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Applying Material Flow Cost Accounting (MFCA) to Improve Both Production Processes and Environmental Performance: Applied Study at Najaf Thermal Brick Manufacturing Plant

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Abstract

This study aimed to explain the mechanism of MFCA by applying this method to the Najaf thermo –stone brick manufacturing plant, also called (thermo- stone). In particular, the study aimed to manage manufacturing processes in relation to material, energy and data flows to ensure that the manufacturing process could continue efficiently and in line with any specific objectives. In flow management, a plant is viewed as a system of material flows, Starting with the purchase of input materials, moving through certain manufacturing processes, and ending with the distribution of products to customers.) Material losses that happened throughout the production process, such as poor-quality defects, waste, damaged products, etc., are present with the flow of materials. This indicates that the material is left behind in the production as undesired residues for both the economy and the environment. The transparency of material flows and pertinent costs have received the most attention. Consequently, conditions have been set up for the proposal of policies and measures linked to significant cost and material reductions. Measures aimed to cut back on material consumption might also result in cost savings in the material handling and waste disposal fields. The MFCA is highlighted in the study as a tool for material flow management. The study also found that companies that decide to employ MFCA had higher success in terms of their ability to attain superior economic and environmental performance. Companies now understand how crucial it is to exercise environmental responsibility and how doing so can boost their prosperity both environmentally and financially

Keywords: *Material Flow Cost Accounting; Environmental performance; Economic performance*

Introduction

Companies are under pressure today from a modern, competitive, and environmentally concerned society to increase production while having the least negative impact on the environment. Thus, a few different approaches have emerged to support management decisions in terms of economic performance while also taking the environmental impact and production levels into account Tachikawa & Kokubu (2013) Götze (2011). and the accounting function is looked at as a guarantee in calculating and reducing costs to the possible minimum Al-Mudhafar and Al-Hawazi (2022). Material Flow Cost Accounting (MFCA) is currently one of the primary instruments of Environmental Management Accounting (EMA). Thus, MFCA is one of the approaches that is believed to be a technique that can contribute to reducing societal pressure because it provides for harmony between sustainability and profitability. Craveiro (2017). Material

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flow cost accounting, in accordance with ISO 140513 standard, is the management tool to enhance the transparency of energy and material flows and consumptions. This method was developed to support industrial companies in terms of material and energy efficiency and to support management decisions by delivering effective value to the company's waste, presuming that economic impact is one of the most crucial elements in a company's environment. MFCA's results should motivate and drive managers to reconsider their strategy in order to boost production efficiency Kasemset (2015). Material flow management (MFM) is seen as a holistic lifecycle-oriented approach. It supports the responsible and efficient use of industrial materials and energy flows in order to achieve environmentally and economically efficient use of natural environmental resources including the reduction of emissions and related wastes. The basic concept of a material-based approach is the principle of comprehensive balance. This principle states that all "inputs" that enter the economy and come from the environment will, sooner or later, return to the environment in the form of waste and emissions Muñoz& Hubacek (2007). The design of highly integrated process chains with low total energy demand and reduced energy losses (as well as demand for materials and losses) is a key objective (innovation of energy-efficient products and processes in production engineering) Götze, (2011). Activities aimed at improving this process are related to different levels: one manufacturing step (for example, a transformation process) and combinations of two or more steps up to a process chain covering all the manufacturing activities required to produce a particular product (or component). In this context, the research question arises: how can the economic effects of such formations and alternative technologies to the chain of operations be assessed?

To address this research question, material flow cost accounting (MFCA) will be discussed as a means of identifying and quantifying the financial effects of reducing material/energy use and losses. The rest of the paper is organized as follows. In Section 2, the basic framework for material flow management is presented. Then, in Section 3, material flow cost accounting is introduced as a way to overcome the drawbacks of other environmentally or economically oriented accounting and valuation methods. In the fourth section, the results of the application of material flow accounting are addressed, and the basic procedure and analysis of the MFCA advantages are described. In the fifth section, conclusions of the study are presented.

