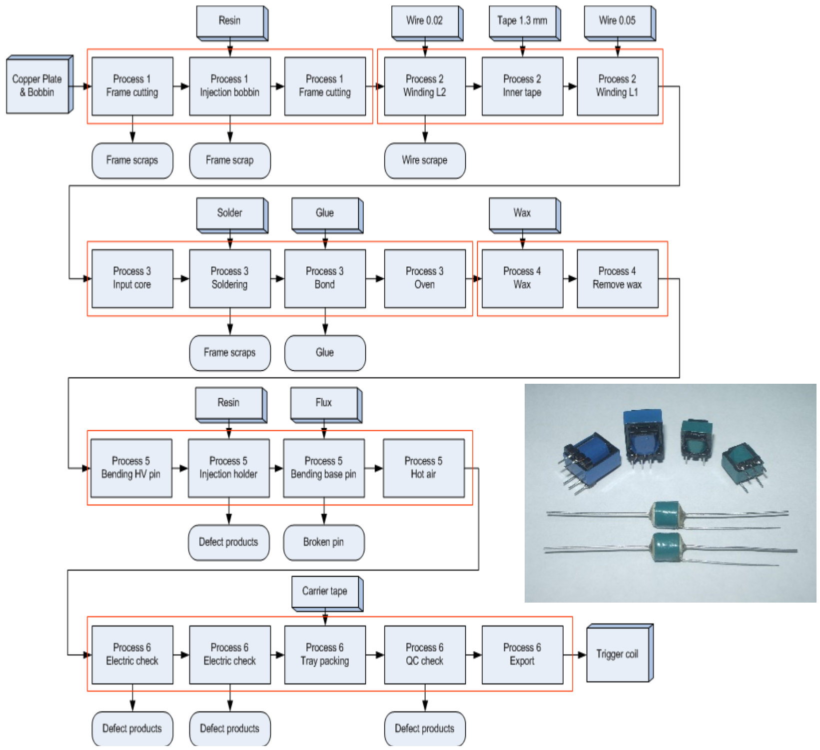


Fig 2. Material flow process chart of trigger coil

TABLE I. PERCENTAGE USED IN COST ALLOCATION FROM MASS BALANCE AND MC OF EACH PROCESS

Process	Unit	Positive Material Cost	Negative Material Cost	Total
1. Frame cutting and Injection	Gram	3,638.75	1,366.25	5,005.00
	Percentage*	72.70%	27.30%	100.00%
	THB	1,047.45	319.55	1,367.00
2. Winding	Gram	4,446.25	85.00	4,531.25
	Percentage	98.12%	1.88%	100.00%
	THB	3,095.70	281.50	3,377.20
3. Bond and Oven	Gram	4,621.25	265.00	4,886.25
	Percentage	94.58%	5.42%	100.00%
	Baht	3,141.37	388.33	3,529.70
4. Wax	Gram	4,621.25	1,000.00	5,621.25
	Percentage	82.21%	17.79%	100.00%
	THB	3,141.37	1,350.00	4,491.37
5. Bending	Gram	10,046.25	190.00	10,236.25
	Percentage	98.14%	1.86%	100.00%
	Baht	10,363.15	173.17	10,536.32
6. Packing	Gram	10,003.05	43.19	10,046.24
	Percentage	99.57%	0.43%	100.00%
	THB	10,443.60	44.55	10,488.15

