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Article

Designing Quality Improvement and Economical Production Quantity: Application of Material Flow Cost Accounting and Cost of Quality

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Abstract: Material flow cost accounting technique is a technique used to analyze environmental costs for the purpose of identifying costs in two parts: positive cost and negative cost. Which will be an indicator of the efficiency of the production process Because it affects the quality of products delivered to customers and customer satisfaction. There are also techniques. MFCA is used in conjunction with Cost of quality techniques to increase the confidence that products that are going out of the production process will have good performance. For the use of the design of the production process, find the size of the lot. Proportion of waste in production lot and number of shipments. The objective of the optimization problem is the maximum ratio of positive product cost to total cost (PC/TC). The researcher uses particle swarm optimization techniques to find the answer. which is the size of the product lot size, Number of product lot shipments and Proportion of waste in production lot in a serial multi-stage process. the results of MFCA analysis showed that the highest portion of negative product cost was material accounting for 53.29% and following by System cost of 4.75% comparing with the total product cost.

Keywords: Material flow cost accounting; optimal lot size; particle swarm optimization; serial multi-stage process.

1. Introduction

The current conditions of the global economy are fiercely competitive, with no restrictions on whether to be a small or large business. Which these organizations will not stop developing the process of allocating resources to be used within the organization by focusing in the direction that will reduce costs and still have to maximize the benefits to meet the needs of customers and most importantly, must ensure that the products that customers receive are quality (Berry & Waldfogel, 2010; Jacobson & Aaker, 1987; Maynes, 1976). The matter of production and the size of the production that is suitable to the needs of the customers by the production model that is created to create confidence for the operator that can meet the needs of customers (Al-Gasawneh et al., 2021; Sebastianelli & Tamimi, 2002). However, because the number of products produced may lead to wastage and the cost of inventory management within the organization, it must have the ability to arrange the production of products to be used for efficiency and benefits. The maximum product produced from the production must be of quality and must be done on time. The quality inspection in each organization must have a policy which in the establishment of a station for quality inspection must be considered the cost incurred. In general, quality inspection points will be produced in the final production process before being sent to customers. Which may be what follows is the quality of the work that does not meet the needs of the customer If the product is not quality delivered to the customer, it will lose the trust of the customer immediately. Therefore, the planning and design of the inspection point must be planned for maximum efficiency (Fagan, 2002; Liu et al., 2020).

In the production of products, if in the production, the size of the production lot affects the quality of the product (Eskierka 2011). In each production, it is necessary to have the cost of preparation before production, such as the cost. Pay for setting up machines expense for production the cost of purchasing raw materials, etc. In general production will focus on the production of the lot size of the product with a small size (Abdul-Jalbar et al., 2005). Then, gradually deliver the product to a lot for customers in order to reduce time. In waiting and causing the production to not have much inventory Is the cause of inventory costs Which inventory costs will be considered in the perspective of supply chain management By calculating the cost of the manufacturer's inventory together with the consignee But in the present, most organizations will focus on managing environmental problems. With an emphasis on environmental conservation using (Material Flow Cost Accounting: MFCA) Is considered in every activity, which is to use the principle of balancing the incoming mass, must be equal to the mass released at each center of work volume (Quantity Center) Which will consider the cost of the main group, i.e. material cost, system cost, waste treatment cost and also in conjunction with the cost of quality which will consider the cost such as the cost Prevention costs Appraisal costs, failure costs, costs from the penalty cost.

Production can be obtained by providing MFCA is a measure of the efficiency of the production process (Doorasamy, 2015; Hyršlová et al., 2011; Wagner, 2015). However, the product cost will be divided into positive product cost and negative product cost, which will result in the number of products that we need. They will respond to customer needs as a guideline for creating results. Profit for the organization, then will create a mathematical model to find answers. The model diagram of the production process, along with defining the variables in which the production model is created, which within the research will use the concepts of Ullah & Kang (2014) with the following details. There are steps i defined by i = 1, 2,…, I which the final step is the customer shown as shown in the production lot size Qi Which will have input of Good raw materials $W1_{i,j}$ and waste materials $W2_{i,j}$ as shown in Figure 1 (See Appendix A1).

The production process will be divided into 2 stage according to Figure 2. Production stage 1, there is a constant production of waste. By using the function of by using the function $Q_i = \frac{\beta_i(1-\beta_i{}^{Q_i})}{1-\beta_i}$. Then will be forwarded to the station to check the quality Which the product is not inspected Which products that are not inspected will be sent to the waste management process, which is replace process, rework process, scrap process , where the proportion of each process is fixed, including $f1_{i,j}$, $f2_{i,j}$, $f3_{i,j}$ Which good products will be sent to the next process. There are following assumptions on this study: (i) In the production process, there will be no disruption in the production cycle. (ii) Demand are pre-determined and constant. (iii) In the production stage 1, each process adopts the acceptance sampling plan as quality inspection. (iv) In the production stage 2, there is a 100% quality inspection. (v) Rework process can occur only once and (vi) The delivery of each process is lot size.