Literature Review

Since the 1980s, growing concern about climate change and resource scarcity has pushed companies to conduct their activities with as minimal environmental impact as possible Wagner (2015). Additionally, the need to adhere to guidelines and the requirements imposed on resource consumption and emissions drives companies to enhance their practices in this area. However, However, companies must boost their productivity to be competitive in the global market. Christ & Burritt (2015), Therefore, managers must balance their efforts and face the challenges to achieve both economic and environmental objectives Sygulla,et al(2014). that the options available to improve the process depend on the ability of the company management to improve the equipment by purchasing modern equipment and training employees and this is done through Manage the cost that will be spent Al Robaaiy et al (2022).

Several authors have suggested Material Flow Cost Accounting (MFCA) as one of the tools that might assist companies in decision-making process for economic and environmental improvements in order to meet these requirements Kokubu & Tachikawa, (2013). It is an accounting technique that helps to protect the environment by concentrating on tracking waste and outputs and enhancing environmental and economic performance.

In the late 1990s, Bernd Wagner and his teams developed the concept of material flow accounting in Augsburg, Germany as an accounting technique that helps to protect the environment by concentrating on tracking waste and outputs and enhancing environmental and economic performance Chang, et al (2015). Material Flow Cost Accounting (MFCA) is aimed at supporting material flow-oriented analysis and decision-making in order to improve resource and cost efficiency. This approach has the capability of integrating economic and environmental objectives to contribute to the reduction or use of materials more effectively and efficiently. It is important to note here, that energy flows usually fall under the term material flows see, Kokubu, et al (2009). Visualizing, measuring material losses, and putting an emphasis on this type of losses can help managers make better decisions. This is accomplished by increasing the general level of material flow transparency physically Strobel & Redmann, (2002). Examples of the application of MFCA in practice can be found in Germany and Japan (see, for example, Chang,et al (2015), and Fakoya,et al (2015). The emphasis on materials mentioned above makes them particularly suited for manufacturing. Despite the fact that the model was invented in Germany, there are still few German implementations, whereas Japan's Ministry of Economy, Trade, and Industry has actively promoted MFCA, which has resulted in a faster spread. Kokubu, et al (2009)

Material flow cost analysis can be carried out at many process levels, from single techniques or manufacturing stages to entire value creation chains including numerous independent companies. Since MFCA, like most other environmental cost accounting techniques, complements the current set of traditional cost accounting techniques rather than replacing them, it can be viewed as a particular partial accounting technique to enhance economic and environmental decision-making concerning materials and the use of (energy). Based upon MFCA's guide, Loen (2018) a brief procedure to apply Material flow cost accounting is proposed as the following

1. Preparation

In the phase of preparation, it is highly significant to clearly identify target products, processes lines. Following that, the target process 's rough analysis is made and the quantity centers are determined, and the MFCA study 's scope is also determined. Lastly, recording conducted on the materials that are used in the target process or product, and data collection is planned.

2. Data Collection and Compilation

At this stage, data are collected, material types are classified. In each process, inputs and waste quantities are determined, and data relevant to energy (labor) costs and system costs are calculated. Following that, the system's allocation rules are then determined, along with the energy (labor) costs.

3. Calculation of Material Flow Cost Accounting

The gathered data are entered into a model created for MFCA calculation. The mass balancing concept can be used to allocate the costs of positive and negative products. A positive product cost represents the cost added to processed product that is released to the following step, while a negative product cost represents the cost added to recycled and wasted materials. The MCFA calculation results are verified, and then analyzed to identify the negative product costs and their reasons.

4. Identifying the Conditions that are Corrected or Improved

Then, identifying and listing the improvement conditions, namely cost reductions and material losses.

5. Formulating Improvement Plan

For formulating a plant of improvement, It is crucial to examine how much and how likely each alternative is to be able to reduce material losses. Following that, the calculation and evaluation of cost reduction is then completed by reducing material loss (MFCA calculation), which is used to set priorities for improvements or create plans for improvement.

6. Implementation of Improvement

The improvement strategy is put into action in the real world. Following the execution of the improvements, data -collecting must be conducted for evaluating each plan in the following stage.

