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MATERIAL FLOW COST ACCOUNTING AS WASTE REDUCTION METHOD: APPLICATION IN A STEEL PIPE PRODUCING COMPANY

Yüksek Lisans Tezi

ŞULE BAYKARA

İstanbul, 2020

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İstanbul, 2020

BEYAN

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Learning is not attained by chance, it must be sought for with ardor and attended to with diligence…

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GENERAL KNOWLEDGE

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ABSTRACT

MATERIAL FLOW COST ACCOUNTING AS WASTE REDUCTION METHOD: APPLICATION IN A STEEL PIPE PRODUCING COMPANY

In recent years, businesses have started to pay more attention on environmental issues due to stakeholder pressures and especially public regulations. Therefore, businesses have to consider their environmental performance as well as their financial performance. Global competition is measured by environmental efficiency as well as profitability. This situation not only brings up the issue of reducing the negative effects of businesses on the environment, but also combating waste caused by production processes. These issues that

need to be studied for businesses have revealed topics such as environmental accounting and material flow cost accounting.

Material flow cost accounting (MFCA) is an accounting approach in which environmental sensitivities are taken into consideration and the concept of sustainable development stands out. MFCA aims to reduce the negative effects of the business on the environment and increase the efficiency in production. This issue can create a competitive advantage among businesses. The most distinctive feature that distinguishes MFCA from other methods is the determination of material losses both physically and monetarily and presenting them to business management.

In this thesis, material flow cost accounting, as a new method that supports and improves financial and environmental performance, has been examined in terms of its applicability and reduction of waste costs in an enterprise.

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ÖZET

ATIK AZALTMA YÖNTEMİ OLARAK MALZEME AKIŞ MALİYET MUHASEBESİ: ÇELİK BORU ÜRETEN BİR İŞLETMEDE UYGULAMA

Son yıllarda işletmeler, paydaş baskıları ve özellikle kamu düzenlemeleri nedeniyle çevresel konulara daha çok önem vermeye başlamıştır. Bu nedenle işletmeler finansal performanslarının yanında çevresel performanslarını da göz önünde bulundurmak zorundadır. Küresel çapta rekabet, karlılığın yanında çevresel verimlilikle de ölçülmektedir. Bu durum işletmelerin çevreye verdikleri olumsuz etkileri azaltmanın yanında üretim süreçlerinden kaynaklanan israfla mücadele konusunu da gündeme getirmektedir. İşletmeler

için üzerinde çalışılması gereken bu konular çevresel muhasebe ve malzeme akış maliyet muhasebesi gibi konuları ortaya çıkarmıştır.

Malzeme akış maliyet muhasebesi çevresel hassasiyetlerin dikkate alındığı ve sürdürülebilir kalkınma kavramının öne çıktığı bir muhasebe yaklaşımıdır. Malzeme akış maliyet muhasebesi hem işletmenin çevreye olan olumsuz etkilerini azaltmayı hem de üretimde verimliliği amaçlar. Bu konu işletmeler arasında rekabet üstünlüğü yaratabilir. Malzeme akış maliyet muhasebesini diğer yöntemlerden ayıran en belirgin özellik malzeme kayıplarının hem fiziksel hem de parasal olarak belirlenmesi ve işletme yönetimine sunulmasıdır.

Bu tezde, finansal ve çevresel performansı destekleyen ve geliştiren yeni bir yöntem olarak malzeme akış maliyeti muhasebesi örnek seçilen bir işletmede uygulanabilirliği ve atık maliyetlerinin azaltılabilirliği açısından incelenmiştir.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

BS : Balance Sheet

EMA : Environmental Management Accounting

IFAC : International Federation of Accountants

IS : Income Statement

ISO : International Organization for Standardization

KGK : Kamu Gözetim Kurumu

METI : Ministiry of Energy, Technology, and Industry

MFCA : Material Flow Cost Accounting

MOH : Manufacturing Overhead

TBMM : Türkiye Büyük Millet Meclisi

TÜSİAD : Türk Sanayicileri ve İş Adamları Derneği

QC : Quantity Center

INTRODUCTION

Today, businesses, whose main target is profitability, due to the differentiation in competitive factors are obliged to consider the reduction of negative environmental effects from their activities. It is necessary to use scarce resources efficiently, consider the benefit of the society in the use of resources and knowing that is a social task. Sustainable growth for businesses is possible with social sensitivity as well as the goal of profitability.

Environmental damage caused by enterprises' production process and other part of the output called as waste or loss in terms of accounting. These concepts have led to emerge of environmental management accounting and its sub-branch material flow cost accounting.

It is observed that the traditional cost accounting method applied is insufficient in revealing the impact of the business on the environment and in determining the losses that may occur during the production process. In accordance with the social responsibility principle of accounting, the lack of the traditional cost accounting method in fulfilling its environmental obligations has inspired the emergence of environmental management accounting.

Environmental management accounting is based on presenting the effects of resource usage to business management. These data enable the business to know the environmental effects. The subject of environmental protection requires the losses that may occur in the production process of the enterprises to be taken into consideration. This issue, which is extremely sensitive for stakeholders, has also increased the social responsibility awareness of businesses. The concept of contemporary business management has become a concept that businesses need to develop and formulate on environmental awareness. Considering this, the concept of material flow cost accounting has emerged.

MFCA, with its sustainable business management approach, is an approach in which the factors that cause material loss in the production process are identified and improved as well as the negative effects of the businesses on the environment.

In the first chapter, the traditional cost accounting and its importance, objectives and concepts for businesses are mentioned. In the second chapter, environmental management accounting concept, historical development, usage areas and benefits, which is an auxiliary branch of cost accounting are presented. In the third chapter, the definition and concept of MFCA, some studies in the literature, its emergence, its elements, its relationship with EMA and its implementation processes are explained. In the fourth chapter, the hypothesis was tested with the data obtained from the selected business and the results were analyzed.

CHAPTER I

COST ACCOUNTING

1.1. Concept of Cost Accounting

It has seen that there are similar definitions in literature related to cost accounting. Cost accounting is an account recording system that allows the cost of the goods or services to be determined and monitored in terms of the places where they occur and the types of products or services which they are related (Türker & Akesen, 2008).