Note: *Rp_i and 1-Rp_i

Cost item		1. Frame cutting and Injection	2. Winding	3. Bond and Oven
Newly input total cost	Total	2,204.63	4702.14	1347.75
	Newly input MC	1367	2329.75	434
	Newly input SC	412.5	1123.75	743.75
	Newly input EC	425.13	1248.64	170
Total cost handed over from previous process	Total	0.00	1656.43	6,021.14
	MC from previous process	0.00	1047.45	3,095.70
	SC from previous process	0.00	299.90	1396.94
	EC from previous process	0.00	309.08	1528.50
Process total of input cost	Total	2,204.63	6,358.57	7,368.89
	Input MC	1367	3,377.20	3,529.70
	Input SC	412.5	1423.65	2140.69
	Input EC	425.13	1557.72	1698.50
Percent quanlity of negative product		27.30%	1.88%	5.42%
Percent quanlity of positive product		72.70%	98.12%	94.58%
Positive product cost total	Total	1656.43	6,021.14	6,772.35
	Positive product MC	1047.45	3,095.70	3141.37
	Positive product SC	299.90	1396.94	2024.59
	Positive product EC	309.08	1528.50	1606.38
Negative product cost	Total	548.20	337.43	596.55
	Negative product MC	319.55	281.5	388.33
	Negative product SC	112.60	26.71	116.10
	Negative product EC	116.05	29.22	92.12
	Waste treatment cost	65	0.35	2.19
Sales of byproducts and recycled meterials	Selling prices	0	0	0

Cost item		4. Wax	5. Bending	6. Packing
Newly input total cost	Total	1,530.25	10,163.45	2421.24
	Newly input MC	1350	7394.95	125
	Newly input SC	156.25	2737.5	1875
	Newly input EC	24.00	31	421.24
Total cost handed over from previous process	Total	6,772.35	6,274.60	16,155.33
	MC from previous process	3141.37	3141.37	10363.14819
	SC from previous process	2024.59	1792.88	4446.29
	EC from previous process	1606.38	1340.34	1345.89
Process total of input cost	Total	8,302.60	16,438.05	18,576.57
	Input MC	4,491.37	10,536.32	10,488.15
	Input SC	2180.84	4530.38	6321.29
	Input EC	1630.38	1371.34	1767.13
Percent quanlity of negative product		17.79%	1.86%	0.43%
Percent quanlity of positive product		82.21%	98.14%	99.57%
Positive product cost total	Total	6,274.60	16,155.33	18,497.24
	Positive product MC	3141.37	10363.15	10443.60
	Positive product SC	1792.88	4446.29	6294.11
	Positive product EC	1340.34	1345.89	1759.53
Negative product cost	Total	2028.00	282.72	79.33
	Negative product MC	1350.00	173.17	44.55
	Negative product SC	387.96	84.09	27.18
	Negative product EC	290.04	25.45	7.60
	Waste treatment cost	0	5.36	2.1
Sales of byproducts and recycled meterials	Selling prices	0	0	0

Fig 3. MFCA analysis (Cost Unit: THB)

Then, the cost allocation for all costs and processes can be presented as Fig. 3 using percentage of positive and negative mass from Table I to allocate positive and negative costs of SC and EC as mentioned as equation (4) to (9). The results of cost allocation for this product can be concluded as Table II.

TABLE II. COST ALLOCATION OF ELECTRONIC PRODUCTION LINE BEFORE IMPROVEMENT (COST UNIT: THB)

	MC	SC	EC	WC	Total
Input	13,000.70	7,048.75	2,320.01	75.00	22,444.46
	57.92%	31.41%	10.34%	0.33%	100.00%
Positive	10,443.60	6,294.11	1,759.53	0	18,497.24
	56.46%	34.03%	9.51%	0	100.00%
Negative	2,557.10	754.64	560.48	75.00	3,947.22
	64.78%	19.12%	14.20%	1.90%	100.00%