7. Evaluating the Improvement Effects

After improvement implementation is complete, the amount of inputs and waste materials are calculated, and the calculation of MFCA is performed once more for comparing the improved process with the previous one. Total costs and negative product costs after improvement are calculated and used for evaluating the effects of improvement.

Case Study: The research was applied at Najaf (thermo-stone) brick production plant which is the second largest plant in the Republic of Iraq. The plant serves as a building unit for the construction of walls for various buildings and provides a wide range of brick sizes. Due to its lightweight, excellent temperature insulation, and fire resistance, it is frequently used in Iraq for the construction of internal and external partitions of structural buildings (concrete, iron). This is because it is suitable for areas with high temperatures and areas located on a seismic line. Moreover, it is also a cost-effective material to utilize because its light weight eliminates the need for large foundations.

The MFCA method was applied in three stages (preparation, data collection, and calculation), and the costs of product and material losses were tracked over the course of a full year (12 months) in 2021.

Description of the Manufacturing Process

After the materials (gypsum and sand) are examined and approved in the laboratory, the flow of materials during the manufacturing process starts with delivering the materials to the milling section. During this phase, which represents the first phase, inputs are crushed and homogenized using the dry milling process and this process is carried out through cylindrical tubes containing inside them steel balls for milling gypsum and the formation of the material (Cellular) as it is the main material for the manufacture of thermo-stone. Cellular material is then moved to the second phase, mixing stage, when ingredients (Alumina powder, cement and lime) are added together with a quantity of water to combine these ingredients to create thermo- stone. This mixture is transferred by block moving trolley to the third phase, initial drying phase, which is steam-filled rooms at a temperature of (80-100) degrees Celsius, this process takes from (6-8 hours). The fourth phase involves cutting the brick paste, which is performed longitudinally and transversely by cutting machines. After that, the brick paste is returned to the brick incinerator, this time at a temperature of 110 degrees Celsius, where it is kept for 14 hours before being removed to complete the cooling process. At the final phase, thermo-stone blocks are eventually removed from the brick incinerator to complete the cooling process. The damage rate could reaches to 5% due to being broken or overheated at this point, and the thermo-stone blocks are thus ready and transferred to the sales and marketing department for consumers.

The entire manufacturing process is carried out through three cost centers (Figure 1) within the management accounting system of the current plant

- **Preparation of Materials**: during this center, relevant costs are incurred in terms of milling and blending inputs and production of cellular material. Cost center uses basic materials (gypsum and sand), however, within the center, these materials are inexpensive, and the damage rate owing to dust volatilization is roughly 7%.
- **Mixture Preparation**: The mixture is prepared at this plant, which also covers energy costs and major cost components including (Alumina powder, cement and lime) the estimated losses within this center are approximately 4% resulting from cleaning machines and volatilization of materials.
- **Manufacturin:** This center includes pressing the mixture and cutting it within brickmolds, drying up in furnaces (special chambers), and sorting the final product. Approximately 9% of this center's production is damaged, by either mold breaks or distortion or overheating.

The entire manufacturing process is divided into three cost centers and as shown in Figure (1) as follows:

1. **Preparation of Materials**: at this center, the relevant costs include blending and milling cost of basic ingredients before manufacturing. The basic ingredients are used in the process of producing thermo-stone blocks, namely sand and gypsum inserted into a ball-milling machine commonly used for crushing and milling the materials into an extremely fine form, and this process results 7% material loss.
2. **Mixture Preparation:** at this center, basic mixture is prepared to manufacture thermo-stone (cellular), this cost center includes cost items that are represented by the input costs from raw materials added to the basic materials from the previous cost center, which include the following (Alumina powder, cement and lime.
3. **Manufacturing:** at this center, the mixture from the second stage is transported by block moving trolley to steam-filled rooms at a temperature of 60-70 °C, the entire drying process takes between 6 and 8 hours. After the drying process, the material is taken out of brick furnaces then cut by longitudinal and transverse cutting machines. After that, the cut bricks are placed back into the furnaces for 16 hours at a temperature of 80 °C. Finally, After performing cooling phase, thermo-stone blocks are now ready to be delivered to the marketing department. As a result of damage from being broken during this stage, 9% of the ready-made blocks render unusable.