In another definition, cost accounting is a calculation and recording system that computes and monitors the total and unit costs of the products (Ayboğa, 2003). In addition, cost accounting data is used to calculate the unit costs and to determine the selling price of the manufactured products. Managers use cost accounting data in many important decisions such as preparing budgets, determining profits, and sales policies.

Concept of cost accounting can be listed in four items (Civelek & Özkan, 2011).

- Cost accounting is applied in production enterprises that produce goods and services.
- Cost accounting concentrates on economic events in relation to production costs in particular.
- Cost accounting mainly deals with the recognition, summarizing and reporting of costs.
- Cost accounting especially assists managers in making business decisions.

Cost accounting aims to identify, measure, report and analyze various elements of direct and indirect costs of products and services produced and sold in enterprises (Hacırüstemoğlu & Şakrak, 2002).

Cost accounting, according to Vanderbeck's definition (2012), provides detailed cost information that business managers need to control the costs of outputs from their operations in production operations and plan the future.

Business managers use this information to decide how to direct businesses to their most productive and profitable areas. The information obtained from cost accounting improves the planning process by comparing the past cost, which is the basis for the future production operations of the enterprise. With the planning process, management can estimate future costs and production results, and analyze data on additional investment decisions and whether any changes in marketing strategies will be needed.

In summary, cost accounting is expressed as an inward-looking type of accounting and the data required by the decisions regarding the production function in the enterprises are provided by cost accounting.

1.2. Importance of Cost Accounting for Enterprises

One of the factor that plays an important role in determining the profitability of businesses is calculation of unit costs. The main goal of cost accounting is to help the decision makers by calculating the unit costs of the products and services produced according to the method and documentation scheme chosen by the business managers in accordance with the structure of the enterprise. In order to realize these objectives, cost systems are formed by using different cost methods. Factors such as technology, production structure, organizational structure and quality of information needed by managers are decisive in the creation of these systems (Kaygusuz, 2006).

In other words, Büyükmirza (2008, p. 44) emphasizes the importance of cost accounting for businesses; that all managerial decisions of the companies from planning to auditing should be acted in accordance with cost benefit analyzes and cost accounting is the data provider for these analyzes.

In addition, cost accounting is a system in which all the expenses incurred for determining the costs of products or services in businesses are gathered. Thus, it plays a major role in determining the price for businesses.

1.3. Purposes of Cost Accounting for Enterprises

The existence of cost accounting is aimed at achieving some of purposes in a business as a field of activity.

The purposes of cost accounting can be collected under four titles (Şener, 2008):

- Determining the unit cost of products or services,
- Helping expense control,
- Assist business managers in planning,
- Assist decision makers (internally).

1.3.1. Determining Unit Costs of Products or Services

Determining the unit costs of the produced products or services enables the enterprises to see their expenses in an integrated way. The main task of cost accounting is to ensure that the unit costs of the goods or services produced by the entity are determined as accurately as possible (Erol, 2008). In enterprises, unit cost is calculated by dividing the total cost of products produced in a given period by the total number of products produced (Ertuna, 1982).

Determination of unit costs is necessity for the following reasons:

- Preparation of Financial Statements: As it is known, finished and semi-finished products are important items of the balance sheet (BS) in a manufacturing enterprise. Similarly, the cost of goods sold is an important item of the income statement (IS). In order to form the BS and IS of the manufacturing firms, the unit costs of the manufactured and semi-finished products must be known. Service businesses should determine the cost of services given. In summary, the BS and IS which is the main

output of financial accounting, requires the calculation of unit or total costs of the product or service produced.

- Setting Price: In order to establish a cost-price relationship, unit costs must be known by the enterprise. On the other hand, to achieve the profit maximization that firms aim, they have to monitor the profit / loss situation in detail at certain points of production processes (Türker & Akesen, 2008).
- Valuation of Inventories: In the valuation of inventories, the costs of goods and services produced using various techniques must be calculated and reported within the scope of cost accounting.

If business managers want to affect costs, they need to understand the relationship between the volume and mix of the products they produce and the expenses they are exposed to. Production costs are like a bridge between output and operating costs. If inadequately designed production cost systems produce inaccurate production costs, enterprises may take inadequate decisions about resource procurement, product mix, pricing, order acceptance and customer relationships.

1.3.2. Helping Expense Control

As a result of the development of competition in the market, another goal of cost accounting is to increase profit by decreasing expenses. By comparing the actual and standard expenses incurred during the operation process, the expense status of the enterprise and its development can be kept under constant supervision (Akesen, 1989).

Cost accounting raises awareness of business managers about expenses. Monitoring of the expenses by the cost centers reveals which cost centers are operating efficiently. The benefits of expense control are summarized as follows:

- Expenses are allocated as wide as possible in terms of their types. For this reason, it can be easily determined which expenses are decreased or increased over time and precautions can be taken accordingly.

- Expenses can be monitored and controlled not only in terms of type but also in the places where they are incurred. The aim is to determine which costs are higher in a cost center at a certain period of time.

1.3.3. Helping Managers in Planning

The main purpose of the planning department in enterprises is to determine a general program by considering the type and amount of sales expected in the future periods and to coordinate the budgets and programs to be prepared within the framework of this program (Bursal & Ercan, 1992). Cost accounting provides information required for future planning in enterprises. Planning is to make forward-looking forecasts. Plans indicate the future activities of the enterprise, the expenses they will require, the values to be generated because of these activities, the products to be sold and the income to be obtained (Saban & Erdoğan, 2010). The ability of plans to give accurate results depends on the cost accounting which provides accurate information as well.

Expense budgets are short term plans. Deviations are determined by making comparison with the budgets and actual costs (Uslu, 1991). Expense control and planning are two tasks that always work together. Therefore, cost accounting should be an information provider for that cycle.

1.3.4. Helping Decision Makers

Businesses often face non-routine situations. Capacity building, machine renovation, production of an existing product decisions such as interruption of production, modification of the existing production process, and the start of the production of a new product are included in this scope. Making such decisions often requires a choice from many alternatives. Taking such non-routine decisions, referred to as special-purpose decisions, requires reliable cost accounting information (Karakaya, 2014).

