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The Role of Material Flow Cost Accounting in Reducing Waste Losses: An Applied Study in the "Rasan Steel Factory" for the Manufacture of Steel Structures

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Abstract

This study aims to show case the pivotal role of Material Flow Cost Accounting (MFCA) in mitigating waste within industrial companies. It delves into the concept of MFCA, elucidating its implementation steps, cost elements, and its critical role in waste loss identification. The primary objective is to empower industrial entities to confront competition, ensure longevity, attain success, and achieve excellence in evolving markets by curtailing waste and subsequently reducing costs – a decisive factor in securing competitive advantages.

To fulfil the study's objectives and validate its hypotheses, the researchers employed a practical approach, implementing the MFCA methodology using real data from the "Rasan Steel" plant, a steel structure manufacturing facility. Among the pivotal findings of this study is the emergence of MFCA as a contemporary approach for waste measurement and reduction. It aims to strike a balance between financial and non-financial information, providing insights into quantitative and material flow processes.

In conclusion, this study offers several recommendations, foremost of which is the necessity for industrial firms to prioritize environmental concerns. They should embrace MFCA to quantify and assess the costs associated with waste and wastage losses, and subsequently, make concerted efforts to minimize them. This strategic move will enable them to keep pace with the dynamic shifts in competitive markets and foster sustainable practices.

Keywords: *Material Flow Cost Accounting, MFCA, Waste loss.*

1. Introduction

Economic entities have come to realize the significance of intense competition in the modern business environment and the rapid changes in all economic and social areas. With the increasing channels of product distribution and technological advancements, coupled with shorter product life cycles, competition has grown rapidly. This has compelled industrial companies to enhance their products' quality, reduce their costs, and continually seek to gain a large market share and a distinctive competitive position. They also seek modern and efficient approaches and techniques to improve the quality of their products and enhance the efficiency of resource utilization, meaning the search for

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efficient and sustainable use of natural resources. One of these modern approaches and techniques is Material Flow Cost Accounting (MFCA).

The core concept of Material Flow Cost Accounting is based on identifying all inputs (materials, energy, water, and other inputs) and outputs (primary products, secondary products, waste, and emissions) within a quantifiable boundary. The calculation involves the costs related to materials, energy, and the incurred system losses. The term "product" refers to any item that is either transferred to the next stage of production (quantitative boundary) as suitable or exits the unit as a final product. Material Flow Cost Accounting does not only focus on material losses in the narrow sense but includes all materials, energy, and other economic resources that have not been transformed into good products and are left as losses, waste, or emissions.

Material Flow Cost Accounting concentrates on the material flows and the associated costs. It provides a data and information system in both physical and monetary units, as material costs are a significant element in Material Flow Cost Accounting and represent an important factor in economic entities. Material flows within the quantitative boundary are reconstructed, and the data are analysed to determine which portion of materials flows and transforms into positive products and which portion remains as material losses. Material Flow Cost Accounting also monitors energy costs, which include all costs related to energy sources used within the quantitative boundary. Additionally, costs of system losses for products and material losses, such as personnel costs and disposal costs, are allocated.

Each material flow for the company can be treated as a carrier of system costs, whether it relates to raw materials, the manufacturing process, products, or material losses. Material losses left from the quantitative boundary must also be allocated, such as costs related to waste disposal and emissions. (Hyrslova et al., 2011: 6)

2. Literature Review

2.1 Material flow and management

The term "materials" refers to any raw material, auxiliary material, component, catalyst, or part used in the manufacturing of products. Any material that does not become a part of the final product is considered a material loss throughout the manufacturing stages (Ameri, 2017: 35).

Materials can be defined as "the substances from which products are manufactured" (ICAI, 2016: 7). Materials are categorized into two types:

Direct Materials: These are materials that can be clearly identified in the product, easily measured, and directly consumed in the production of the product. They become an integral part of the final product.

Indirect Materials: These are typically materials that do not become a part of the final product. They cannot be easily traced directly to the product but can be allocated or absorbed by cost centre or cost units.

The process of converting these materials into final products is referred to as "material flow," which can be defined as "all processes of transforming raw materials into final products". Material flow is also described as "a system to understand what happens to materials by processing them and converting them into final products" (Sznopek & Brown, 1998: 1). Material waste and resource loss occur at various stages of the production process, including: Material loss during processing, defective products, and impurities. Residual materials in manufacturing equipment after processing. Consumables such as solvents, cleansers, and water. Raw materials that become unsuitable for use (Ameri, 2017: 35).

Materials flow management refers to the systematic, responsible, integrated, and efficient control of material and service flows, along with all processes of converting materials into products. It facilitates activities that add value to the customer, providing the economic and social objectives. There are various tools that can be applied in managerial accounting, including input-output analysis for material flows, which is a practical method that provides reliable data. This method enhances transparency in material and energy flow within the production process and increases accuracy in cost allocation to cost centres responsible for waste generation. Materials and energy tracking require methods and labelling schemes, and the input-output model helps in tracking these flows. It ensures that input levels, totalling 100%, must be balanced with outputs (products, scrap, waste), and it includes materials measured in physical units, including energy and water. Materials flow lists are used to track materials, provide technical information, and organize production. They contribute to transparent production processes by utilizing both physical data and cost data, aiding in production optimization. These lists don't only cover materials but also illustrate material losses during production stages. Simultaneously, they make the cost flow transparent by using physical and cost values. Materials flow generally includes three types of costs: material costs (the value of materials and costs related to materials involved in the processes), system costs (internal costs within the unit for materials' preservation and allocation, such as personnel costs and depreciation), and disposal and delivery costs (costs associated with flows leaving the unit, like transportation and waste disposal) (Hashem & Salman, 2017: 13).

2.2 Material flow cost accounting concept

Material Flow Cost Accounting (MFCA) serves as a new accounting approach by providing information that assists economic units in obtaining a better understanding of the financial and economic impacts of practices and processes related to material and energy consumption. This approach involves tracking and assessing the physical material flow within the unit and allocating the appropriate costs associated with this flow. With the information provided by this approach, decisions can be made that help economic units introduce appropriate changes to these practices and processes, enabling the desired improvements. This, in turn, aids the management of these economic units in identifying available opportunities for achieving financial savings and reducing the negative effects associated with resource consumption practices (Prox, 2015: 486).

Material Flow Cost Accounting is also known as Material and Energy Accounting or Cost Flow Accounting, primarily aimed at identifying material and energy flows within a value creation system over a specific period. It includes assessing the potential for cleaner production at the unit level and making initial estimates of waste generation costs (Wahyuni, 2009: 12). It is an accounting method directly linked to resource efficiency (Yagi & Kokubu, 2018: 2).