2. Materials and Methods

2.1. Serial multi-stage production model

From the serial multi-stage process model, which can show the steps to calculate as follows: where i is the process and j is the stage.

Stage j = 1
The amount of waste products in the production process, stage 1 of the production process i

$$V2_{i,1} = \frac{W2_{i,1}}{b_i} + \frac{\beta_i\left(1-\beta_i{}^{\frac{W1_{i,1}}{b_i}}\right)}{1-\beta_i}$$

The amount of good products in the production process, stage 1 of the production process i.

$$V1_{i,1} = \frac{W1_{i,1}}{b_i} + \frac{\beta_i \left(1 - \beta_i^{\frac{W1_{i,1}}{b_i}}\right)}{1 - \beta_i}$$

Probability for receiving production lot size

Accept: $Pa_i = \binom{n_i}{0} (f_i)^0 (1 - f_i)^{n_i} = (1 - f_i)^{n_i}$

Rejects: $1 - Pa_i$

The amount of waste that is detected in the production process, stage 1 of the production process i

$$u_{i,1} = (1 - Pa_i)V1_{i,1}$$

The amount of waste that is Replace process, , stage 1 of the production process i

$$Rp_{i,1} = u_{i,1} f1_{i,1}$$

The amount of waste that is Rework process, , stage 1 of the production process i

$$Rw_{i,1} = u_{i,1} f2_{i,1}$$

The amount of waste that is Scraps process, , stage 1 of the production process i

$$S_{i,1} = u_{i,1} f3_{i,1}$$

Total good quality outcomes from stage 1 of the production process i

$$O1_{i,1} = V1_{i,1} + Rp_{i,1}$$

Total Waste quality outcomes from stage 1 of the production process i

$$O2_{i,2} = V2_{i,1} - u_{i,1}$$

Stage *j* = 2

The amount of waste products in the production process, stage 2 of the production process i

$$V2_{i,2} = Rw_{i,1} \varepsilon_{i,2}$$

The amount of good products in the production process, stage 2 of the production process i

$$V1_{i,2} = Rw_{i,1}(1 - \varepsilon_{i,2})$$

The amount of waste that is detected in the production process, stage 2 of the production process i

$$u_{i,2} = \delta_{i,2} V2_{i,2}$$

The amount of waste that is Replace process, , stage 2 of the production process i

$$Rp_{i,1} = 0$$

The amount of waste that is Rework process, , stage 2 of the production process i

$$Rw_{i,1} = 0$$

The amount of waste that is Scraps process, , stage 2 of the production process i

$$S_{i,1} = u_{i,2}$$

Total good quality outcomes from stage 2 of the production process i

$$O1_{i,2} = V1_{i,2}$$

Total Waste quality outcomes from stage 2 of the production process i

$$O2_{i,2} = V2_{i,2} - u_{i,2}$$

Therefore, the total outcomes reach into next process where;

$$W1_{i+1,1} = O1_{i,1} + O1_{i,2} \text{ and } W2_{i+1,1} = O2_{i,1} + O2_{i,2}$$

Reject items are waste;

$$Scrap_i = S_{i,1} + S_{i,2}$$

2.2. Modeling of MFCA analysis

MFCA technique is used to analyze the environmental cost by dividing the cost used as Raw material costs, system costs, energy costs and waste costs (Sahu et al., 2021; Tajelawi & Garbharran, 2015). Which will know the cost incurred as a positive cost and negative cost.

Material cost of process i;

$$MC_i = C_i^{material} \quad (1)$$

System cost of process i;

$$SC_i = C_i^{setup} + C_i^{process} + C_i^{inspection} + C_i^{network} + C_i^{replace} + \quad C_i^{inven} \quad (2)$$

Energy cost of process i;

$$EC_i = C_i^{energy} \quad (3)$$

Waste treatment cost of process i;

$$WC_i = WC_i \quad (4)$$

Therefore, concluding overall production system:

Total cost (TC);

$$TC = MCi + SCi + ECi + WCi \quad (5)$$

Total positive product cost(PC);

$$PC = PMCI + PSCI + PECI \quad (6)$$

Total negative product cost (TNC);

$$TNC = \sum_{i=1}^{I} NMC_I + \sum_{i=1}^{I} NSC_I + \sum_{i=1}^{I} NEC_I + \sum_{i=1}^{I} WC_I \quad (7)$$