Business managers use different systems to generate accurate cost information. These systems are designed to provide help in making decisions. Some of these decisions may include making a new product, making changes to the production system, and making special decisions for investments such as machinery or buildings. Especially in renewal and expansion investments, it compares the profitability of old and new investments and provides cost data. The correct decision making of the decision makers depend on detailed cost information.

1.4. Cost, Expense, Expenditure, and Loss Concepts in Cost Accounting

In this section, the basic terms of cost accounting, cost, expense and expenditure concepts are explained briefly.

1.4.1. Concept of Cost

In order to talk about the concept of cost for businesses, two basic conditions must be met (Bursal & Ercan , 2002):

- In order for an expenditure to enter the production cost, this should be done in order to obtain the product or service that constitutes the subject of activity of that business,
- Spending has a value that can be measured in money.

Cost information can be used both inside and outside the enterprise. Internally, cost is mostly used to determine the sales price, to determine the results of the business activities and to make various business decisions. Externally, costs are used in comparisons between businesses, in control, in providing information to official and professional organizations.

1.4.2. Concept of Expense

Concept of expense for an enterprise is the decrease in the assets or the increase in the liabilities of the entity as a result of the delivery of goods, production, service or other

operations related to the main business subject in a certain period. In order to be able to talk about the expense, the costs that are expired have to be related to the operation of the business and the existence of the asset. Resource expenditures not related to operating activities and maintenance of assets are not considered as expenses. Decrease in assets or increase in liabilities must be incurred for operating activities to be considered as expense. The money spent by the owner or owners for personal expenses cannot be classified as expense. An expenditure or a consumption of products or services must provide financial benefits to the entity and contribute directly or indirectly to the entity's purpose (Akdoğan, 2004).

In summary, the concept of expense is the monetary equivalent of goods and services consumed by periods to ensure the continuity of businesses.

1.4.3. Concept of Expenditure

The concept of expenditure refers to payments made by money or similar payment instruments for any reason other than the production of goods or services of businesses (Altuğ, 1989).

Although the concepts of expenditure and expense are intertwined, they are considered different in terms of accounting system. According to Akdoğan (2004), in order for the expenditure to turn into expense, it must be made for the continuation of business activities.

1.4.4. Concept of Loss

The concept of loss for the enterprise is the use of unnecessary or inefficient resources that occurs during the performance of its activities. In other words, it refers to wasted consumption. At this stage, the function of cost accounting refers to the identification and recording of the losses that may occur in production or service businesses (Karakay, 2014).

1.5. Classification of Costs in Cost Accounting

Costs can be classified in many ways. It is important to classify costs so that businesses can calculate their costs quickly and easily, maintain effective control, and meet management requirements in terms of planning and decision making. The classification of costs can be made as follows.

1.5.1 Direct Raw Material Costs

Direct costs are the costs that can be charged directly to the production cost of a product or service without using any distribution key.

During the production process, all raw materials that can be directly and physically related to the products are direct raw materials. Direct raw materials cover expenses for obtaining all raw materials (Horngren, Foster, & Datar, 1999).

Unlike direct materials, indirect materials are not directly linked with products produced. Indirect materials have one of these two features:

- They do not physically become part of the product or
- They are not suitable for direct distribution to products. For these reasons, enterprises reflect indirect materials as part of their overheads.

1.5.2. Direct Labor Cost

Labor is the physical effort spent in the production of a product. The sum of all payments made to employees in return for such physical efforts constitutes labor costs. After the raw materials are processed through the production process, the labor of the employees who are physically and directly related to the process of converting raw materials into finished products is called as direct labor (Weygandt, Kimmel, & Kieso, 2012).

The labor related to the production other than the direct labor expenses is expressed as indirect labor cost and reported within the manufacturing overhead costs (Walter & Skousen, 2009).

1.5.3. Manufacturing Overhead Cost

Overheads are the third component of the production costs that are indirectly related. Overheads include production costs that cannot be defined as direct raw materials and direct labor (Garrison & Noreen, 2000). These costs are indirect materials, indirect labor and factory repair, insurance, maintenance, utility programs, and property taxes.

Overheads are costs that cannot be directly linked to products or services (Walter & Skousen, 2009). So, general production costs can be defined as the sum of indirect raw materials, indirect labor and other costs related to production.

Overhead costs are the total costs of the indirect production costs, cost objects, and finished unit and process. However, it is not possible to reveal these objects in an economic way. That is, the cost of each object is not clearly certain to participate in the product (Anderson , 1995).

1.6. Basic Cost Systems in Cost Accounting

There have been major changes in all stages of production processes in recent years. Automatic and robotic systems, which are among the new production technologies, have been the most important technological development affecting cost and management accounting. With a significant transition from labor intensive production to capital intensive production, new production environments use production systems where research and development are maximum. One of the effects of this change is the change in cost factors. When traditional production is evaluated, there are changes in the cost elements that form the unit cost, namely the product cost structure. In this context, cost systems are divided into two as traditional and modern.

1.6.1. Traditional Cost Accounting Systems

Cost determination and calculation techniques of traditional cost accounting approach have long been used as basic instruments for product development, planning and cost management in both production and service sectors. Considering the change that cost accounting has undergone so far, it is necessary to underline that the requirements of businesses to affect their own cost status are increasingly important in their value creation processes. Measurement of product and service costs is done depending on the cost system adopted by the company.

The traditional cost system acts with the assumption that the products consume all resources in proportion to the production amounts. Cost systems used by manufacturing companies are mostly in the form of traditional cost systems. Traditionally, while costing products, it is based on three basic cost items, namely direct labor cost, direct raw material cost and manufacturing overheads (Akdoğan, 2004).

However, since traditional approaches are only based on using past period data or current period estimates, the impact of enterprises on their research and development capabilities is limited. Erol and Atmaca (2006), stated in their study that traditional cost system is insufficient in providing accurate and sufficient cost information because of developments in technological and economic environment.

1.6.2. Modern Cost Accounting Systems

Technology-based change in production processes has significantly reduced the importance of traditional cost accounting approaches, and interest in new (modern) cost accounting approaches has increased day by day. This paradigm shift in cost accounting led to the conclusion that long-term planning is required in costing systems and businesses should have a cost system to allocate more resources to research and development. New cost accounting approaches differ from traditional cost and management accounting.