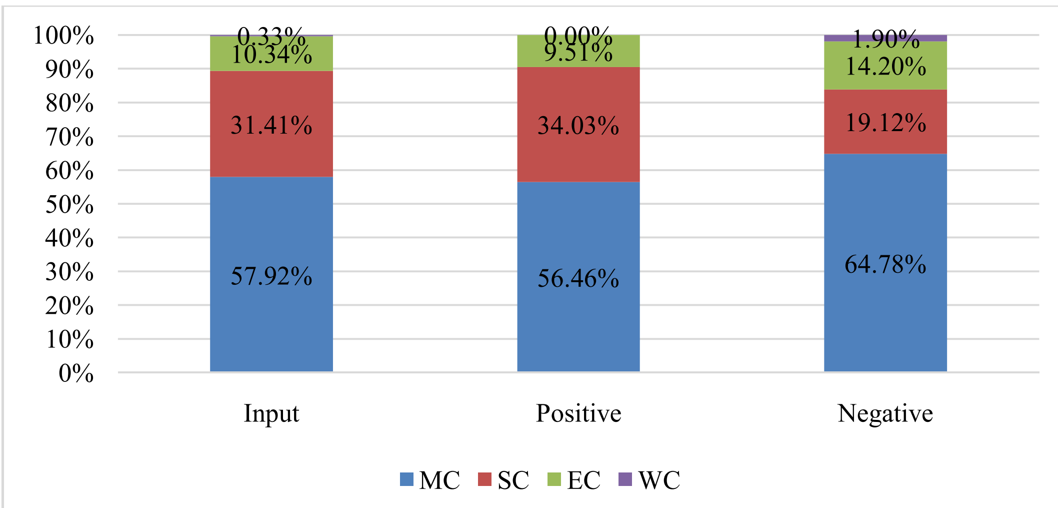


Fig 4. Cost diagram of electronic parts factory

From Table II and Fig. 4, the results showed that the total cost of this production was 22,444.46 THB consisted of MC as 13,000.70 THB (57.92%), SC as 7,048.75 THB (31.41%), EC as 2,320.01 THB (10.34%) and WC as 75.00 THB (0.33%). The total cost can be allocated as the cost of positive and negative product as 18,497.24 THB (82.41%) and 3,947.22 THB (17.59%), respectively. Since, the largest portion of negative product cost was MC as 64.78%, the improvement was concentrated on reducing negative cost of MC. Based on mass balancing in cost allocation, when MC was reduced, the reduction of waste material quantity was consequently affected to reduction in EC and SC. The same result from reducing MC was directly affected in WC reduction as well.

B. Problem Finding

To find to root cause of the negative cost of MC, Pareto chart was used to analyze material wastes from the production line as Fig. 5. Using 80:20 rules, wastes from frame scrap and wax were approximately 80% from the total waste. In this study, waste from frame scrap was concentrated. From the observation, it can be identified that frame scrape was mainly occurred during cutting process because the inappropriate working method.