Material Flow Cost Accounting supports material flow analysis and decision-making to improve material and cost efficiency by integrating economic objectives. This is achieved by contributing to the use of materials more efficiently, ultimately enhancing transparency in both the physical and monetary aspects of material flow (Sygulla et al., 2011: 3). The core concept of material flow analysis is "material balance," meaning that inputs are equal to outputs. According to Cost Flow Material Accounting, inputs encompass all materials necessary for the manufacturing process, including primary and secondary raw materials, direct and indirect labor, water, electricity, machinery, etc. The final output is classified as positive product output or negative product output. Positive products are semi-finished or finished goods, while negative products are waste resources or recyclable materials. To convert production into monetary units, input costs must equal the costs of positive products plus the costs of negative products (Chang et al., 2015: 122).

Material Flow Cost Accounting is a new accounting and evaluation method that combines financial and material data to determine the consumption of materials, energy, and resulting waste in both physical and monetary units. It reveals deficiencies related to material and energy consumption and uncovers hidden costs (Guenther et al., 2017: 5). It serves as a strong incentive for industrial companies to reduce waste and material input, leading to cost reduction, increased productivity, improved manufacturing processes, and, consequently, acts as a general tool to help economic units find ways to reduce environmental impact while increasing profitability through cost reduction (APO, 2014: 2).

Material Flow Cost Accounting is an effective tool used to assist economic units in better understanding the financial impacts of materials and energy used. It works towards improving production processes by focusing on reducing lead times, waste, and defects. It differs from Material Flow Accounting, which studies material flows at a national or regional level and is often referred to as national economic material flow analysis, usually conducted by national statistical offices (Mei, 2012: 124). The purpose of Material Flow Cost Accounting is to enhance the growing transparency of material and energy usage practices by developing a material flow model that monitors and defines material flows within the unit. Furthermore, it evaluates the costs associated with these material flows, which can impact the performance of economic units, aiming to identify financial benefits and mitigate negative effects (Morion, 2020: 22). From the above, we can clarify the concept of material flow cost accounting through Figure (1):

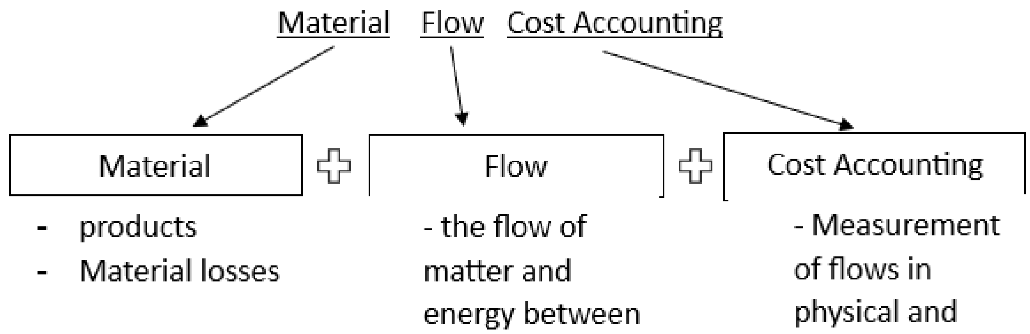

Figure 1. Material flow cost accounting concept

Source: APO, Asian Productivity Organization, (2014), "Manual on material flow cost Accounting: ISO 14051", Vol:1, Hirakawa Kogyo's Co., Ltd, Japan:4

The researchers view Material flow cost accounting as an administrative information system that explores all incoming materials flowing during the production process. It measures the output from the final product and its waste. Material flow cost accounting is a method that provides a detailed breakdown of the material flow in the production process, starting from raw material inputs and then through the production process to the outputs of the final product. It enables obtaining transparent information about material and energy flow, including managing and supporting decisions related to increasing the efficiency of materials and energy used. This is in contrast to traditional accounting systems, which typically do not account for lost (unutilized for production) energy but allocate it directly to production costs. Material flow cost accounting relies on the concept of material balance, dividing costs into positive product costs and negative product costs during the manufacturing process. Consequently, it provides information about the costs of material loss and efficiency reduction.

2.3 Steps to apply the entrance to material flow cost accounting

In the year 2000, the Japanese Ministry of Economy, Trade, and Industry (METI) established a working group (ISO/TC 207/W68) to develop a material flow cost accounting (MFCA) framework. In 2001, METI initiated a project to implement this framework in four companies: Nitto Denko, Canon, Tanabe, and Seiyaku (Zhang & Liu, 2015, 1456).

In 2007, METI proposed the development of a new standard specifically for MFCA, known as ISO 14051, within the ISO 14000 family of environmental management standards (Kokubu & Nagasaki, 2020: 71). The goal was to establish and standardize the principles and general framework for MFCA as a management tool to help economic units better understand the potential financial impacts of material and energy use practices and identify opportunities for financial improvements through changes in those practices (Christ & Burritt, 2016: 3).

Many countries, including the United Kingdom, Malaysia, Brazil, Finland, Mexico, and South Africa, participated in the development of this standard alongside Japan and Germany. ISO 14051 was officially adopted in 2011 and published as "Environmental Management - Material Flow Cost Accounting - General Framework" (Schmidt & Nakajima, 2013: 360-361).

In May 2014, preparations began for a new standard focusing on guidelines for extending MFCA to the supply chain due to potential material loss savings when there is closer collaboration between suppliers and buyers.

In 2017, the second standard, ISO 14052, was released as "Environmental Management - Material Flow Cost Accounting - Guidelines for Practical Implementation in the Supply Chain" (ISO 14052, 2017: 1-5).

With the issuance of ISO 14051 and ISO 14052, global recognition of material flow cost accounting increased, and its legitimacy grew.

Implementing material flow cost accounting in any company, regardless of its industry, requires collaboration among multiple departments and divisions. Furthermore, the level of detail and complexity in the analysis depends on various factors such as the unit's size, manufacturing process, and available information. Implementing MFCA should be seen as a gradual process, starting with understanding the concept, recognizing its importance for the company, and then implementing it to assess the performance of the production system. Decision-making in economic units is often driven by economic considerations. In this regard, MFCA can support decision-making by calculating the financial impact of waste, emissions, and losses, making it a valuable decision-making tool (Cecilo, 2017: 6).

According to the literature on MFCA, the implementation of this approach involves three steps: (Kawalla et al., 2018: 194)

Designing the material flow structure.

Quantifying material and energy flows.

Monetizing material and energy flows.

The international standard ISO 14051 suggests the possibility of integrating these MFCA implementation steps into the Plan-Do-Check-Act (PDCA) continuous improvement cycle, as illustrated in Figure 2.