While traditional cost accounting focuses on the activity steps by adopting only the internal approach to costs, in modern cost management, the center of interest is the impact of the operational external environment on cost processes. In other words, while traditional cost accounting expresses an understanding of the business; modern cost accounting emphasizes the importance of external factors and the external environment. The main benefit of the new cost accounting approaches is that costs can be reduced by determining which activities composes the costs and which measures should be taken. On the other hand, since new approaches in cost accounting include not only cost, but also organizational goals as a whole, it helps business management to make its decisions on a more scientific and rational basis (Uyar, 2018).

As a result of modern cost accounting systems, the concept of environmental management accounting has been brought to the agenda. In the second part, environmental management accounting, which is a new subject in management and cost accounting, will be discussed.

CHAPTER II

ENVIRONMENTAL MANAGEMENT ACCOUNTING (EMA)

2.1. Concept of Environmental Management Accounting

When the literature is examined, there is not a single generally accepted definition of environmental management accounting. However, improving environmental management and economic performance through the use and development of environmental related accounting techniques is one of the best definition (IFAC, 2005).

Environmental management accounting, which can also be called green accounting or natural resource accounting, is expressed as the use of environmental resources and accounting of the effects that will result from the use of these resources (Gautam, 1997).

In another definition, environmental management accounting is defined as accounting for environmental events and showing them in financial statements (Aslan, 1995).

TÜSİAD (2005, p. 25) stated environmental management accounting with a broad definition as follows: It is a method used to classify the activities of an enterprise as environmentally, to record and monitor these changes, to reveal the monetary and physical dimensions of all these changes, and to determine the real profitability of the enterprise by transferring these studies to the business balance sheet.

The United Nations reached a consensus with a working group representing more than thirty countries and defined EMA as follows. The conceptual framework of EMA concerns the definition, evaluation and use of two types of information in the internal decisions of the business. The first is the use of energy, water and materials of the enterprise and physical information in this process; the second one is the monetary information

regarding environmental costs, earnings and savings arising from their activities (United Nations, 2001).

In the light of all these definitions, it has become necessary to take into account the financial aspects of the financial changes of the enterprises as well as their environmental aspects. In other words, following both financial and non-financial changes is a continuous issue for businesses.

2.2. Reasons for the Emergence of Environmental Management Accounting

Industrialization and economic growth in developed and developing countries brought environmental problems along such as global warming, increase in air and water pollution rate, decrease in forests, chemical and radioactive wastes. (Xiaomei, 2004, p. 48). This situation caused pressure from the external parties on the enterprise. As a result of operational activities, the need to measure and report the adverse effects on the environment has arisen. Therefore, a consensus has been reached that traditional cost accounting is insufficient to provide the information needed in decisions to be taken in order to fulfill the environmental management responsibilities of the enterprise (Jasch, 2006, p. 1190). It has been understood that these deficiencies can be eliminated by developing environmental management accounting as a strategic element of business management (Masanet-Llodra, 2006, p. 393).

Lazol et al. (2008, p. 62) stated that environmental problems arising as a result of economic and technological developments have led to the development of a number of techniques to solve these issues and the inclusion of environmental issues in the accounting system in accordance with the social responsibility principle of accounting. The concept of environmental accounting has emerged as a result of this interaction between the business and its environment.

A study by the International Federation of Accountants emphasized one of the reasons for the emergence of environmental management accounting is the costs of

environmental impacts resulting from business operations and these costs are an important part of organizational decision-making processes (International Federation of Accountants, 2005, pp. 18-19), (Gale, 2006, p. 1230).

Burritt et al. stated that the main task of cost accounting is to provide the information to business executives they will need in decisions about the financial performance of the business, while environmental management accounting is an accounting system that classifies, measures and reports the environmental impact of the business in the production process (Burritt, et al., 2002, p. 40; Burritt & Saka, 2006, p . 1263).

Another reason for the emergence of EMA is that it is a necessary method to analyze the issues such as the amount of raw material usage, energy flow and environmental cost information as a tool to help other financial information in order to make routine and environmental decisions within an enterprise (Memiş, 2009).

It can be stated that environmental management accounting emerged in order to help cost accounting and other accounting branches based on the definitions above.

2.3. Historical Development of Environmental Management Accounting

The emergence of environmental management accounting is based on the search for a solution on environmental problems with the effect of industrialization and to reduce these problems. In other words, the inability of the enterprises to remain indifferent to the problems of the environment in which they interact, caused the emergence of environmental accounting.

The first studies on environmental accounting in the world started in the 1960s and it was seen that the basis of these studies was evaluated in terms of social and economic context (Korukoğlu, 2011, p. 81).

Mathews (1996) divided the issues and studies associated with environmental accounting in this direction into three periods:

- First Period 1971 - 1980: In this period, the development of non-financial qualitative measurements came to the fore. Researches usually involve social accounting issues. These topics include empirical research, simple and prescriptive models.
- Second Term 1981 - 1990: In this period, accounting standards on environmental issues have been determined and legal arrangements have been made. Discussions were held on the role of accounting in the transfer of information on environmental activities.
- Third Period 1991 - 1995: In this period, more remarkable developments took place on the conceptual framework of environmental accounting. With the maturation of environmental accounting, environmental information and the start of environmental auditing, it has been observed that businesses include environmental accounting systems in their internal accounting.

In this period, the most obvious development in environmental management accounting was the publication of ISO 14000 Environmental Management Standards and the revised ISO 14001 Environmental Management Standards by the international standards organization (ISO), and these standards bring a new approach to the accounting system (Karacan, 2002, p. 5).

In parallel to all these developments in the world, from the perspective of Turkey to the subject, we see that environmental management accounting confront us as a new concept.

The issue of environmental management accounting in our country was brought to the agenda for the first time at the Ecological Cost Analysis Seminar in Investments held between 21-25 November 1994. In the seminar, environmental damages, environmental pollution costs and environmental policies related to these problems were addressed in line with environmental accounting (Doğan, 1995).

On the other hand, in the process of European Union accession, Turkey Grand National Assembly (TBMM) adopted and implemented European Union Acquis Program as Quarterly and Environmental Accounts (Öztürk, 2018, s. 79).

Moreover, information about the importance of environmental management accounting for Turkish companies and how they should be applied is presented in the publication of Turkish Industrialists and Businessmen Association (TÜSİAD) in 2005 (TÜSİAD, 2005, p. 81).