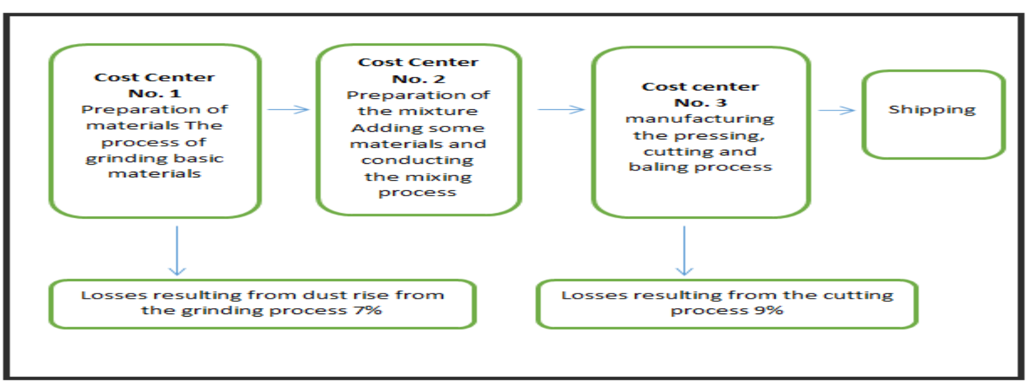

Figure (1): MFCA Diagram.
Source: Performed by Researchers Based on Palásek (2009).

MFCA method was applied at Najaf Thermo-Stone Production Plant, the entire manufacturing process was divided into four quantity centers as follows:

1- **Material Processing**: this quantity center corresponds to the cost center (material preparation). Due to material losses in dust volatility caused by the milling process used to produce the basic materials for thermo-stone, allocation costs of energy and system will be determined by this center's profit and loss statement.

2- **Mixture Preparation:** as in the previous quantity center, it also fully corresponds to the cost center (mixture preparation), since the determination and allocation of costs for energy and the system will also depend on the cost center.

3- **Firing:** this quantity center does not correspond to the cost center set by the existing plant management. This quantity center was formed for the purpose of obtaining a more realistic view of the material flow to know and evaluate material losses arising from this center. The material losses within this center include evaporated water as a result of the compressing (firing) process that occurs throughout this procedure.

4- **Cutting, Firing and Packing**: This cost center is established to know the material flow more accurately. The cutting process, as well as the evaporated water as a result of the second firing process that follows the cutting process, cause material losses within this center.Figure (2) illustrates the material flow process at the plant.

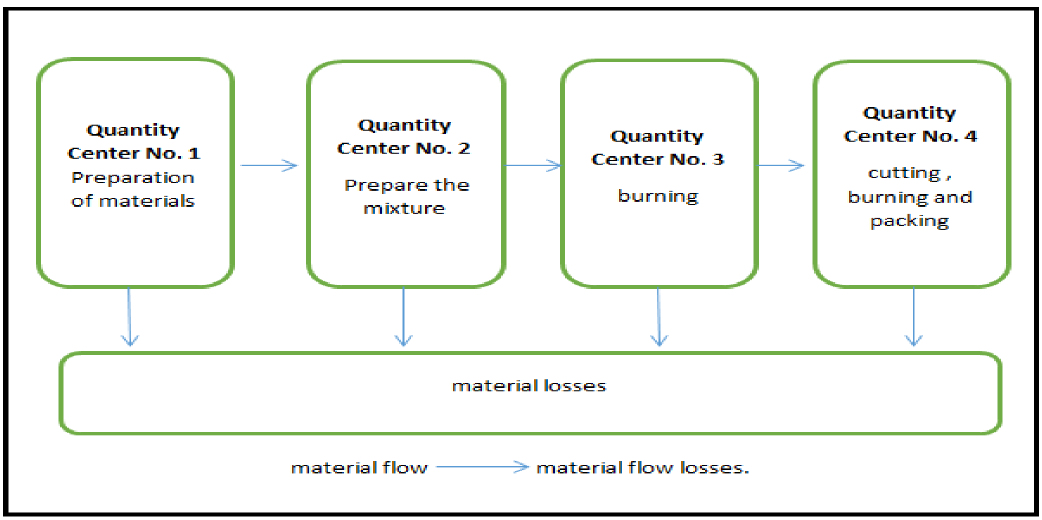

Figure (2): MFCA Diagram
Source: Prepared by the Authors (2022).