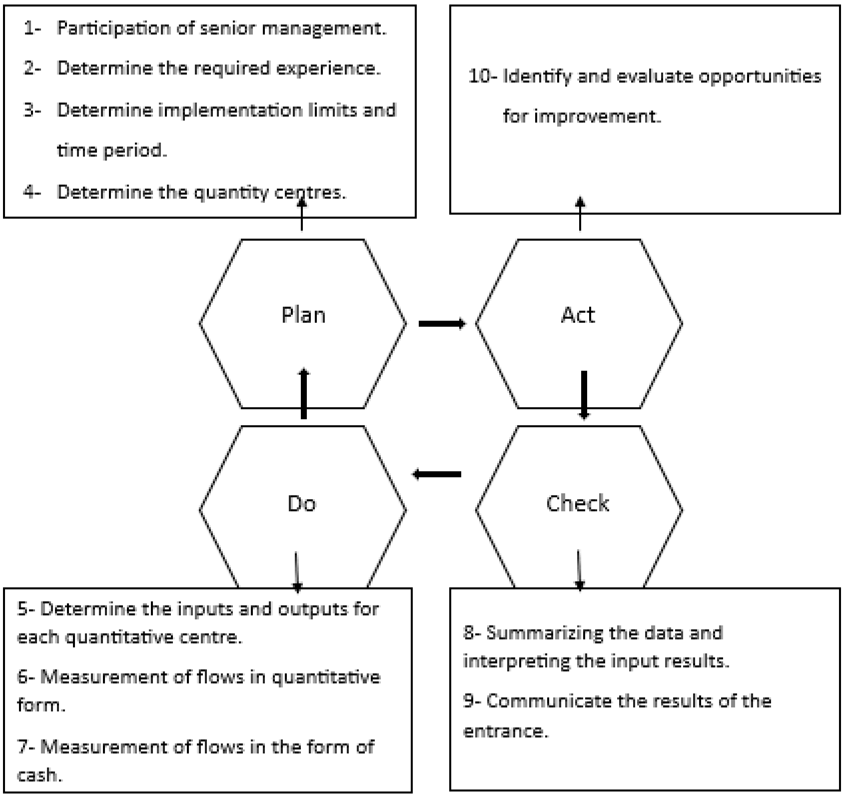

Figure 2. Continuous improvement cycle (plan, do, check, act) to implement material flow cost accounting

Source: Schmidt, A, Hache, B, Herold, F, Gotze, U, (2013), "Material flow cost Accounting with Umberto", Energy-related and economic balancing and evaluation of technical systems – insights of the Cluster of Excellence Eni PROD, Proceedings of the1st and 2nd workshop of the cross-sectional group 1, Wissenschaftliche Scripten, Auerbach:234

Here is an explanation of these steps:

Plan stage: This stage includes a set of procedures, namely:

1- Engagement of Senior Management in the Factory: The entrance to material flow cost accounting needs the support and participation of the unit management to achieve it successfully. Employees and workers in production departments must understand the practicality, advantages and benefits of this approach. (Singh, 2015: 4)

2- Identification of Necessary Expertise: The entrance to material flow cost accounting requires cooperation and coordination between multiple departments such as quality, engineering and logistics. In addition to a multi-experienced work team that can provide the information required for analysis. These experiences include operational experience, quality control and accounting experience. (Kokubu & Tachikawa, 2013: 355)

3- Determination of Scope and Timeframe: To model material flows and energy use, the limits of the analysis must be defined. Analysis boundaries can include one or several processes, the entire unit or even entire supply chains. Once the boundaries of the analysis are defined, the time period for data collection must be determined. This period must be long enough to consider any significant change in the process that allows the collection of valuable data. Depending on the production process selected for the analysis, the appropriate period could be the time required for a production batch or a month. One, third of a year, half a year or a full year. (Cecilo, 2017: 8)

4- Identification of Quantity Centres: The quantity centres are determined in light of the available information on the nature of the unit’s activities, or in light of the cost centre records or any other available information about the unit. However, if the process is not a significant contribution to the formation of the product, it can be included in another quantity centre. The centres of quantity must be carefully selected and defined. Because if quantity centres are chosen roughly, some relevant information about the location of material losses and negative product costs may become unclear. (ISO:14051, 2011: 31)

Do stage: This stage includes a set of procedures, namely:

5- Identifying Inputs and Outputs for Each Quantity Centre: the inputs and outputs of each quantitative centre must be determined, usually the inputs of the quantitative centre are raw materials, operational materials and energy (Nakkiew & Poolperm, 2016: 802) and the outputs are good products, waste, emissions and energy losses. All material movements within each quantity centre (including changes in inventories) and energy utilization between different quantity centres over a specified period are measured. Energy loss and energy actually used can be estimated separately. (Sygulla et al., 2011: 3)

6- Measuring Flows in Quantitative Form: Based on the flow structure, material flows and energy use must be measured in the form of physical units. Noting that materials are estimated in units of mass such as kg, tons, and energy is estimated in kilowatt-hours. To ensure consistency of analysis, the inputs and outputs of each centre must be a balanced quantity (the principle of quantitative equilibrium) taking into account possible changes in inventory. (Cecilo, 2017: 9)

7- Measuring Flows in Monetary Form: In this step, material flows and energy use are measured in the form of monetary units. In order to measure the flows of materials, energy and inventory in the form of cash (flow costs), the costs are divided into four categories, which are the costs of materials, energy, system and waste management, and as we previously explained the concept of each of them in detail. (Nertinger, 2015: 156)

Check stage: This stage includes two steps:

8- Data summarization and interpretation of input results: a summary of the input outputs and their interpretation is prepared. This is done by preparing a chart that combines the costs of a good product with wastage losses in all processes called the Material Flow Cost Matrix. In general, the administration enables reviewing the data of this matrix to determine the quantity centres in which there is a financially and economically significant loss. (Singh, 2015: 5)

9- Communicating the Input Results: After analysing and interpreting the results according to the entrance of the material flow cost accounting obtained, the unit management must be informed to take appropriate action, and allow the identification of quality control and material losses of financial or economic importance. In general, information may support a wide variety of decisions within a unit with the goal of improving resource efficiency and economic performance. (Cecilo, 2017:10)

Act stage: This stage includes a final step, which is:

10- Identifying and Evaluating Improvement Opportunities: After the results of the material flow cost accounting approach helped to understand the repercussions and motives of material uses and losses, the entry data must be reviewed, to evaluate an opportunity to improve the financial performance of the system, and therefore, the material flow cost accounting approach model may support the assessment of future financial benefits for the company. (Inwai et al., 2014: 8) Based on transparency in material and energy flows, opportunities to improve financial performance are identified and evaluated before the cycle starts again. (Schmidt et al., 2013: 235-236)

3. Methodology

The researchers utilized a case study method to achieve the study's objectives and test its hypotheses. This involved applying the Material Flow Cost Accounting (MFCA) approach to real data from the "Rasan Steel" plant, a steel structure manufacturing facility, as the practical application side of the study.