In addition, a draft was prepared in accordance with financial reporting standards by the Public Oversight, Accounting and Auditing Standards Authority (KGK) on 12/13/2018 in our country and presented to the opinions and suggestions of the public. In this draft plan, 378-Environmental Regulatory Provisions and 478-Environmental Regulatory Provisions are included in order for the companies to monitor the provision amount related to their environmental liabilities (KGK, 2018).

2.4. Purposes of Environmental Management Accounting

As with other accounting branches, the main purpose of environmental management accounting is to provide data to those who will use this information. According to Kaya (2006, p. 44), environmental management accounting has certain purposes for businesses outside of this basic approach. These objectives can be listed as follows:

- Calculating resource inventory,
- Helping to calculate product cost accurately,
- Helping to calculate real profit or loss,
- Facilitating compliance with competition conditions in international markets,
- Helping to improve environmental performance.

Environmental management accounting aims to develop new financial or non-financial accounting information and control systems in order to complete the inadequate aspects of traditional accounting practices, reduce environmental costs, develop evaluation with different performance measurement reports for internal and external stakeholders of enterprises, and obtain more environmental benefits (Özkol, 1998, p. 21).

2.5. Elements of Environmental Management Accounting

Environmental management accounting is an accounting system in which monetary information related to environmental costs and revenues is collected, analyzed and reported. In a sense, it represents a roof concept consisting of wide and different tools that can be used in the management of the information flow in the internal and external environment of the enterprise (Herzig, et. al., 2006, p. 493).

In the light of these definitions, it is possible to say that environmental management accounting consists of two factors: monetary environmental management accounting and physical environmental management accounting (Burritt, et. al., 2002, p. 41; Schaltegger et. al., 2000, p. 14).

2.5.1. Monetary Environmental Management Accounting

Monetary environmental management accounting refers to an approach that emerges by extending the traditional management accounting approach to the interactions between the business and its environment (stakeholders) (Burritt, et.al., 2002, p. 41). In a broader sense, the concept of environmental management accounting is an approach that gathers and analyzes information that is the subject of monetary events and is needed more in internal business decision making.

In terms of business, monetary environmental management accounting emerges as a resource that is not directly presented to the external stakeholders of the business and provides information needed in the management decisions of the business.

According to IFAC (2005), monetary environmental management accounting is concerned with costs arising from the interaction between business activities and the environment, as well as revenues and savings from the same interaction. Environmental income is mainly composed of input by-products, waste and scrap sales, tax exemption, and high profit margin provided by environmentally friendly products.

In other words, monetary environmental management accounting refers to the accounting process of issues such as penalties arising from non-compliance with environmental laws and reduction of environmental damage according to the laws of the country in which the business operates.

2.5.2. Physical Environmental Management Accounting

Environmental management accounting, also known as ecological management accounting in the literature, helps to provide the information needed in internal decisions regarding the physical effects of the business in the environment in which it operates. This information may also be the information required by the public authority under the laws of the country in which the business operates. This information helps complete the shortcomings of traditional management accounting. Accordingly, the characteristics of physical environmental management accounting can be listed as follows (Burritt & Schaltegger, 2000, p. 261):

- It is a tool that can be used to identify environmental strength and weaknesses of businesses.
- It is a technique that can be used to emphasize the environmental quality relatively.
- It is a tool that can be used for direct or indirect control of environmental results arising from the activities of businesses.
- It is a tool that provides impartiality and transparency in communicating with the internal and external stakeholders of the business.
- It is an environmental management accounting tool suitable for promoting and supporting environmentally sustainable growth.

It can be said that the main subject that separates monetary environmental management accounting and physical environmental management accounting from each other is time. Because environmental issues and problems are considered long-term. Monetary issues can be measured in a shorter time, while physical issues (ecological) are longer. According to Burritt et al (2002, pp. 42-43), this topic is classified as follows:

- Monetary or physical environmental management accounting may be past, present or future-proof.
- It can be used for short or long term.
- It can provide information about routine or non-routine events.

In the light of this information, a comprehensive and integrated environmental management accounting is detailed in the table below.

		Environmental Management Accounting (EMA)			
		Monetary EMA		Physical EMA	
		Short-Term	Long-Term	Short-Term	Long-Term
Past Oriented	Routine Info.	Environmental cost accounting	Capital expenditures and revenues as a result of environmental impacts	Material flow cost accounting (evaluation of the effects of material flows on the environment)	Accounting for environmental impacts
	Non-routine Info.	After an unexpected environmental event occurred, the costing decision for this event	Environmental life cycle costing	Evaluation of short-term effects on the environment	Evaluation of environmental investments after they are made
Future Oriented	Routine Info.	Environmental activity and capital budgeting	Long-term environmental planning	Physical environmental regulation (for material flow)	Long-term physical environment planning
	Non-routine Info.	Advanced environmental costing	Evaluation of environmental investment projects and target pricing	Environmental impacts that may occur	Evaluation of physical environment investments and life analysis

Table 1: Framework of EMA *(Schaltegger, Hahn, & Burritt, 2000)*

2.6. Usage Areas and Benefits of Environmental Management Accounting

While some businesses approach environmental management accounting with a simple perspective, they only deal with environmental information of a monetary nature, while others use environmental management accounting techniques that provide both monetary and non-monetary information with a more holistic approach (Setthasakko, 2010, p. 317).

In addition, this information provided by environmental management accounting can be used by businesses not only in environmental management decisions, but also in routine management activities (Staniskis & Stasiskiene, 2006, p. 1252). The main usage areas of information provided from environmental management accounting can be listed as follows (Jasch, 2003, p. 668) (United Nations Division for Sustainable Development, 2001, p. 9):

- Evaluation of environmental expenses and revenues on an annual basis,
- Product pricing,
- Budgeting,
- Evaluation of projects in the investment phase,
- Investigation of environmental protection projects in terms of cost and savings,
- Design and implementation of environmental management system projects,
- Comparison of environmental performance with businesses operating in the same industry,
- Determining numerical targets related to environmental performance,
- Determination of projects for production without disturbing the ecological balance,
- External reporting on sustainable production,
- To ensure the reporting of environmental data to the public authority.

