 1. The Collected of ability level

Period	Collectable Rate
h	r_{th}
1	0,1
2	0,5
3	0,2
4	0,1

Table 2. Data for Part 1 and 2

Data for Part 1 and 2		Tipe Part, *m*					
		1			2		
		Attribute, *n*			Attribute, *n*		
		1	2	3	1	2	3
Purchase Cost	c_{mn} ($/pc)	10	6	5	12	10	5
The cost of taking part for re-use	d_{mn} ($/pc)	2	-	-	1	-	-
Income from sale re-producible part	e_{mn} ($/pc)	1	1	-	3	3	-
Cost of stockfill	w_m ($/pc)	-	-	1	-	-	1
Re-usable Rasio	α_m	0,7	-	-	0,8	-	-
Re-producible Rasio	α_m	0,5	0,6	-	0,6	0,7	-
Inventory Cost	b_{Im} ($/pc.perioda)	1	1	1	2	2	2

Table 3. The Demands of Product

Period	Collectable Rate
T	q(t) (pcs)
1	10.000
2	12.000
3	12.000
4	11.000
5	9.000
6	6.000
	60.000

Table 4. Goal Value – Solution for the 1st and the 2nd Issues

		Case	
		1	2
Profit	*(x 10^3 $)*	925	1014
Recycle speed for part 1	*(%)*	66.2	54.0
Recycle speed for part 2	*(%)*	72.8	0.0

The goal value is obtained by resolving the 1st and the 2nd issues listed in Table 4. In this example, the solutions for the 1st and the 2nd issues are different; total profit decreases when the recycling rate is maximized.

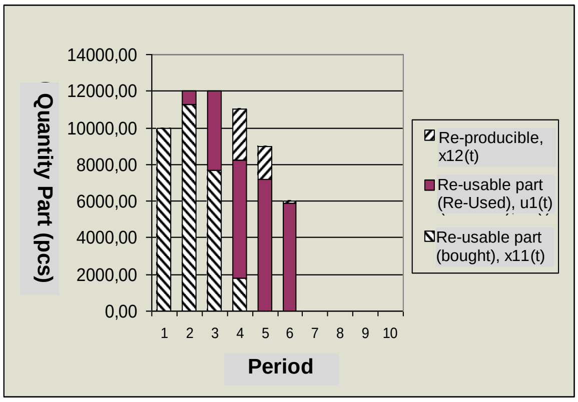

Figure 3. The Quatity of the 1st and the 2nd parts to Reach the Goals in the 1st Issue

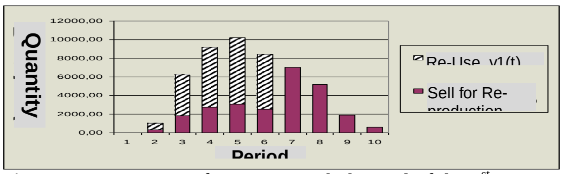

Figure 4. Disposition of part 1 to reach the goal of the 1st issue

The recycling plan for part 1 is obtained by solving Problem 1 illustrated in Figures 3 and 4. Figure 3 shows the quantity of part 1 requirements with certain attributes. In planning, re-usable parts are used during the planning period, and some amounts are not re-usable parts, namely re-producible parts which are only used in periods 4 and 5. Dissipation conditions for part 1 are represented in figure 4; after period 7 all parts are sold to suppliers of raw materials, when production has stopped in period 6.

5. Conclusion

In this text, recycling-oriented manufacturing systems and basic parts flowing through the product life cycle in the system are explained, thus, manufacturing activities can elegantly adapt to the ecological environment.

The system of optimization model with two objectives, namely the maximization of the total profit and the recycling rate, is built by taking into account the reuse and reproduction of parts after the use of the product. It is completed to obtain a set of efficient recycling-sales relationship plans between two objectives. A procedure was developed using the goal programming method.

The model is intended to develop theoretically the fundamental procedures for optimal recycling planning. Thus, this procedure cannot be directly used in practice, but this can be very useful as a guidance in the company in developing a recycling plan.

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