THE USE OF MATERIAL FLOW COST ACCOUNTING TECHNIQUE TO REDUCE LOSSES WITHIN THE WOODEN FURNITURE PRODUCTION PROCESS

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Abstract
This study looked at how to reduce production losses using Material Flow Cost Accounting (MFCA), an environmental impact assessment technique used to help enhance productivity, and improve environmental management. MFCA focuses on both the costs of products and the costs associated with materials losses, and its ultimate purpose is to identify opportunities for reducing materials usage and losses, improve the efficiency of materials and energy usage, and reduce adverse environmental impacts. The research was carried out at a furniture factory in the north of Thailand, where problems such as high costs and residual wood waste have been experienced in recent years. Therefore, this research study aimed to analyse, classify and identify the losses incurred during the case study company's production process, and then develop and propose guidelines for improvement. The MFCA concept was employed to analyse resource use inefficiencies within the production process, as well as the causes of these inefficiencies. An estimate of the losses incurred in terms of costs was produced using the MFCA. Material loss data in terms of material costs, system costs, energy costs, and waste management costs obtained during the MFCA analysis were then summarized and prioritized using Pareto diagram. The results of the analysis helped identify ways to improve the design of the process and the product. Suggested solutions were developed and then put into practice, with the amount of wood and chemicals used during the process reduced as a result. Moreover, the standard working procedures used during each process step were redesigned. The results showed that MFCA helped total input costs for the production of the night table decrease by 19.55%, with negative product costs falling from 38.54% of input costs to 27.2% of input costs. In summary, this case study found ways to adapt the wooden furniture production process in the study factory, so as to reduce both losses and the adverse environmental impacts of the process.

Keywords: Wooden Furniture, Material Flow Cost Accounting

Introduction
Currently, interior design and furniture manufacturing businesses are very popular in northern Thailand due to the increase in housing and condominium developments in the country. Within this sector there is a lot of cost competition among companies, and also a need to produce environmentally – friendly products. This research was carried out at a furniture factory in the north of Thailand. The company's competitors are local small-scale manufacturers, as well as traders who could gain advantages through effective cost administration, and materials and waste management processes. This case study looked at the production problems experienced during the wooden furniture manufacturing process at the case study company, focusing on the creation of wood waste through the duplication of tasks caused by non-standard work, resulting in wood materials and painted furniture losses.

This research used Material Flow Cost Accounting (MFCA) technique as a tool to carry out an environmental impact assessment, to help illustrate the changes in value of the materials transfer process, and to help classify and identify losses incurred during the production process (ISO, 2011). This MFCA method was used to assess the losses incurred by classifying the materials, labour, energy and waste management costs into positive costs, and those costs incurring losses, or negative costs (Nakajima, 2006). MFCA focuses on both the costs of products and the costs associated with materials losses, and its ultimate purpose is to identify opportunities for reducing materials usage and losses, improve the efficiency of materials and energy usage, and reduce adverse environmental impacts (ISO, 2011; Nakajima, 2006). MFCA technique can be used in all industries, such as the production of souvenir music boxes (Chompu-inwai *et al.,* 2013), a small industry sector in Thailand. In Chompu-inwai *et al.* (2013), after using MFCA technique to analyse the materials flows during the wood cutting process, the causes of losses could be identified and the suggested solutions based on various engineering techniques were then developed. MFCA can also be used to make productivity improvements; as a tool for managers to work in real-time (real time monitoring) on abnormal losses occurring during production runs, or used alongside ERP systems in large industrial processes to minimize losses (Fakoya and Margaretha van der Poll, 2013).

Therefore, this research study aimed to analyse, classify and identify the losses incurred during the case study company's production process, and then develop and propose guidelines for improvement. The MFCA concept was employed to analyse resource use inefficiencies within the production process, as well as the causes of these inefficiencies (Nakajima, 2010).

Research Methodology and Results

The study focused on production of the basic night table model at the case study company, which is made of teak and teak plywood and is a proprietary format at the case study factory. The data collected in this study was related to the production of one basic night table, as shown in Figure 1.

Figure 1: Night Table - Basic Model

There are four major of tasks within the night table production process: woodworking, painting, assembly and packing. Therefore, the data analysis performed by MFCA defined each job as a quantity center (QC). A brief explanation of the production process is as follows:

- A hardwood frame is made and then a veneer and pieces of teak added to form a cabinet with a pattern design.
- The painting process includes using an abrasive, then a wood filler and wood stain, before a lacquer coating is added.
- Assembly includes installing fittings such as rails, hinges and handles, to make the cabinet ready to use.
- Packing is the final step. The wood pieces are cleaned and packed in foam (to prevent damage), then also wrapped in paper before being sent to the client.