The primary aim of the research was to comprehensively explore MFCA, encompassing its concept, implementation steps, cost elements, and its pivotal role in waste reduction within industrial contexts.

The application of MFCA in any organization, regardless of its industry, mandates a systematic approach. The level of detail and complexity in the analysis depends on factors such as the scale of operations, manufacturing processes, and data availability. Implementing MFCA is a sequential process, from understanding the approach to recognizing its relevance to the organization and evaluating production system performance. Economic decision-making often hinges on financial considerations, and MFCA facilitates this by quantifying the financial impact of waste, emissions, and inefficiencies. Additionally, the study considered compliance with the international standard ISO 14051, which allows for the integration of MFCA steps into the continuous improvement cycle (Plan-Do-Check-Act, PDCA). The hypothesis of the research is that the use of the Material Flow Cost Accounting (MFCA) approach helps to reduce waste loss, which helps the research sample company.

Data for this study were obtained from the "Rasan Steel" plant, chosen for its suitability in terms of production processes for the study's methodology. This selection ensured that the research could effectively apply to the plant's operations.

Data collection methods included interviews with managers, accountants, and engineers at the plant, as well as the acquisition of official documents and reports to validate and supplement the data obtained through interviews.

The data collected were subjected to MFCA methodology. This involved applying MFCA principles to the factory's data, tracing material flows, calculating cost elements, and identifying areas of waste. The analysis process aimed to develop a comprehensive understanding of the factory's operations, processes, and cost structures and determine causal relationships between material flows, costs, and waste to pinpoint opportunities for improvement.

The study's temporal scope covered the period from October 1, 2021, to December 31, 2021, specifically focusing on the "INTERNO" project within the "Rasan Steel" plant. Cost data for the entire year of 2021 were collected and analysed to provide a holistic view of the plant's financial performance during this timeframe.

A notable limitation of this study was the challenge in obtaining accurate data and numbers from industrial companies in the Kurdistan Region. This limitation may have influenced the comprehensiveness and accuracy of the findings, and efforts were made to mitigate this constraint.

In summary, this study employed a case study methodology to apply Material Flow Cost Accounting (MFCA) to the operations of the "Rasan Steel" plant. Data collection involved interviews and official documents, with analysis conducted systematically using MFCA principles. The study aimed to provide insights into waste reduction strategies in the steel manufacturing industry.

4. Case analyses

4.1 factory profile

The "Rasan Steel" factory, which produces steel structures, was established in 2008 under the licensing of the Investment Authority affiliated with the Presidency of the Council of Ministers in the Kurdistan Region government, with license number 135. The factory operates under the Industrial Projects Law and is located in the Southern Industrial Zone in Erbil Governorate. It started with a capital of approximately $4,282,291, and its facility covers an area of 18,790 square meters.

The main purpose of establishing this factory is to manufacture steel structures to meet the basic needs for constructing buildings and warehouses in the Kurdistan Region and throughout Iraq, thereby supporting the national economy of the Kurdistan Region. The primary activity of the factory is the production of steel structures used in the construction of buildings and warehouses. The annual production capacity of the factory is approximately 4,000 tons.

4.2 Application of the material flow cost accounting approach in the "Rasan Steel" plant

The researchers are attempting to apply the Material Flow Cost Accounting (MFCA) approach in the "Rasan Steel" factory, which manufactures steel structures, using the designed theoretical steps of the study as follows:

1-Engagement of Senior Management in the Factory:

The researchers received support and collaboration from the Board of Directors of the "Rasan Steel" factory to successfully implement the MFCA approach.

2-Identification of Necessary Expertise:

To gather the required data and information for applying MFCA, the researcher relied on the expertise available within the "Rasan Steel" factory. This expertise includes department managers, supervisors, engineers, financial experts, manufacturing workers, and quality control personnel, all of whom can provide the necessary information for the application and analysis.

3-Determination of Scope and Timeframe:

The scope of the MFCA application covers all activities of the factory related to the "Interno" project, which is one of the projects executed by the factory. It includes activities from the procurement of raw materials from suppliers to the delivery of the project to the client. Data for analysis was collected for the period from October 1, 2021, to December 31, 2021, which corresponds to the duration of the project. This data was obtained from cost reports, manufacturing reports, personal interviews with department managers and manufacturing operations, and direct observations of the manufacturing processes.

4-Identification of Quantity Centres:

Quantity centres were determined within the boundaries of the analysis based on the available data regarding the nature of the factory's activities. After studying the manufacturing system in the "Rasan Steel" factory, the manufacturing process was divided into two quantity centres: the manufacturing quantity centre and the assembly quantity centre, as illustrated in Figure 3.

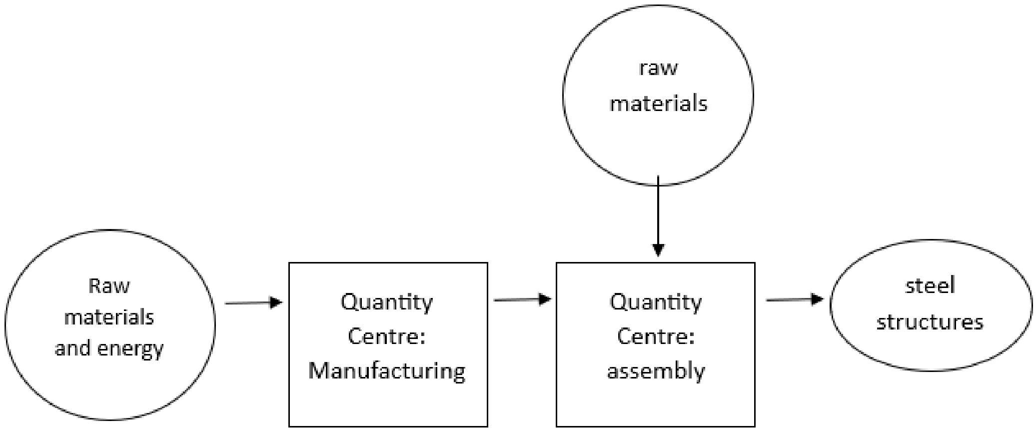

Figure 3. Quantitative centres in the "Rasan Steel" factory

Source: Prepared by the researchers based on data from the factory.

5-Identifying Inputs and Outputs for Each Quantity Centre:

In this step, inputs and outputs for each quantity centre were determined. For the manufacturing quantity centre, inputs consist of raw materials such as "Ip profile, L profile, Rod, Plate, SHS, and channel" as well as energy sources like electricity, gas, fuel, and oils. Outputs from this centre include good products (iron columns) and losses. On the other hand, for the assembly quantity centre, inputs are derived from raw materials (sandwich panels), and its outputs are steel structures. It's important to note that there is no energy usage in the assembly quantity centre, as the installation of the columns is performed by external contractors, as illustrated in Figure 4.