Collection and Analysis of Data

Some of the data needed to employ the MFCA approach, during the data-gathering process, had to be calculated using the plant's quantities and equations and information of the manufacturing process. Furthermore, it was essential to reconstruct the material flows by quantity centers using (Mass (weight) Units), see Table (1). The first step in the data collection process, however, is the process of building material flows on portions of quantity centers (weigh units). Then, for cost centers, knowing the prices of raw materials and other materials used in production. Besides, identifying material losses and distributing them to other quantity centers as parts of products or from material losses. The material costs of the losses representing the costs (waste) of the entire manufacturing process and of all quantity, centers were obtained (see Table 2).

It was also vital to determine the energy and operational costs (quantity) incurred by the plant and by all production (quantity) centers during the study period when collecting data.

The second phase of the MFCA application led to identifying the material flows to each center and the entire manufacturing process denominated in Iraqi dinars (see Table 3). Data on energy costs, operational costs of the system and of quantity centres (see table 4).

Table 1: Materials Within the MFCA Method.

Item	Quantity center NO .1	Quantity center NO .2	Quantity center NO .3	Quantity center NO.4
Products (total Materials in t)	1400	1328	357	2650
Share in the total usage of materials in the center	%93	%95	%89	%84
Materials losses (total Materials in t)	98	66.4	39.27	424
Share in the total usage of materials in the center	%7	%5	%11	%16

Source: Prepared by the Authors (2022).

The total balance of material flows in the plant is based on the assumption that the entire manufacturing process, for which the material flows were monitored, to which the MFCA method was applied, is consistent. The final quantity center's products (manufacturing center), has material losses equal to the total of all material losses incurred in all quantity centers (see Table No. 3)

Table 2: Materials Cost Within the MFCA Method.

Item	Quantity center NO .1	Quantity center NO .2	Quantity center NO .3	Quantity center NO.4
Products (Material costs in ID)	16400000	119400000	121900000	124900000
Share in the total material of costs in the center	96%	91%	90%	88%
Materials losses (Material costs in ID)	656000	10746000	12190000	14988000
Share in the total material costs center	4%	9%	10%	12%

Source: Prepared by the Authors (2022).

Table 3: Materials and Material Costs Within the MFCA Method.

Item	Total materials(t)	Share in the total usage of materials	Material costs in ID)(	Share in the total material costs
Products	428	%67	124900000	%76
Materials losses	272.15	%33	38580000	%24

Source: Prepared by the Authors (2022).

Energy and operational cost data were obtained from profit and loss computations for cost centers. The operational costs of the system do not reflect all reported cost items, but only costs related to relevant material flows. Table 4 illustrates the data related to energy and operational costs of quantity centers during the study period.

Table 4: Energy and System Costs (ID).

Item	Quantity center NO .1	Quantity center NO .2	Quantity center NO .3	Quantity center NO .4	Total
Energy cost	3.000.000	1.000.000	2.500.000	3.500.000	10.000.000
System cost	10.400.000	8.800.000	9.600.000	16.800.000	45.600.000
Total	13.400.000	9.800.000	12.100.000	20.300.000	55.600.000

Source: Prepared by the Authors (2022).

MFCA Calculation

Following the allocation of materials, energy, operational expenses, material losses, and determining the total costs relevant to material flows. It was important to allocate resources among all quantity centers based on the proportion of materials consumed by the product and the material losses. The first and second phases in both processes (Material Preparation and Mixture Preparation) are simple to calculate the MFCA, due to the fact that its inputs are raw materials and not outputs of a production process from other centers. On the other hand, the energy and operational costs of the third phase cannot be neglected. According to the ratio of the product's material content to the damage caused by a certain manufacturing phase, the energy and operational costs incurred during the manufacturing phase were allocated.

Table (5) shows the allocation of energy costs, operational costs on the product and material losses resulting from quantity centers as well as determining their total costs.