All four tasks are shown in Figure 2.

Figure 2: Four QCs Used to Make a Night Table

Data Collection
The researchers collected employee and machine use data by department, and this contained information on working times and raw materials used during production of the night table. Data on the materials used were divided into three types: Main materials, Auxiliary materials and Sub-materials, and these were collected from the Stores and Accounting Department. Some of the technical terms used here are: Main materials - means materials used primarily to make the product, Auxiliary materials - means materials that are not a component of the product, and Sub-materials means materials used as components of the product.

Next, a Material Flow Model for the night table was constructed according to the QC configuration. This flow chart showing details of the input materials, output products and waste is shown Figure 3, which describes the use of all three types of materials; Main materials, Auxiliary materials and Sub-materials, dividing them into the four QCs. It was found that weight loss occurred among the raw materials, and that waste was very common for the plywood and teak wood activities. Losses were also found to take place as a result of the lacquer paint work.

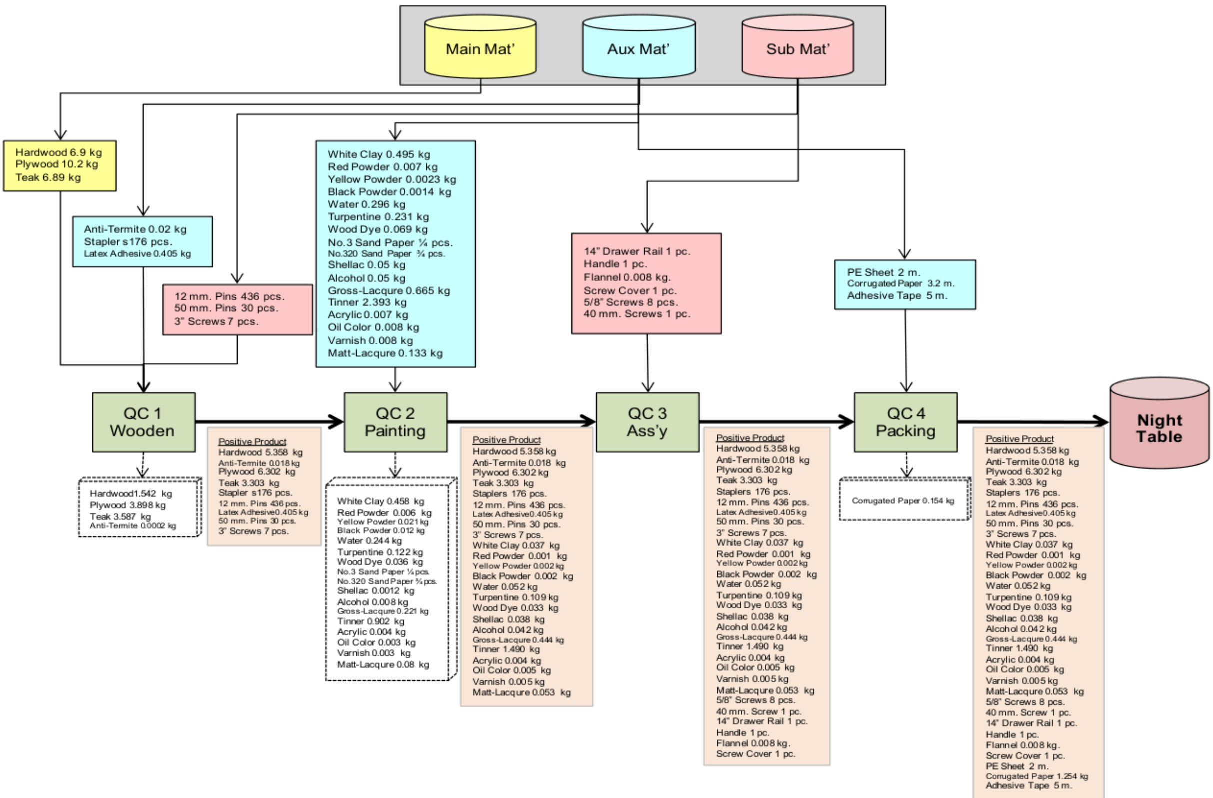


Figure 3: Material Flow Model

MFCA Calculation
MFCA technique was used to assess losses across all four categories, including; materials costs, system costs, energy costs and waste management costs. For materials costs, a Material Balance Table was created for each of the four QCs used in the production of one night table. Table 1 shows Materials Balance Tables for QC 1 (woodworking), which compares the physical inputs and outputs in this quantity center. It can be seen that 24.51 kilograms of materials entered this quantity center, while the amount of materials leaving the quantity center was: 15.48 kilograms or 63.16% as products, and 9.03 kilograms or 36.84% as waste.