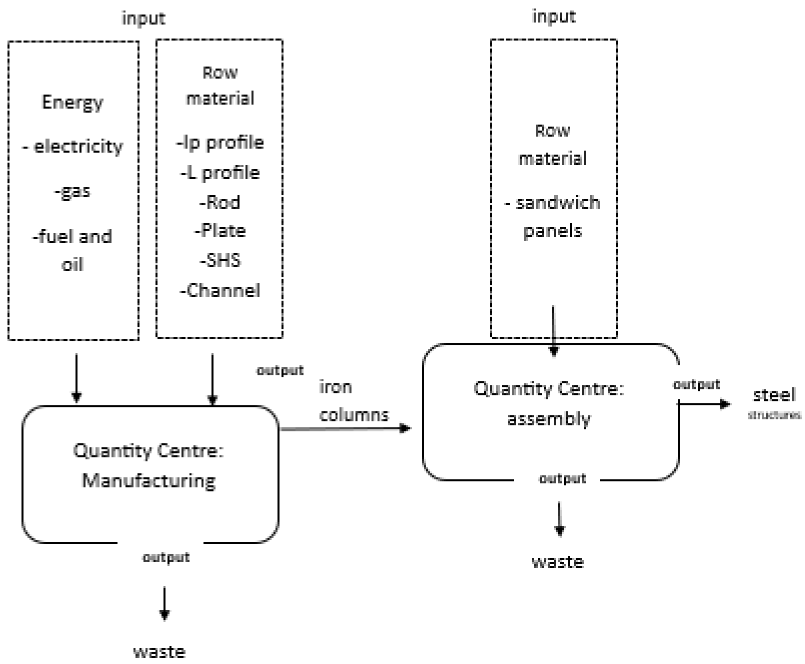

Figure 4. Inputs and outputs for each quantity centre in the "Rasan Steel" factory

Source: Prepared by the researchers based on data from the factory.

6- Measuring Flows in Quantitative Form:

In this step, inputs and outputs for each quantity centre are quantified. Inputs represent the resources received from the previous quantity centre, while outputs consist of good products and losses. The sources of losses and emissions in the quantity centres include:

Remaining materials from the manufacturing quantity centre that are not used in the manufacturing process.

Remaining materials from sandwich panel layers in the assembly quantity centre, which increase the measurements required for the assembly process.

In this context, a quantitative flow structure was prepared for the "Rasan Steel" factory, as illustrated in Figure 5. The quantity centres covered by the analysis include manufacturing and assembly. In this step, it is essential to verify the quantitative balance within each quantity centre and in the overall manufacturing process as well.

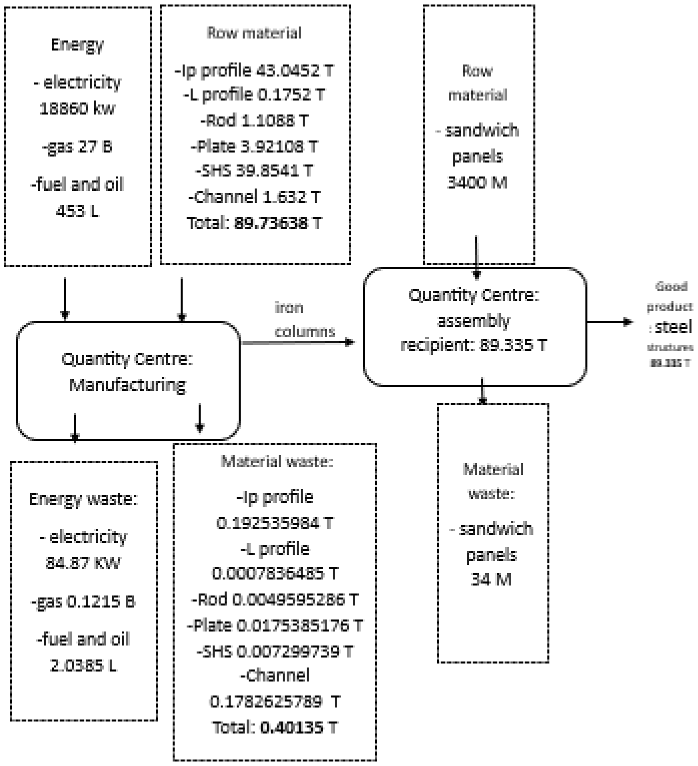

Figure 5. The quantitative flow structure in the "Rasan Steel" factory for the "Interno" project (the last quarter).

Source: Prepared by the researchers based on data from the factory.

Figure 5. illustrates that the quantitative flow in the "Rasan Steel" factory for the "Interno" project consists of two quantity centres: the manufacturing quantity centre and the assembly quantity centre. Inputs for the manufacturing quantity centre include raw materials such as "Ip profile" (43.0452 tons), "L profile" (0.1750 tons), "rod" (1.1088 tons), "Plate" (3.92108 tons), "SHS" (39.8541 tons), and "channel" (1.632 tons). Additionally, it includes energy sources like electricity (18,860 kWh), gas (27 litters), and fuel and oils (453 litters). Outputs from this centre consist of good products (iron columns) amounting to 89.335 tons, as well as material losses, including "Ip profile" (0.192535984 tons), "L profile" (0.0007836485 tons), "rod" (0.0049595286 tons), "Plate" (0.0175385176 tons), "SHS" (0.007299739 tons), and "channel" (0.1782625789 tons), and energy losses, including electricity (84.87 kWh), gas (0.1215 litters), and fuel and oils (2.0385 litters). The assembly quantity centre receives inputs from the manufacturing quantity centre in the form of iron columns (89.335 tons) and raw materials, specifically

sandwich panel layers (3400 m). Outputs from this centre include good products (steel structures) amounting to 89.335 tons and material losses from the sandwich panel layers (34 m). It's noteworthy that there is no energy usage in the assembly quantity centre as the installation of the columns is performed by external contractors.

7- Measuring Flows in Monetary Form:

In this step, the quantitative flows of inputs and outputs in each quantity centre are translated into financial form by costing the quantity centres and then allocating the costs of the quantity centres to the good products and losses. This is done through the following process:

Step 1: Costing Quantity Centres: In this stage, costs are classified into four categories, namely, material cost, energy cost, system cost, and loss management cost, as previously discussed in the theoretical side of Material Flow Cost Accounting (MFCA). For this reason, costs in the "Rasan Steel" factory for manufacturing steel structures were identified and classified according to these categories as follows:

Material Cost: The manufacturing of steel structures requires the use of several types of raw materials, as mentioned earlier, such as Ip profile, L profile, rod, plates, SHS, channel, and sandwich panel, according to each quantity centre. Data regarding the quantities of raw materials consumed by the quantity centres were collected in the previous step. From this stage, the material costs were determined through cost reports in the factory. The average cost per unit of materials was then calculated as the materials flowed through the quantity centres using the following formula:

Material Cost = Quantity of materials used in each quantity centre * Average cost per unit of materials

This calculation is illustrated in Table 1.