Table 5: Costs of Products and Material Losses (ID).

Item				
		Products:		
Share in the total usage of materials in the center	%93	%95	%89	%84
Material costs	16400000	119400000	121900000	124900000
Energy costs	930000	2375000	3115000	8400000
System costs	8184000	9120000	14952000	38304000
Total costs	25514000	130895000	139967000	171604000
		material losses:		
Share in the total usage of materials in the center	%7	%5	%11	%16
Material costs	656000	10746000	12190000	14988000
Energy costs	70000	125000	385000	1600000
System costs	616000	480000	1848000	7296000
Total costs	1342000	11351000	14423000	23884000

Source: Prepared by the Authors (2022).

MFCA Application Results

The results reveal that the Najaf thermo-stone production plant produced (2,650) tons of bricks and approximately (627.5) tons of material losses (waste) throughout the study period, with the relevant cost with material losses totaling approximately (51,000,000) million Iraqi dinars. Based on the results, we can recommend that the plant management focus mainly on the processes that take place within the cost center (cutting, firing, packaging) that produced the most material losses. The first phase of the manufacturing process produced (424) tons of waste at an estimated cost of (24,000,000) Iraqi dinars; these losses were caused by evaporation and exposure to breakage during the brick cutting process, followed by the Materials Preparation Center, which came in second place with material losses. The recommendation concerns the method of processing raw materials, specifically the method of milling materials. One of the proposed plant management solutions is to install filters to regulate volatile materials, allowing such materials to be recycled back into the production phase. Additionally, the operational and energy costs related to its manufacturing are lost in in a way that cannot be recovered. Regarding the other cost center, it functions well with potential for improvement in terms of water consumption and recycling. While the cost center (manufacturing) is very effective. Typically, thermo-stone brick production is a traditional process Due to the familiarity of the manufacturing process, as it is challenging to propose improvements to this technology. The MFCA approach can aid in the creation of new technologies that will improve upon the drawbacks of current technological methods. For these and other reasons, it is evident that it is not possible to totally prohibit the production of material losses, but it is useful to strive to minimize them while maintaining the desired level of product quality for customers.

Conclusions

Unlike traditional methods, MFCA method is one of the management accounting methods, as the MFCA monitors material flows, product –related cost and material losses, MFCA targets not only waste disposal costs, but also all economic resources used. In terms of material losses, the data obtained helps management in making decisions that lead to more effective results, reduce the extent of material losses, boost the economic efficiency of production, and so favorably affect the environment. (MFCA method contributes in improvement creation on two levels, the first is the economic level, in which (MFCA) focuses on material costs, since in industrial companies the cost component is very important, if compared with traditional accounting systems, t These systems provide insufficient information on material costs and companies lack detailed information on how certain materials flow through them. However, MFCA data and materials are kept apart in the centers since it is simple to manage and calculate their costs regardless of whether they are completed or passive products (waste).Then, the information obtained can be used to support decision-making and research processes to correct and propose measures to find solutions to the drawbacks. The second level is the environmental level, in which the MFCA focuses on reducing and recycling materials and thus reducing costs by reducing the quantities of materials and energy consumed. It will eventually have the environment impact, particularly the fact that natural resources will sooner or later run out and that some of them are almost depleted. MFCA is a crucial tool for management to use as a reference point for increasing environmental efficiency. When the MFCA method was used in the Najaf thermo-stone production plant, rebuilding material flows was primarily dependent on an in-depth understanding of the manufacturing phase and each quantity center because it was difficult to identify material flows in quantity centers, particularly when manufacturing centers used pre-treated materials from other centers. Since the selection of quantity centers has a significant impact on the quality of information, the MFCA application has demonstrated the necessity of determining the optimal volume of each quantity center in order to avoid losing pertinent and crucial data. In addition, the quality of the data obtained is greatly affected by the identification of energy and system costs and their accurate allocation to each quantity center. The researchers faced several limitations, including the difficulty of obtaining the required data, and the accounting system adopted in the company is a traditional system, the study recommends that further studies be conducted in other companies for the purpose of adopting material flow accounting to reduce costs to the lowest possible level.

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