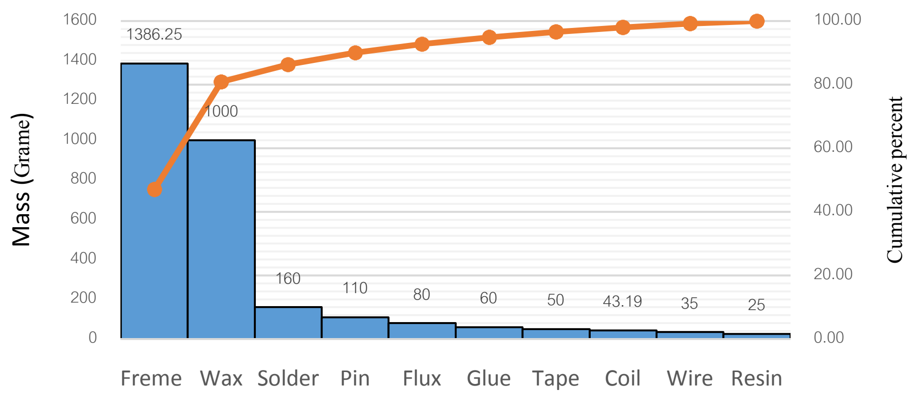
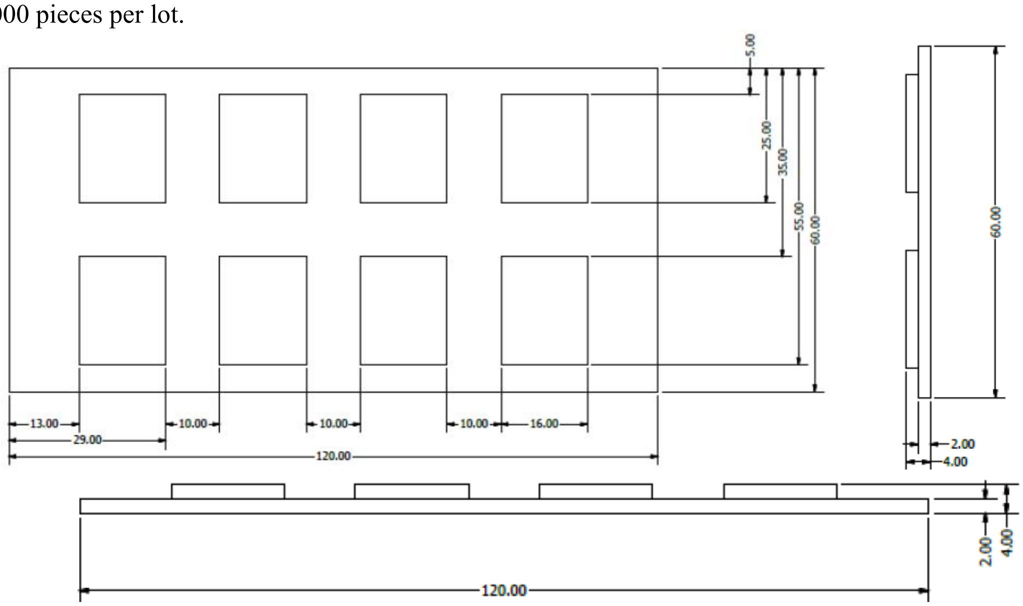


Fig 5. Pareto diagram of material wastes

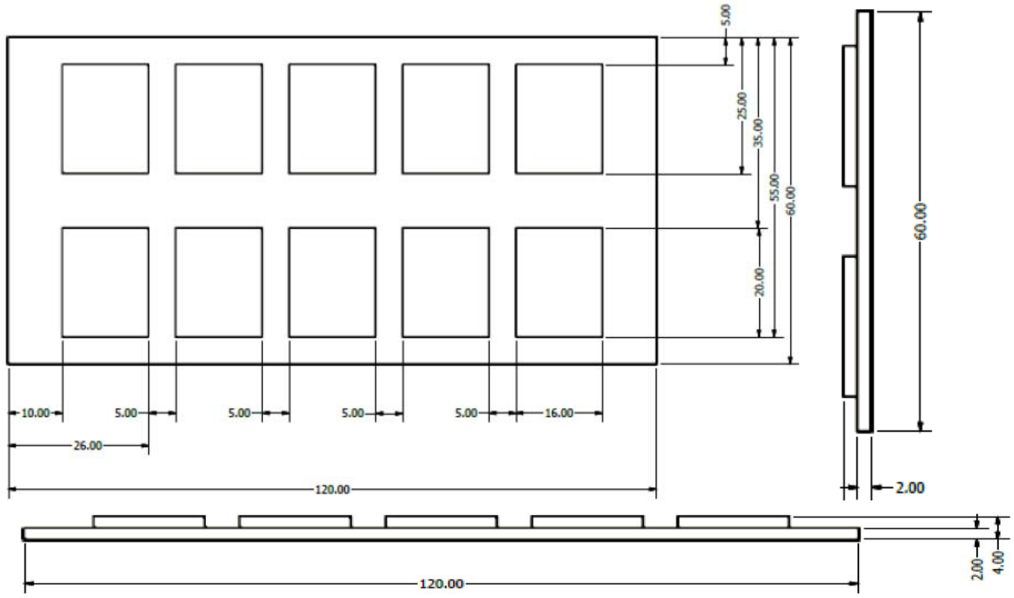
C. Improvement Planning and Proposing

At 1st process (Frame cutting and Injection), the step of this process was at which the workers fixed the copper plate to the jig before it was cut by the cutting machine. During this step a lot of waste was generated because to fix copper plate with the jig, tool holding allowance was needed for fixing the plate on the jig. By this working condition, after the plate was cut in pieces of work, the area of allowance was turned to be frame scrap. Fig. 6(a) presented the drawing of frame and jig with the size as 120x60 mm. The size of product is 16x20 mm. and the gap between each product row was 10 mm. Normally, one frame can be cut to produce 8 work pieces. The remaining frame after work pieces were cut was going to be the waste. The waste occurred as 1,341.25 g. per lot or 20,000 pieces.