This chapter focuses on issues such as the reasons for the emergence of EMA, its historical development, elements, areas of use and benefits. In the third section, material flow cost accounting will be discussed as an advanced version of EMA.

CHAPTER III

MATERIAL FLOW COST ACCOUNTING (MFCA)

3.1. Concept of Material Flow Cost Accounting

The concept of material flow cost accounting appears as a more advanced type of cost accounting and environmental management accounting systems. When the literature is examined, it is seen that there are similar approaches to the concept of MFCA.

According to Fakoya (2015, p. 1021) and Sygulla et al. (2013, p. 107), MFCA is a management approach that helps businesses better see the environmental and financial results of their raw material and energy use and tries to achieve efficiency in raw material and energy use while application processes.

In another definition of MFCA, it is expressed as the most specific area of environmental management accounting with the approach of companies to focus on material flows, internal costs and standards (Schaltegger & Zvezdov, 2015, p. 1334).

MFCA is a system developed for managing the use of material resources for enterprises, reducing the negative effects on the environment (Rohn, et al., 2011).

MFCA is a method reduces the activities that do not create a value for enterprises and provides process efficiency (Otlu & Demir, 2005, p. 168).

Nakajima (2006) has defined MFCA as a system that enables businesses to reach their economic goals in terms of environmental sustainability approach.

In other words, the MFCA method makes production costs much more visible compared to the traditional costing system (Kokubu & Nakajima, 2004).

3.2. Some Studies in the Literature on the Concept of MFCA

When the literature is examined, it has seen that many articles, books and book chapters are published on MFCA wordwide. Some of these have been done to examine the concepts and history that form the basis of MFCA, while others have been examined through case studies and the application processes of the method. Some of the studies on the concept of MFCA are given below.

In an article published by Nakajima (board member of METI) in Japan (2009), the characteristics and approaches of the three companies that applied MFCA were evaluated. He stated that Nitto Denko, one of these companies, reduced material waste about by 10 percent, while Tanabe Seiyaku reduced carbon waste from 41 percent to 30 percent, while Shimizu Printing reduced waste rates within a certain trend. As a result, he mentioned how companies should use this method and the differences between traditional cost methods and MFCA.

Implementing the MFCA method in a large brewery in Austria, Jasch (2009) stated that traditional costing methods are insufficient to provide information to management on waste quantities. MFCA helped save $ 186,000 in the brewery enterprise by uncovering areas with improvements.

Hyrslova, Vâgner and Palâsek (2011) applied the MFCA method at Lasselsberger, a ceramic tile manufacturer in the Czech Republic, and revealed material, energy and system losses are more than it thought. At the last stage of the application, how the results should be evaluated for the company and the improvements that should be made in the production processes were mentioned.

Lagioia et al. (2013) suggested that MFCA might be a suitable method for integrating monetary and physical data into production processes by reducing wastes in small businesses. With this hypothesis, they examined the production processes of an enterprise that produces a garbage bag in Italy and operates in the plastic industry. They found that this business did not accurately record its environmental impact using traditional accounting

systems. They argued that losses and environmental impacts generated during the production process can be assessed and reported using the MFCA method.

Tachikawa (2014) claimed that MFCA, which is a method of reducing environmental impacts in work efficiency and production, can be applied to all sectors with or without an environmental management system in production or service businesses that use materials and energy of any scale.

In the MFCA application carried out by Fakoya (2015), the amount of waste generated during the production process was reported in the 6-month data set analysis collected from the pilot company. Accordingly, while 9 liters of water are used for each 1 liter of beer production, with the improvements made after application, 7 liters of water has been used per 1 liter.

Schaltegger and Zvezdov (2015) stated in their article that MFCA is not only organizationally oriented, but also a method that promotes the development of the society and that practitioners can evaluate this method in terms of sustainability.

Wan, Ng R.T, Ng D.K. and Tan (2015) presented two case studies using the mathematical method to demonstrate that waste recovery is important under the MFCA method. As a result of the case studies, they explained how hidden costs, carry forward costs, and quality costs affect the results when they are revealed on the production line.

Schmidt, Götze and Sygulla (2015) examined the relationship between the results of MFCA and the investments made by businesses in production lines in the aluminum industry. It is mentioned how the method guides the companies in the long run in monetary terms.

Chompu-inwai, Jaimjit, and Premsuriyanunt (2015) presented in the first part of their analysis in the small and medium-sized wood enterprise which applied MFCA, the 70 % material loss and its causes, and in the second part they offered improvement suggestions to reduce the losses.

Kasemset, Chernsupornchai and Pala-ud (2015) applied MFCA to the production line of a textile factory operating in Thailand and reduced waste material output by 8.51 %. They concluded that MFCA is an important tool for businesses to reduce costs and encourage managers and engineers to improve the process.

Sulong, Sulaiman and Norhayati (2015) mentioned that the MFCA method applied in five companies operating in Malaysia contributes to both economic and environmental sustainability. However, they stated that in order to increase the efficiency of MFCA, the supply chain should also be taken into consideration in production enterprises. In addition, some views restricting the MFCA method are also pointed out in their study.

Nakajima, Kimura and Wagner (2015) prepared a survey based on MFCA and sent it to the purchasing department of 1561 industrial enterprises. According to the survey results, it is concluded that MFCA promotes information sharing and low carbon consumption with the supply chain.

Khaled et al. (2017) in their study, the perception of MFCA in the supply chain was tested with an empirical study by sending questionnaires to randomly selected 1200 industrial companies in Malaysia. 123 of these companies answered the questionnaire and the companies with high environmental performance that decided to implement MFCA showed that supplier integration had a positive effect on MFCA implementation.

Tu and Huang (2019) presented a study listing 32 businesses that implement MFCA on a sector basis, compiling losses and proposed improvements. In this article, they examined the relationship between MFCA and green production. As a result, they stated that there is a complementary relationship between these two issues and they are supportive in financial and environmental issues.

Yagi and Kokubu (2019) analyzed 125 production firms in Japan based on some MFCA related ratios between 2010 and 2015, concluded that the biggest impact on waste growth was due to material use efficiency (raw material to cost ratio).