Cost of quality (COQ);

$$COQ_i = \sum_L C_L^{Prev} + \sum_L C_L^{Appraisal} + \sum_L C_L^{Failure} \tag{8}$$

2.3. Mathematical model

Decision variables;
$W1_{1,1} \in [200, 3000]$: Amount of good quality materials feed into process i=1.
$W2_{1,1} \in [0, 200]$: Amount of poor-quality materials feed into process i=1.
$B_1 \in [1, 10]$: Number of product lot shipments process i
$f_i \in [0, 1]$: Proportion of waste in production lot
$n_i \in [1, 100]$: Samples of sampling plans

Objective function;

$$Maximize \ \frac{Positive\ Product\ Cost}{Total\ Cost + COQ} \tag{9}$$

Subject to;

$$\frac{W1_{I,1} + W2_{I,1}}{T_C} \geq d \tag{10}$$

Where Eq. (10) is Products must respond Customer demand. tc is cycle time (year/lot). Note that the limited inspection resource constraint i.e. inspection persons, inspection time are not mentioned in this study.

2.4. Design of PSO parameters

In the PSO method, there are four control parameters used: Where c1, c2 is a constant. The learning factor value is 2 (Chen et al 2011), number of particles is 30 and velocity is [20, -20], number of iterations is 40

Table 1. PSO parameters

PSO parameters	Value
c1= c2	2
N	30
V	[20, -20]
I	5

3. Results

The experimental data tests and results will be described in this section. The developed model from previous section have been coded in MATLAB R2016a and performed on a laptop computer Core i7 CPU @2.5 GHz and 8 GB RAM to implement the PSO algorithm which generate the optimal inspection and lot size solution (Appendix A5). In case study, the experimental data was obtained from the case study manufacturer. Since the present production has no replacement and rework process (〖f1〗_(i,1), and 〖f2〗_(i,1)=0) the detected items in stage1 will categorized as reject or scrap. The production parameters used in the mass balance calculation are shown in Appendix A2. All material costs are kept confidential. Assuming that the customer demand (d) = 15,000 units per year, electrical rate (En) = 3.7 per kWh, operating person each process = 1, inspection person (in case inspection) = 1, labor cost (Lc) = 4000 per day and labor hour (h) = 8 hours per day. Table 4 (Appendix A3) shows Considering the inspection proportion as a decision variable to be optimize increase the Cost ratio of objective function (TPC/TC) to 0.401461. Table 3 (Appendix A3) shows the calculated positive and negative product cost of the current production process for a given set of parameter and variables. Only 40.193% of the total cost is the positive product cost, while

59.857% becomes negative product cost in which 53.74% is the material loss cost. The result shows that this manufacturing incurs high wastage of using materials in production.

4. Conclusions

In research, MFCA techniques are used to help analyze the environmental costs in dividing costs into Cost, positive cost and negative cost Which is used in conjunction with the design of the production process to find the economical lot size and the product inspection strategy. The objective of the optimization problem is the maximum ratio of positive product cost to total cost (PC/TC). The researcher uses PSO techniques to find the answer. which is the size of the product lot size, Number of product lot shipments and Proportion of waste in production lot in a serial multi-stage process.