In order to convert products and materials losses into monetary units, the total materials costs for each QC were calculated by multiplying the physical amount of each material by a unit cost, resulting in 729.01 Thai Baht's worth of materials losses (negative product) and 1,023.27 Thai Baht's worth of product costs (positive product).

The Materials Balance Tables for QCs 2, 3 and 4, set out in a similar way to QC 1, show the proportions of negative product (by mass) as 48.25%, 0.00% and 10.12% respectively.

Materials Balance Table – QC 1 Woodworking							
Materials Purchased		**Inputs**		**Waste**		**Output**	
Materials Inputs	**Cost/kg**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
45 mm. Hardwood	16.96	6.900	117.00	1.542	26.15	5.358	90.85
Anti-Termite	110.00	0.020	2.20	0.002	0.22	0.018	1.98
Stapler	276.92	0.023	6.34	0.000	-	0.023	6.34
6 mm. Plywood	88.24	10.200	900.00	3.898	343.94	6.302	556.06
12 mm. Screws	563.33	0.013	7.37	0.000	-	0.013	7.37
Latex Adhesive	27.20	0.405	11.02	0.000	-	0.405	11.02
50 mm. Screws	550.00	0.024	13.20	0.000	-	0.024	13.20
Teak	100.00	6.890	689.00	3.587	358.70	3.303	330.30
3 inch. Screws	176.00	0.035	6.16	0.000	-	0.035	6.16
Total		**24.51**	**1,752.28**	**9.03**	**729.01**	**15.48**	**1,023.27**
Quantity Percentage		100.00%		36.84%		63.16%	
Unit	THB	kg	THB	kg	THB	kg	THB

Table 1: Materials Balance Table for QC 1 (Woodworking)

Table 2 shows an example of the MFCA method used to allocate costs to the positive and negative categories for systems costs and energy costs. In QC 1, 36.84% of the materials inputs were turned into negative product (by mass). In this QC, there were the systems costs of 232.54 Thai Baht, energy costs of 41.29 Thai Baht, and waste management costs of zero. Based on the mass-based materials distribution percentage between positive product and negative product, this meant 85.66 Thai Baht of systems costs and 15.21 Thai Baht of energy costs were then allocated to the negative cost for this QC. Total waste management costs were assigned to materials losses, as these costs are incurred only through materials losses (ISO, 2011). As a result, total negative costs for QC 1 were 829.88 Thai Baht. A similar approach was used to calculate and allocate costs for the other QCs. The positive materials costs, systems costs and energy costs for QC 1 were then used as previous costs for the cost evaluation for QC 2. The total materials, energy and systems costs (before allocation) for QC 2 were the costs of inputs from previous QC (QC 1), plus any new inputs in QC 2.

QC 1 Negative Product Mass = 36.84%	**MFCA Cost Evaluation for QC 1: Woodworking**				
	Materials Costs	**Systems Costs**	**Energy Costs**	**Waste Management Costs**	**Total**
	THB	**THB**	**THB**	**THB**	**THB**
Previous Cost	-	-	-	-	-
New Input	1,752.28	232.54	41.29	-	2,026.11
Total Input	1,752.28	232.54	41.29	-	2,026.11
Positive Cost	1,023.27	146.88	26.08		1,196.23
Negative Cost	729.01	85.66	15.21	-	829.88

Table 2: MFCA Cost Evaluation for QC 1 (Woodworking)

Costs	**Materials Costs**	**Systems Costs**	**Energy Costs**	**Waste Management Costs**
Input Costs	2,429.76	635.35	72.90	-
	77.43%	20.25%	2.32%	0.00%
Positive Costs	1,570.57	324.46	33.74	
	50.05%	10.34%	1.08%	
Negative Costs	859.19	310.89	39.16	-
	27.38%	9.91%	1.25%	0.00%

Table 3: Overall MFCA Cost Matrix (before improvement)

The results of all the cost allocations (including all four QCs) are shown in Table 3.

Table 3 shows the total input costs, with the majority in the negative costs category, with the highest being materials costs at 27.38%, followed by systems costs at 9.91% and energy costs at 1.25%. The total negative costs resulting from the production of one basic night table equalled 38.54%.