Table 1. The cost of materials in the "Rasan Steel" factory for the "Interno" project (last quarter).

quantity centres	material	Quantity	cost per unit / $	Material Cost / $
manufacturing	Ip profile	43.0452 T	996.529	42895.79
	L profile	0.1752 T	811.644	142.2
	Rod	1.1088 T	930.844	1032.12
	Plate	3.92108 T	1122.423	4401.11
	SHS	39.8541 T	1067.724	42553.18
	Channel	1.632 T	885.184	1444.62
Total				92469
Assembly	sandwich panel	3400 M	14	47600

Source: Prepared by the researchers based on data from the factory.

Table 1. shows that the cost of raw materials for each quantity centre in the "Rasan Steel" factory for the "Interno" project has been calculated. The total cost of raw materials for the manufacturing quantity centre is $92,469, consisting of the following materials: Ip profile ($42,895.79), L profile ($142.2), rod ($1,032.12), Plate ($4,401.11), SHS ($42,553.18), and channel ($1,444.62). The total cost of raw materials for the assembly quantity centre is $47,600, representing Sandwich Panel material ($4,760).

Energy Cost: Several types of energy are used in the Rasan Steel factory, as mentioned earlier: electricity, gas, fuel, and oils. In this stage, it is necessary to determine the energy consumption rates in each quantity centre and then calculate the energy cost using the following equation:

Energy Cost in Quantity Centre = Energy Consumption Quantity * Cost per Unit of Energy

Each quantity centre should bear its share of these costs based on appropriate allocation principles that reflect a causal relationship in resource usage. It's worth noting that energy is only used in the manufacturing quantity centre. Table 2. illustrates the energy consumption quantities in the quantity centres and the total energy cost.

Table 2. Energy costs in the "Rasan Steel" factory for the "Interno" project (the last quarter)

quantity centres	Type of energy cost	consumption	Average cost /$	Energy cost / $
manufacturing	electricity	18860 kw	0.098	1848.28
	gas	27 B	29.697	801.82
	Fuel and oils	453 L	0.58	262.74
	Total			2912.84
Assembly	There are no energy costs			

Source: Prepared by the researchers based on data from the factory.

The table 2. shows that there are three types of energy used in the Manufacturing Quantity Centre at the "Rasan Steel" factory for the "Interno" project, electricity: Cost of $1,848.28 with a consumption rate of 18,860 kWh and a rate of $0.098 per kWh. Gas: Cost of $801.82 with a consumption rate of 27 bottles and a rate of $29.697 per bottle. Fuel and Oils: Cost of $262.74 with a consumption rate of 453 litters and a rate of $0.58 per litter. In the Assembly Quantity Centre, there are no energy costs because the columns are installed by external contractors.

System Cost: The system cost includes all production-related costs except for materials and energy. It encompasses items such as depreciation, labor, maintenance, manufacturing supplies, and overhead costs. The system cost is calculated as follows:

System Cost in the Quantity Centre = Labor Costs in the Quantity Centre + Quantity Centre’s Share of Depreciation + Quantity Centre’s Share of Overhead Costs + Contract Labor Costs + Manufacturing Supplies.

After reviewing the cost records in the factory, the share of each quantity centre in system costs has been determined, as shown in Table 3.

Table 3. The system cost at Rasan Steel factory for the "Interno" project (in dollars) for the last quarter

cost components	Costs in quantity centres / $		Total / $
	manufacturing	Assembly	
Wages (share per centres)	16400	-	16400
Depreciation (share per centres)	2750	-	2750
Share of Overhead (share per centres)	10300	-	10300
Labor (contractor)	8486	11169	19655
Manufacturing Supplies	15978	-	15978
Total	53914	11169	65083

Source: Prepared by the researchers based on data from the factory.

Table 3. shows that there are several types of system costs at the "Rasan Steel" factory for the "Interno" project, which were based on the data from the accounting department of the factory. The total system cost for the "Interno" project was $65,083. The system cost for the Manufacturing Quantity Centre was $53,914, which consists of the following components: Labor Costs: $16,400 - This includes the salaries of the employees in the factory. Depreciation of Machinery and Equipment: $2,750. Overhead Costs: $10,300 - These are administrative and general expenses. Labor Charges: $8,486 - These are costs associated with some tasks carried out by external contractors. Manufacturing Supplies: $15,978. On the other hand, the system cost for the Assembly Quantity Centre was $11,169. This cost covers the expenses related to the installation of columns and sandwich panel layers by external contractors.

cost of waste management: The cost of waste management is determined at this stage for each quantity centre. Waste, emissions, and losses occur during the cutting of raw materials. Raw materials enter the manufacturing process with specific and fixed measurements. After entering the manufacturing process, they are cut and shaped according to the required measurements. Small pieces that are not suitable for manufacturing are separated and disposed of. Energy waste may occur due to the decreased efficiency of industrial operations. Table 4. illustrates the cost of waste management at the "Rasan Steel" factory for each of the quantity centres.

Table 4. The cost of managing losses at the "Rasan Steel" factory for the "Interno" project (last quarter).

quantity centres	Wastage quantity	cost of waste management/ $
manufacturing	0.40138 T	750
Assembly	34 M	500
Total		1250

Source: Prepared by the researchers based on data from the factory.

The table 4. shows that there are costs associated with managing losses for each quantity centre, which are the costs of loading and transporting damaged materials. The total quantity of losses in the manufacturing quantity centre was 0.40138 tons, as shown in Figure 5., which consisted of the following: (IP profile 0.192535984 tons, L profile 0.0007836485 tons, rod 0.0049595286 tons, Plate 0.0175385176 tons, SHS 0.007299739 tons, and channel 0.1782625789 tons), and the cost of loading and transporting them was $750. Meanwhile, the quantity of losses in the assembly quantity centre was 34m² of sandwich panel material, as shown in Figure 5., and the cost of loading and transporting it was $500.

The second step is to allocate the costs of quantity centres to good products and losses using the following principles:

For the materials and energy component: Allocate the cost of materials and energy between good products and loss based on volume/mass ratio between them. For system costs: Allocate the system costs between good products and losses using appropriate principles. (0.45%) is allocated to losses in the manufacturing quantity centre, based on interviews with the manufacturing department and factory management and by dividing the total quantity of losses by the total quantity of incoming materials to the centre (0.40138 /89.73638 = 0.45%) as shown in Figure5. Meanwhile, (1%) is allocated to losses in the assembly quantity centre (34/3400 = 1%) as shown in Figure 5. For the costs of loss management: They are allocated directly to loss.