The solution was proposed to design new jig at cutting process. Based on "S" or "Simplify" from ECRS concept, the new jig was proposed as Fig. 6(b). The new jig was designed to use for the same size of copper plate but reducing tool holding allowance from 13 mm. to 10 mm. and the gap between each product row from 10 mm. to 5 mm. This solution helped in reducing waste of copper plate scrap and increasing the number of product per one plate from 8 to 10 pieces. Consequently, as presented as Table III, material waste can be reduced to 465.50 g. as 34.71% reduction and total work pieces per lot increase to 22,000 pieces per lot.



(a)



(b)

Fig 6. The cutting method of (a) Current and (b) Improvement

TABLE III. THE COMPARISON OF RESULTS BETWEEN BEFORE AND AFTER IMPROVEMENT

	The number of copper waste (g.)	The number of product (pieces per lot)
Before improvement	1,341.25	20,000
After improvement	875.75	22,000

D. Evaluating Improvement Plan by MFCA Analysis

The solution was evaluated by re-analyzing MFCA. The results from MFCA calculation was showed in Table IV. The total cost after improvement was 22,300.92 THB that consisted of MC as 12,880.80 THB, SC as 7,048.75 THB, EC as 2,320.01 THB and WC as 51.36 THB. The total cost of positive product was 18,555.80 THB as 83.21% and the total cost of negative product was 3,745.13 THB as 16.79%. The comparison between Table 2 and Table 4 showed that the total input cost was decreased from 22,444.46 to 22,300.92 THB because the number of product per plate was increased. In addition, when the positive product cost of MC was equal as 10,443.60 THB, the negative product cost of MC was decreased from 2,557.10 to 2,437.21 THB. Fig. 7 presented cost comparison between before and after improvement situations. The comparison showed that the total product cost was reduced from 22,444.46 to 22,300.92 THB. Moreover, the percentage of total positive cost was increased from 82.41% to 83.21% while the percentage of total negative cost was reduced from 17.59% to 16.79%.

TABLE IV. COST ALLOCATION OF ELECTRONIC PRODUCTION LINE AFTER IMPROVEMENT (COST UNIT: THB PER 20,000 UNITS/LOT)

	MC	SC	EC	WC	Total
Input	12,880.80	7,048.75	2,320.01	51.36	22,300.92
	57.76%	31.61%	10.40%	0.23%	100.00%
Positive	10,443.60	6,322.95	1,789.25	0	18,555.80
	56.28%	34.08%	9.64%	0.00%	100.00%
Negative	2,437.21	725.80	530.76	51.36	3,745.13
	65.08%	19.38%	14.17%	1.37%	100.00%