Identifying Improvement Requirements
The negative costs data for materials, systems, energy and waste management costs for the four QCs were prioritized using a Pareto diagram, as shown in Figure 4. It shows the top three loss-making activities in terms of costs, representing 80% of total losses. The Pareto diagram shows that negative materials costs for QC 1 (woodworking), negative systems costs for painting (finishing), and negative materials costs for painting at 60.3%, 15.6% and 10.5% respectively.

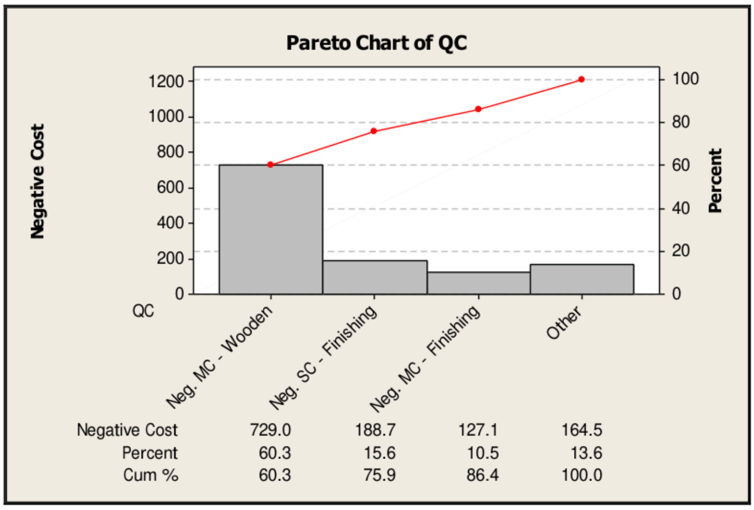


Figure 4: Pareto Diagram of Losses from All QCs

The causes of the negative materials costs in QC 1 were analysed using a Fish-Bone Diagram based on 4M1E (Man, Machine, Method, Material and Environment), as shown in Figure 5.

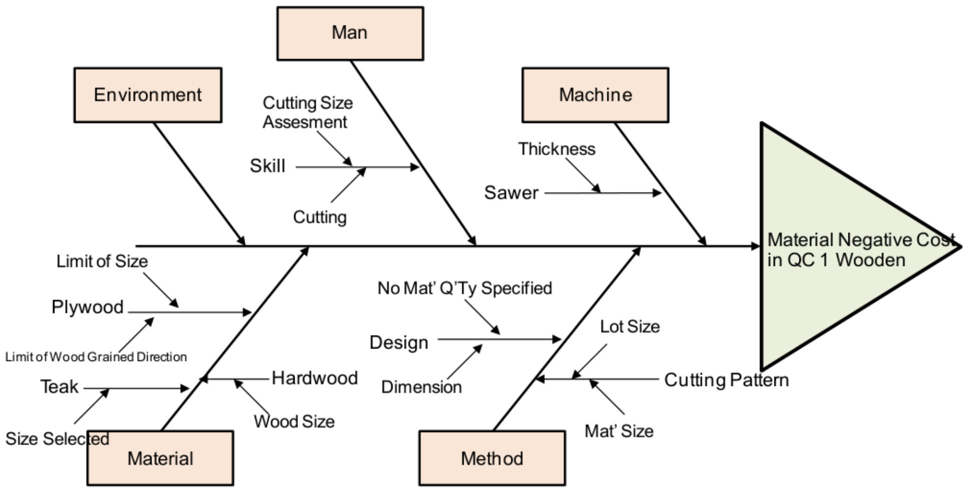


Figure 5: Fish-Bone Diagram for Negative Materials Costs for QC 1 (Woodworking)

Figure 5 presents an analysis of the causes of the negative materials costs found in QC 1 (woodworking), with the most common losses occurring among Plywood and Teak due to the shape of the cabinets, which affected the size of the cuts made for the raw materials, which was limited due to the production plan and the timber selected. In addition, the Fish-Bone Diagram was also used to analyse the causes of the negative systems costs and negative materials costs within the painting QC, finding that the painting process needed to be improved, in particular by producing a standard colour combination, through the provision of skills training for staff, and by refurbishing the working area.