Huang, Chiu, Chao and Wang (2019) presented a literature review and conducted case analysis on a flat-panel part supplier for the year 2013 in their study. Findings showed that material loss were low, but energy and emission waste were higher. So, company introduced a new investment to reduce carbon emissions and track energy consumptions. For the year 2015 wastes reduced by 25%.

Dekamin and Barmaki (2019) have implemented MFCA in the agricultural sector and examined it for its contribution to environmental sustainability. In this study, made on soy bean product, agricultural wastes and energy consumption are measured. Accordingly, energy consumption decreased 0.25%. Cost analysis based on MFCA has been effective in reducing costs in soybean production.

In the study by May and Guenther (2020), using the scenario and uncertainty analysis, the effectiveness of MFCA in reducing agricultural product wastes was examined and it was observed that there was a 13 % increase in profitability with the optimization of material use.

3.3. The Emergence and Development of MFCA

When the literature is analyzed, it was referred that MFCA emerged as a result of the environmental management projects of Kunert, a textile company in Germany in the early 90s. But, before the concept of MFCA, along with industrialization, the concepts of input-output and material flow were already discussed in the German literature in the 1920s and 30s. In the 1960s, environmental protection issues and measurements has emerged. By the 1980s and 90s, new terms related to environmental protection awareness emerged. At the same time, issues such as environmental management practices, environmental record keeping, environmental reporting and ecological accounting have also been brought to the agenda in terms of corporates. In the light of all these developments, Kunert's report published in 1991 is accepted as the first appearance of MFCA (Wagner, 2015, p. 1255).

Kunert's report based on input-output-mass balance was originally created to develop a resource for the environmental management tool. In this context, Kunert's balance sheet shows the physical input for the waste and emission outputs of the products. In this application, which is inspired by environmental management accounting, the report is divided into two parts as corporate balances and process balances. Corporate balances compared input and output amounts that are physically product or waste. Process balances reported processes related to flow accounting in monetary terms (Wagner, 2015, p. 1256).

Kunert's report helped to start an academic research project headed by Bernd Wagner in University of Augsburg. Based on the report published by Kunert, Wagner made three suggestions (Wagner, 2015, p. 1256):

- Firstly, in order to show not only the input and output differences of the raw materials entering the production process, but also to ensure resource efficiency, it is necessary to examine the material flows between the input and output in more detail and determine the exact locations.
- Secondly, the material flow system should focus not only on department improvements (production department) but also on efficient resource utilization processes. This view argues that losses at the end of production can be prevented by R&D or product development with the measurements to be made at the beginning of the production line process.
- Thirdly, business managers make decisions based on financial data, while production department managers make decisions based on physical information. A tool is needed to integrate these two decision makers in terms of both physical and monetary flow.

While these developments were taking place, between 1994 and 1996, the flow cost accounting approach has been developed in Kunert's production site, which addresses how environmental and cost assessment of material flow should be evaluated (Wagner, 2015, p. 1258). After the project studies in Germany, the concept of flow accounting has begun to be handled by other academicians worldwide. Many books and articles have been published by

developing this approach and added new concepts. Some of these new concepts are waste cost accounting, environmentally cost accounting, and flow accounting.

Following these studies, the material flow cost accounting approach has started to be recognized worldwide. Groups consisting of academic world and company representatives attended a workshop held in Germany in 2000. Professor Katsuhiko Kokubu and Michiyasu Nakajima were among these participants from Japan. The cooperation between Germany and Japan has been supported by the Japanese Ministry of Energy, Trade, and Industry (METI) to adapt this approach in Japan. Nakajima (2004) lists the development MFCA to Japan as follows:

- 1999: EMA is initiated by METI.
- 2000: METI established a new project to introduce first trial of MFCA in Nitto Denko.
- 2001: Cannon, Mitsubishi Tanabe Pharma, Takiron was introduced MFCA with Nitto Denko.
- 2004: METI launched a new project to encourage the use of MFCA in enterprises.

After these developments, Japanese METI issued a booklet (2010) containing the results of the companies that applied MFCA. In this booklet, the performances of companies implementing MFCA in Japan between 2000 and 2010 are examined, the efficiency of the method is mentioned. In addition, it has been stated that there are certain levels of waste reduction in companies that implement this method. It is stated that the method also contributed to production planning for the coming years by offering a loss simulation for companies.

One of the most striking international studies on MFCA has been published by the International Organization for Standardization (ISO). In this study, it was stated that MFCA emerged as a sub-branch of environmental management accounting. MFCA has been defined as an auxiliary tool in determining the wastes that may occur during the production process of businesses and their effects on the environment. MFCA, a system that provides

information flow in the supply chain of enterprises according to ISO, tries to develop an integrated approach to increase the efficiency of material use, energy and environmental resources (ISO, 2011).

3.3. The Relationship Between EMA and MFCA

MFCA, which has emerged as a sub-branch of environmental management accounting, also aims to reduce the environmental impact of businesses and increase efficiency (Özçelik, 2017, p. 928). MFCA completes the shortcomings of EMA, as it examines the points where businesses concentrate in a broad perspective. While EMA does not include the wastes occurring in the production systems of the enterprises in the final product cost, MFCA includes these wastes in the cost of the products. Therefore, MFCA appears as a complementary factor of environmental management accounting.

MFCA is a complementary element of EMA in this sense, as it can demonstrate the monetary value of the benefit from the reduction of waste in the production process (Kokubu & Nakajima, 2004, p. 4).

The common aim of MFCA and EMA is to minimize the environmental impact of businesses on their production processes. However, unlike EMA, MFCA measures these effects in monetary terms. From this perspective, it can be said that MFCA is a more advanced version of EMA.

3.4. Elements of Material Flow Cost Accounting

MFCA helps to protect the environment while reducing costs by waste management in the production processes of enterprises. In order to be implemented MFCA in a business, the following elements need to be considered (ISO, 2011).

3.4.1. Quantity Center (QC)

The QC is used to determine the amount of materials physical and monetary. A QC may contain a single or several processes, depending on the material loss amount detected in

unit production. In general, quantity centers are created where material loss or system costs are determined in all processes. Then, appropriate processes are selected for quantity centers and its input materials and outputs are decided. QCs can be based on current information of product management, cost records and other information which is available within the MFCA limits. QCs are the centers where materials are stored or converted. Once inputs and outputs are determined for every QC, this information can be used to establish relationships among the quantity centers. Thus, QC data are combined and evaluated through the entire system.