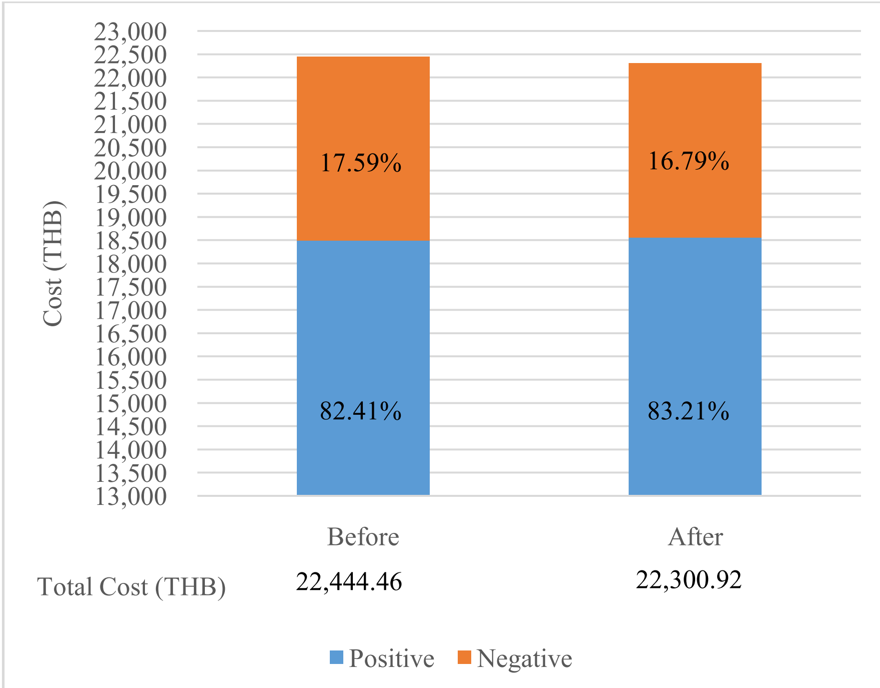


Fig 7. Cost comparison before vs after.

IV. Discussion and Conclusion

This study presented the application of MFCA and ECRS techniques in one electronic parts factory as a case study. The target product/process was selected as a trigger coil product with 6 continuous processes. The results from MFCA showed that the main negative product cost was MC as 64.78% from the total negative product cost. Pareto diagram was presented that frame scrap at the first process was a major waste occurring during the frame cutting operation. Simplify from the ECRS principle was used to propose the solution to reduce material waste at this process. New jig design was proposed to reduce the area of the copper frame that should be cut away. From the proposed solution, waste from frame scrap can be reduced as 465.50 g. and gained more product as 2,000 pieces per production lot. Then, MFCA analysis was re-calculated and the results showed that the total input product cost was reduced from 22,444.46 to 22,300.92 THB and total negative product cost was reduced from 3,947.22 to 3,745.13 THB, while the total positive product cost was increased from 18,497.24 to 18,555.80 THB.

When the new jig design was proposed, the investment cost was approximately 1,500,000 THB. Since, this solution gave the total cost as 22,300.92 THB, the total cost can be reduced as 143.54 per lot when current cost was 22,444,46 THB per lot. The factory produces this product 6 lots per month, on average. The benefit from cost reduction and gaining more profit from additional 2,000 pieces were 23,661.24 THB per month. Thus, return of investment period is about 63 months or 5 years when considering only the benefit at the first process. In practical, the benefit from this improvement should be higher than this 23,661.24 THB when this solution is actual implemented the reduction in processing time from better working method can be affected on SC and EC reduction as well as the increasing in production capacity that can be used for producing other products. Thus, the factory should consider this amount of benefit carefully in order to make the decision on developing the new jig.

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BIOGRAPHY

Chompoonoot Kasemset is an assistant professor in the department of industrial engineering, faculty of engineering, Chiang Mai University, Thailand. She received a D.Eng. in Industrial Engineering and Management, School of Engineering and Technology at Asian Institute of Technology in 2009. Her research interests include operations management, applied operations research, simulation application in production management and Material Flow Cost Accounting (MFCA). Her special field is Theory of Constraints (TOC).

Chawis Boonmee is a doctoral student in division of sustainable and environmental engineering, Muroran Institute of Technology, Japan. He received the M.Eng. degree in industrial engineering from Chiang Mai University in 2015 and the B.Eng. degree (2nd class honors) in field of industrial engineering from Chiang Mai University in 2012. He interested in the field of industrial engineering including optimization, operation & supply chain management, simulation application in production management, decision making and Material Flow Cost Accounting (MFCA).

Penpatchara Khuntaporn is a graduated student in field of industrial mangement, department of industrial engineering, faculty of engineering, Chaing Mai University.