In order to complete the financial measurement process for the overall manufacturing system and its flow, the above steps must be implemented for each quantity centre, and a cost flow model is created to allocate costs to good products and losses, as shown in Tables 5. and 6.:

Tables 5. Allocating costs to good products and losses for the manufacturing quantity centre at "Rasan Steel" factory in the "Interno" project (last quarter).

input			Output			
cost components	Quantity	Cost / $	good products		Waste loss	
			Quantity	Cost / $	Quantity	Cost / $
Material	89.73638 T	92469	89.335 T	92055.397	0.40138 T	413.603
Energy	-	2912.84	-	2899.7315	-	13.1085
System	-	53914	-	53671.387	-	242.613
Waste management	-	750	-	-	-	750
Total	-	150045.84	-	148626.5155	-	1419.3245

Source: prepared by the researchers based on Tables 1., 2., 3., 4., and Figure 5.

Table 5. illustrates how costs are allocated to good products and losses for the manufacturing quantity centre at the "Rasan Steel" factory in the "Interno" project. The cost of raw materials entering the centre, amounting to $92,469 and a quantity of 89.73638 tons as shown in Table 1. and Figure 5., is allocated to the good product at a cost of ($89.335 / 89.73638 * $92,469 = $92,055.397) and to the loss at a cost of ($0.40138 / 89.73638 * $92,469 = $413.603). The cost of energy, which is $2,912.84 as shown in Table 2., is allocated to the loss as follows: Electricity (84.87 kW * $0.098 = $8.3173), Gas (0.1215 BTU * $29.697 = $3.6089), and Fuels and Oils (2.0385 litters * $0.58 = $1.1823), totalling $13.1085. The cost allocated to the good product is ($2,912.84 - $13.1085 = $2,899.7315). Similarly, the system costs of $53,914 are allocated to the loss at a cost of ($53,914 * 0.45% = $242.613) and to the good product at a cost of ($53,914 - $242.613 = $53,671.387). The cost of managing losses, which is $750, is allocated directly to the loss. Thus, the cost of a good product in the manufacturing quantity centre is ($92,055.397 + $2,899.7315 + $53,671.387 = $148,626.5155), and the cost of losses is ($413.603 + $13.1085 + $242.613 + $750 = $1,419.3245).

Tables 6. Allocating costs to good products and losses for the assembly quantity centre at "Rasan Steel" factory in the "Interno" project (last quarter).

input			Output			
cost components	Quantity	Cost / $	good products		Waste loss	
			Quantity	Cost / $	Quantity	Cost / $
Materials received	89.335 T	148626.5155	89.335 T	148626.5155	-	-
New material	3400 M	47600	3366 M	47124	34 M	476
Energy	-	-	-	-	-	-
System	-	11169	-	11057.31	-	111.69
Waste management	-	500	-	-	-	500
Total	-	207900.307	-	206812.617	-	1087.69

Source: prepared by the researchers based on Tables 1., 2., 3., 4., 5. and Figure 5.

Table 6. illustrates the materials received from the manufacturing quantity centre and how costs are allocated to good products and losses for the assembly quantity centre at the "Rasan Steel" factory in the "Interno" project. The quantity of materials received (good product) from the manufacturing quantity centre was 89.335 tons at a cost of $148,626.5155. The cost of new raw materials entering the centre, which amounted to $47,600 and a quantity of 3400 square meters, as shown in Table 1. and Figure 5., is allocated to the good product at a cost of ($3366 / 3400 * $47,600 = $47,124) and to the loss at a cost of ($34 / 3400 * $47,600 = $476). There are no energy costs in this centre. The system costs of $11,169 are allocated to the loss at a cost of ($11,169 * 1% = $111.69) and to the good product at a cost of ($11,169 - $111.69 = $11,057.31). The cost of managing losses, which is $500, is allocated directly to the loss. Thus, the cost of a good product in the assembly quantity centre is ($148,626.5155 + $47,124 + $11,057.31 = $206,812.617), and the cost of losses is ($476 + $111.69 + $500 = $1,087.69).

The tables above demonstrate that the cost of inputs and outputs for each quantity centre has been determined based on their specific physical units. The total cost for each quantity centre has been calculated, taking into account the variations between quantity centres.

Furthermore, the tables provide precise cost allocation for good products and losses based on the resources used in each quantity centre. They achieve a high level of transparency regarding material and energy flows and the associated costs, highlighting areas of inefficiency at the individual quantity centre level, which serve as the basis for performance improvement. They also identify the centres responsible for incurring loss.

8- Data summarization and interpretation of input results:

In this step, the first action is to summarize the data by preparing a cost flow matrix model, which aggregates the costs of both the good product and the losses in all processes and quantity centres. Table 7. illustrates the cost matrix for steel structures at the "Rasan Steel" factory:

Table 7. The cost flow matrix at the "Rasan Steel" factory for the "Interno" project (last quarter).

	quantity centre: manufacturing					
		Material cost/ $	Energy cost/ $	System cost/ $	Waste management cost/ $	Total/ $
input	from a previous quantitative centre	-	-	-	-	-
	New input	92469	2912.84	53914	750	150045.84
(1)Total cost		92469	2912.84	53914	750	150045.84
output	Good product	92055.397	2899.7315	53671.387	-	148626.5155
	Inventory change	-	-	-	-	-
	Waste loss	413.603	13.1085	242.613	750	1419.3245
Total	Good product cost	92055.397	2899.7315	53671.387	-	148626.5155
	Inventory change cost	-	-	-	-	-
	(2)Total Waste loss	413.603	13.1085	242.613	750	1419.3245
	(3)Total cost in quantity centre	92469	2912.84	53914	750	150045.84
quantity centre: Assembly						
input	from a previous quantitative centre	92055.397	2899.7315	53671.387	-	148626.5155
	New input	47600	-	11169	500	59269
(1)Total cost		139655.397	2899.7315	64840.387	500	207895.5155
output	Good product	139179.397	2899.7315	64728.697	-	206807.8255
	Inventory change	-	-	-	-	-
	Waste loss	476	-	111.69	500	1087.69
total	Good product cost	139179.397	2899.7315	64728.697	-	206807.8255
	Inventory change cost	-	-	-	-	--
	(2)Total Waste loss	889.603	13.1085	354.303	1250	2507.0145
	(3)project Total cost	140069	2912.84	65083	1250	209314.84

(1) Total Cost = Previous Quantity Centre Cost + New Inputs

(2) Total Losses = Losses in the Current Quantity Centre + Total Losses in Previous Quantity Centres

(3) Total Costs in the Quantity Centre = Cost of Good Products + Inventory Change Cost + Total Losses

Source: prepared by the researchers based on Tables 1., 2., 3., 4., 5.,6. and Figure5.