Implementing Improvements
Having analysed losses using the Fish-Bone Diagram, a process for reducing waste was developed based on a previous study (Eshun *et al,* 2012), involving: Reduce, Technology Change, Product Change, Recycle and Reuse steps (Eshun et al, 2012), plus improvements in the design (Nakajima, 2010). Some of these concepts were consistent with the problems found, as follows:

- Re-design the product to reduce wood waste, as shown in Figure 6. The figure shows that the re-designed use of space on the plywood sheet resulted in a higher positive product figure and lower negative product figure for the plywood, which fell by 32.79%, as shown in Figure 7.

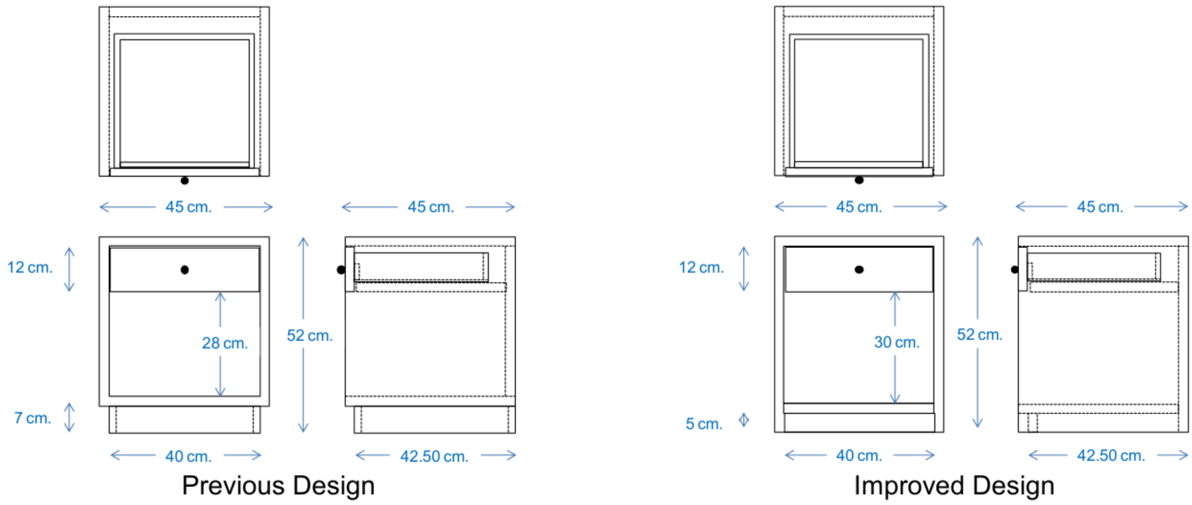


Figure 6: (Left) Night table - Previous Design; (Right) Night table - Improved Design

Figure 7: (Left) Plywood Cutting Pattern - Before Improvement;
(Right) Plywood Cutting Pattern - After Improvement

- The new design shown in Figure 6 was found to result in a reduced negative product for Plywood, plus a reduced amount of teakwood used to make the cabinet stand. The functions of the cabinet remained the same, but by applying the new design, the negative product fell by 49.25%.
- The reason why it had been difficult to estimate the number of teakwood chips produced by the cutting process for the drawer, drawer body and legs, was due to the need to select the right wood piece, a task traditionally carried out using random access schemes. This process required care to be taken over the cutting size for each piece, in order to fit the thickness and length of each wood piece. Table 4, shows the results of the drawer body wood selection process, before and after the cutting improvements were introduced. Improvements in the design and selection process led to negative product decreases of 65.29% by mass.
- The problem of negative systems costs within the painting process was found to be due to a lack of standards, leading to duplicated work and rework. As a result, design standards for painting were introduced and a dust- and humidity-free area created to reduce working time

losses. These changes resulted in a reduction in the length of time taken for each painting job by 12.5%.

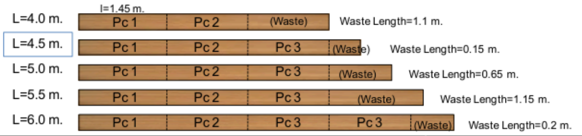
	Before Improved Cutting Teak		After Improved Cutting Teak	
	Length	**Thickness**	**Length**	**Thickness**
Drawer Size	1.40 m.	0.014 m.	1.40 m.	0.012 m.
Teak Selection	- Random selected 4.0 m., 4.5 m., 5.0 m., 5.5 m., 6.0 m. - Cut 1.50 m. length x 1 pc.	0.0254 m. (1.0 inch.)	 -Teak selected 4.50 m. length - Cut 1.45 m. length x 3 pcs.	0.0127 m. (0.5 inch.)