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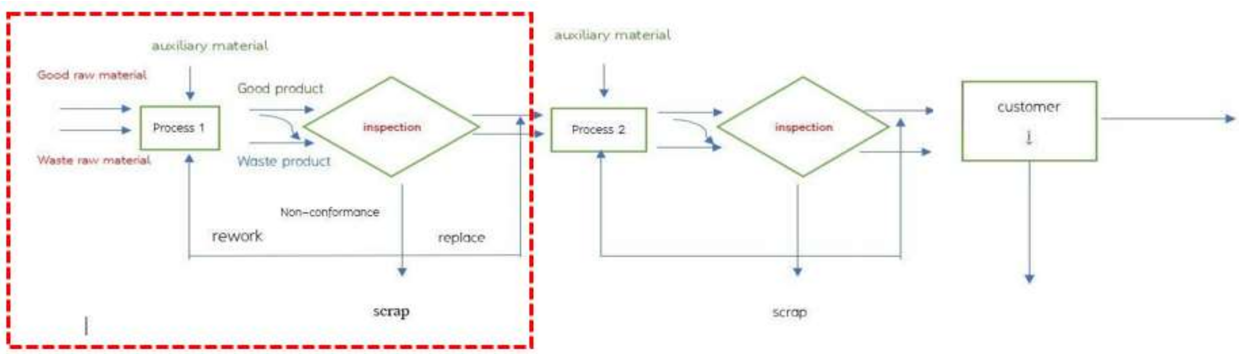
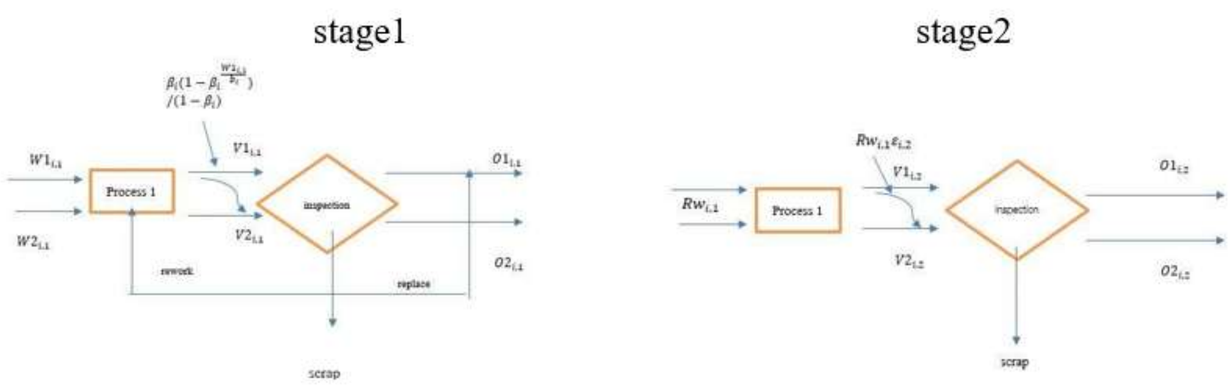
Appendix A1. Serial multi-stage process.



Appendix A2. Processing during stage 1 and stage 2.



Appendix A3. Production data.

Parameter	Process i														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
β_i	0.91	0.9	0.89	0.88	0.87	0.86	0.85	0.84		0.83	0.82	0.81	0.8	0.79	-
$f3_{i,1} = f3_{i,2}$	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	-
$\varepsilon_{i,2}$	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	0.50 %	-
Inspec2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	-
ts_i	4	8	0	0.25	0	0.25	0.5	4	0.5	1	1	0	0	0	-
$tinsp_i$	2.3	8.22	10.7	2	0	0.63	4	3.89	1.71	1	2.63	11.47	0	0	-
$t_{m,i}$	42	42	0	0	0	0	0	42	0	0	0	0	0	42	-
trw_i	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
Pmc_i	25	40	0.75	5.6	0	15	5.6	30	1.5	1.5	1.5	0.75	0	0	-
$Pinsp_i$	2	2	0	0	0	0	0	2	0	0	0	0	0.1	2	-
W_i	0.4344	0.091	0.0412	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.04	0.04	0.04

Appendix A4. MFCA analysis of a present case study manufacturing

MFCA Analysis	Total cost (฿/year)	Positive cost (฿/year)	Negative cost (฿/year)
MC	10,201,337	84,604	10,116,733
	53.74%	0.45%	53.29%
SC	8,008,895.14	7,109,649.34	899,245.80
	42.24%	37.49%	4.75%
EC	770,452.14	426,307.84	344,144.30
	4.05%	2.25%	1.81%
WC	1,387.02	0	1,387.02
	0.01%	0.00%	0.01%
TC	18,982,071.30	7,620,561.18	11,361,510.12
	100%	40.19%	59.86%

Appendix A5. Inspection plan and production lot size obtained by PSO algorithm.

Run	i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Cost ratio
1	W1	1641														0.401461
	W2	0														
	B	9	10	2	10	7	1	3	6	10	10	2	10	10	5	

	n	48	93	82	97	69	13	87	94	71	78	77	45	69	25	
2	W1	1500														0.333489
	W2	500														
	B	5	5	3	10	7	10	10	6	10	10	2	10	10	5	
	n	40	90	80	50	65	20	80	40	51	78	70	45	59	15	
3	W1	500														0.342575
	W2	0														
	B	5	5	10	10	10	10	10	5	10	10	5	10	10	5	
	n	40	90	80	50	60	20	80	20	55	60	70	40	50	20	
4	W1	1000														0.336945
	W2	0														
	B	5	10	5	10	10	10	10	3	10	10	7	10	5	6	
	n	45	50	85	50	66	25	80	40	55	50	60	40	50	20	
5	W1	300														0.309931
	W2	0														
	B	2	2	4	5	3	5	2	3	2	2	2	3	4	5	
	n	20	30	40	50	45	30	35	42	33	15	20	23	20	10	

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