Table 7. shows the total manufacturing costs for the "Interno" project, including costs of raw materials, energy, manufacturing-specific system costs, and loss management costs, along with the new inputs at each stage, the accumulated material amounts at each stage, and the materials entering manufacturing and lost resources at each stage. According to the material flow cost accounting input, the total manufacturing costs for the "Interno" project amount to $209,314.84. These costs are distributed between the good product with a cost of $206,807.8255 and losses with a cost of $2,507.0145. This means that losses represent approximately 1.19% of the total manufacturing costs. Analysing the losses, they consist of material losses costing $889.603, energy losses costing $13.1085, system cost losses costing $354.303, while the cost of managing these losses was $1,250. The analysis reveals that losses in the manufacturing quantity centre amounted to $1,419.3245, representing 56.61% of the total losses, and $1,087.69 in the assembly quantity centre, representing 43.39% of the total losses.

Through the analysis of measurement results, it's possible to compare the manufacturing cost under the current cost system of the factory with the manufacturing cost under the material flow cost accounting. According to the current cost system of the factory, the cost of manufacturing steel structures for the "Interno" project was $209,314.84. However, the accurate cost of the steel structures is $206,874.047 according to the material flow cost accounting. This difference is a direct result of isolating and not allocating loss costs to the steel structures.

9- Communicating the Input Results:

After analysing the results of the material flow cost accounting and indicators of the processing chain, the findings are conveyed to the factory management for appropriate actions to be taken.

10- Identifying and Evaluating Improvement Opportunities:

In this stage, possible opportunities for reducing losses and waste are discussed, identified, and evaluated. These opportunities can lead to cost reduction. Effective plans are created for engaging and negotiating with suppliers to achieve this goal. Additionally, negotiations aim to reduce lead times, and proposals for improvement actions are made. For example, "Rasan Steel" factory can address a portion of its loss by implementing improvements in its machinery and by negotiating with suppliers to reduce lead times.

5. Conclusion and Recommendations

5.1 Conclusion

In an era where traditional cost accounting systems are considered inadequate in providing timely financial and non-financial information about costs and losses throughout the product lifecycle, there is a growing need for modern approaches in managerial accounting to keep up with the developments in the modern manufacturing environment, characterized by intense competition. One such modern approach is the introduction of Material Flow Cost Accounting (MFCA), especially after the adoption of the international standard ISO 14051, which standardized terminology and knowledge related to MFCA, and ISO 14052, which clarified its implementation procedures within various supply chains.

A recent trend in cost measurement methods aims to achieve a balance between financial and non-financial information by focusing on quantitative and material flow-related data. The use of MFCA in measuring and managing material flow provides a clear foundation for companies, offering the necessary data and information to support decision-making. It helps identify corrective actions for material flow and suggests measures that can enhance production efficiency and reduce losses, especially in materials and energy consumption. MFCA provides valuable insights into areas of waste and inefficiency, particularly in materials and energy usage, and allocates the costs accurately. The value of information derived from MFCA fundamentally lies in the philosophical differences between this approach and traditional cost accounting methods. MFCA introduces a new concept of cost allocation, distinguishing between costs associated with good products and those associated with non-conforming products, which are considered losses or waste in the production process. This sets it apart from traditional methods that often treat the cost of losses as hidden within the cost of the final product or as overhead expenses.

The application of MFCA within the production process aids in enhancing the competitiveness of industrial companies by reducing the percentage of non-conforming products (losses) and, consequently, reducing costs for the conforming products. It accurately determines the costs of good products and the costs associated with non-conforming products, which are losses. For example, in the case of the "Interno" project at the "Rasan Steel" factory, the cost of good steel structures was $206,807.83, while the cost of losses (non-conforming products) was $2,507.01, representing 1.19% of the total manufacturing cost.

Furthermore, the analysis identifies the specific areas within the production process that contribute to these losses. In the "Rasan Steel" factory, it was found that 56.61% of the losses were in the manufacturing stage, amounting to $1,419.32, and 43.39% were in the assembly stage, amounting to $1,087.69. This information allows for targeted improvement measures to reduce losses, such as enhancing the efficiency of machinery, replacing old equipment with modern alternatives, reducing manual processes, and adopting modern welding techniques.

In conclusion, the implementation of Material Flow Cost Accounting in the supply chain helps enhance a company's competitive capabilities by reducing losses, thus decreasing costs for conforming products. It also provides valuable insights into the sources of losses and inefficiencies, allowing for corrective actions to be taken. Despite its global importance, the knowledge of MFCA remains limited and underutilized in the Kurdistan region, highlighting the need for its wider adoption in the modern manufacturing environment.

5.2 Recommendations

Based on the conclusions reached by the researchers in both the theoretical and practical aspects of the study, they propose several recommendations that can be beneficial for industrial companies in the Kurdistan region and specifically for the sampled study factory. These recommendations include:

Promoting the Concepts of Material Flow Cost Accounting (MFCA): It is essential to disseminate the concepts of MFCA within local industrial companies, including the sampled factory, to help them compete effectively in the market. Training and awareness programs should be conducted to educate management and staff about the benefits of MFCA and how it can improve cost management and reduce losses.

Identifying Costs of Good Products and Losses for Each Process: Companies, including the sampled factory, should implement MFCA to accurately determine the costs associated with good products and losses for each process. This involves distinguishing between costs related to conforming products and those associated with non-conforming products or losses. By doing so, companies can have a more precise understanding of their cost structure.

Not Allocating Loss Costs to Final Products: A fundamental principle of MFCA is to avoid allocating the costs of losses (non-conforming products) to the final product or considering them as overhead expenses. Companies should adopt this approach to accurately assess the costs of their good products and identify areas where losses occur.

Identifying Specific Locations and Centres Contributing to Losses: By implementing MFCA, companies, including the sampled factory, should identify the specific locations and centres within their processes that contribute to losses. This data will enable them to target improvements more effectively. Understanding where losses occur is the first step in finding solutions to reduce or eliminate them.

Implementing Economically Viable Solutions: Once areas contributing to losses are identified, companies should work on finding economically viable solutions to reduce these losses. This may involve process optimization, upgrading equipment, adopting modern techniques, and improving workflow efficiency. These solutions should be implemented with a focus on cost-effectiveness.

In summary, the researchers recommend the adoption of Material Flow Cost Accounting (MFCA) in industrial companies in the Kurdistan region, including the sampled factory, to enhance cost management, reduce losses, and improve competitiveness. This includes accurately identifying costs associated with good and non-conforming products, avoiding the allocation of loss costs to final products, pinpointing locations and centres contributing to losses, and implementing cost-effective solutions to mitigate these losses. These recommendations can lead to more efficient and competitive industrial operations.

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