Table 4: Teak Wood Selection Methods for Drawer Parts – Before and After Improvements Introduced

- The lacquer stains problem found within the painting process was caused by non-standard colour combinations being used, and their inappropriate use, leading to excess input demands. This process was improved using an experimental design to find more standard colour combinations. The amount of chemical inputs needed was also determined. This new process resulted in a 49.63% reduction in the amount of chemicals required for each painting process and a negative product cost reduction of 63.02% by mass.

Evaluating Improvements Effects

After improving the night table design, and standardizing the logging and painting processes, a post-improvement evaluation was carried out using an MFCA calculations analysis. The cost calculation results were taken from data collected for one unit of the new basic night table design, as shown in Table 5.

Costs	Materials Costs	Systems Costs	Energy Costs	Waste Management Costs
Input Cost	1,864.56	550.98	109.01	-
	73.86%	21.82%	4.32%	0.00%
Positive Cost	1,422.08	347.46	68.43	
	56.33%	13.76%	2.71%	
Negative Cost	442.48	203.52	40.58	-
	17.53%	8.06%	1.61%	0.00%

Table 5: Overall MFCA Cost Matrix - After Improvements Introduced

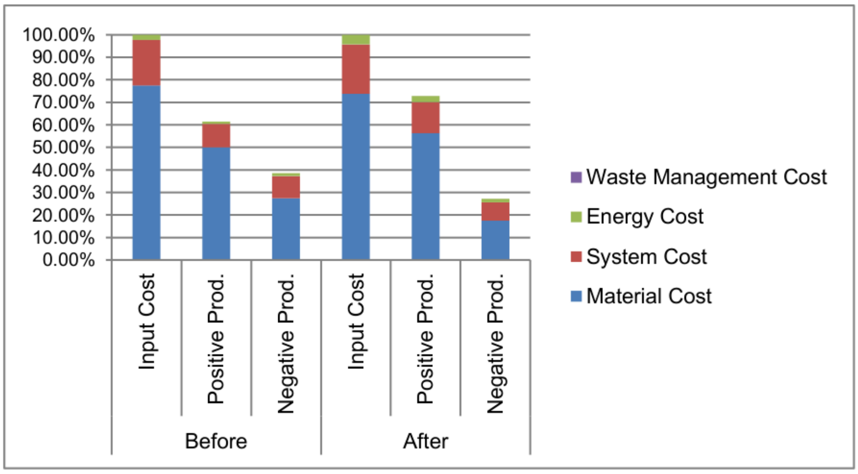


Figure 8: Overview of MFCA Calculation Comparison- Before and After Improvements Introduced (%)

The chart in Figure 8 describes the MFCA calculations prior to making the improvements, showing total negative costs of 38.54% of input costs, and with materials negative product representing 27.38%. The total negative costs, having introduced the improvements, were only 27.20% of the input costs. Meanwhile, the materials negative costs were 17.53% of the total input costs for the night table, a lower percentage than before the improvements were introduced. Prior to the improvements, the input cost value was 3,138.01 Thai Baht per unit, but after the improvements this became 2,524.55 Thai Baht per unit, a decrease of 613.45 Thai Baht or 19.55% per unit. The before-improvements negative costs figure was 1,209.25 Thai Baht per unit, while after the improvements this became 686.58 Thai Baht, a fall of 522.67 Thai Baht, or 43.22%. The negative materials costs before improvements were introduced was 859.19 Thai Baht per unit, but after the improvements was 442.48 Thai Baht, a fall of 416.71 Thai Baht or 48.50%

Conclusion and Discussion

This research study analysed and identified the monetary losses incurred during the study company's production process. Suggested solutions were then developed and put into practice, with the amount of wood and chemicals used during the process reduced as a result. Moreover, the standard working procedures used during each process step were redesigned.

As part of the study, the study company's production process was improved in order to reduce costs and decrease the negative cost that had previously occurred within the production process. After the improvements had been introduced, an assessment was carried out comparing total input costs and negative costs separated into four types, as shown in Figure 8. MFCA techniques were used to improve the night table production process and also bring in a new design (Nakajima, 2010); the aim being to reduce materials losses, and in future, MFCA may be used to further review and improve both product design and process design aspects at the case study company. Such a review will probably have to incorporate all design techniques and strategies, such as Quality Function Deployment (QFD), to create a night table design able to meet the needs of a new generation of customers, and also take into account the raw materials costs incurred by the production process – the best solution for both customers and business owners in a competitive market.

The value of this paper comes from its description of the application of the MFCA approach, and the resulting conclusions as to their effectiveness within an industrial setting.

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