3.4.2. Material Balance

In a production system, physical inputs should be equal to the physical outputs in that system, considering any inventory changes. The material that enters a quantity center comes out in the form of product and lost material. Therefore, in order to ensure that all materials are included in the MFCA analysis, the material balance must be compared to outputs and changes in inventory to identify any missing material or other data gaps. In MFCA, to measure material flow, a balance must be established between material inputs and outputs. For each quantity center, input and output quantities should be measured as physical units and converted to a standard unit (ton, liter, meter etc.).

3.4.3. Cost Calculation

It is important to determine the monetary flow within the physical flow in production processes. During decision process, monetary values guide managers. For this reason, material balance of inputs and outputs are linked to monetary terms by distributing costs to all products and material losses through MFCA. In MFCA, four costs types are determined:

- Material Cost: It represents the cost of a good entering the quantity center. The cost of the material is calculated by multiplying the physical amount of material that it enters into the production process by the unit price. The cost of the material is the cost directly charged to the product in MFCA.

- Energy Cost: Energy costs are the cost of electricity, fuel, and heating. These costs are calculated on the basis of measured or estimated energy use for each quantity center and allocated based on the physical amount proportion.
- System Cost: System costs are the costs that arise during the flow of material within the enterprise such as depreciation, labor, maintenance costs. Again, these costs allocated according to physical material flow proportion.
- Waste Management Cost: It is consisted re-processing of rejected products and recycling, air emissions, wastewater, and monitoring, storage, processing or disposal of solid wastes. Waste management costs are only distributed to material losses.

3.4.4. Material Flow Model

The material flow model is the fourth element that forms the boundaries of the flow system by combining the three elements listed above. The flow model is designed to see deficiencies in the production system and waste output. Especially in complex production lines, the flow model helps to see the gaps in the system and to develop new improvements. Moreover, the flow model can be adapted not only to a production line, but also to a multiple production line, the entire plant or the supply chain. The purpose of creating this visual flow model is to see the quantity centers and movements where the materials are converted.

3.5. Differences Between Traditional Cost Accounting and MFCA

The MFCA is a method which was designed to be applied as an evaluation tool to improving the resources efficiency. It presents not only the overall accounting performance, but also points the real value of the material losses which are commonly assumed as a necessary product waste by the traditional methods. One of the basic difference is treatment of material inefficiencies (ISO, 2011). When a process is analyzed from the perspective of traditional costing method material and energy losses are assigned to product cost. Traditional methods accept inefficiencies as ordinary part of the processes.

Another difference is MFCA focuses on the relationship between input and output in the production process and the loss is occurred when input and output have difference based on weight. In traditional management approaches, the difference between input and output during product design and development phase is expressed as waste. However, this waste can be ignored by management if it can be reduced and expected to be recovered with estimated profits. The most distinctive feature of MFCA is that it measures the inevitable costs that traditional cost management ignore (Kokubu & Tachikawa, 2013, p. 352).

MCFA is an accounting approach that aims to determine the monetary value of the negative results of the outputs generated during the production process. This approach has classified the production facility as material movements and quantity centers. At this stage, the focus of MFCA is to evaluate the products passing through the production process and the wastes or losses that occur as common results of the production, and cost is assigned to both outputs. With this aspect, MFCA differs from traditional cost accounting. Unlike, in traditional cost accounting, which assignes costs to salable and usable products, costs are assigned to waste or losses resulting from products and production as mentioned above in MFCA (ISO, 2011; Kokubu, et. al., 2009; Viere, et. al., 2011).

As a summary of those mentioned above, in traditional cost accounting, the cost of the waste is included to the costs of raw materials. That means, the costs of normal wastes are loaded to the units produced, which increases the cost of manufactured goods. Wastes can either be sold at a low price, or they can be used in production as a first item and material, or they can be used to produce a new by-product by re-production. In traditional costing methods, the physical quantity of the wasted input during production is considered less important and tends to be ignored if these losses are within accepted criteria.

Consequently, traditional methods allocate material losses to final product and cost of final products and losses are recorded to overhead account. Unlike traditional costing, MFCA increases transparency by measuring the cost of production losses, which traditional cost accounting ignores. The information obtained from the implementation of MFCA is

motivating for businesses and managers to improve the efficient use of materials and energy. MFCA material costs and processing costs are distributed not only to the final product and by-products, but also to material losses, and these losses are considered as a product, thereby drawing attention to the cost of the losses.

3.6. Implementation Process of MFCA According to ISO 14051

Some steps and processes must be followed for the implementation of MFCA. The fast and convenient implementation of MFCA depends on various features such as the size of the business, its organizational structure, the number of processes, and the structure of the quantity centers.

In the literature, the implementation steps of MFCA first appear in a guidance published by ISO as ISO 14051. Following this publication, MFCA implementation steps are shortened and listed under similar titles in the another MFCA guidance published by Asian Productivity Organization of Tachikawa (2014) and in the study of Kokubu and Tachikawa (2013).

According to ISO 14051 these steps are following (ISO, 2011):

Step 1: Determining the Roles and Responsibilities of Management

A project can be successful usually with support and grasp of company's management. If management understands the usefulness and benefits of MFCA, it will be easier to get attention from whole the company. To implement effectively, management should assign roles and responsibilities and provide resources by establishing application teams. Collaboration is needed among teams and departments because different information sources are required to complete MFCA analysis.

Step 2: Understanding the Elements of MFCA

The basic elements of MFCA need to be understood for efficient and effective implementation in businesses. These elements are discussed in detail under heading 3.4.

Step 3: Boundary and Scope of the Process and Building a Model for Material Flow

To understand the boundary of the MFCA, data need to be specified clearly. At the beginning, there is a specific process or product which is focused before the implementation to other products. A single/multiple process, an entire facility, or a supply chain can be defined as boundary. One or more process with significant economic and environmental impacts should be the focus point. After shaping the boundary of system, the process is classified in the QCs by using procurement and process information. Quantity center implies the place where materials are transformed. Among quantity centers, if there is a significant loss, flow classification can be made separately. After boundary and quantity center determination, MFCA data collection needed to be specified for a certain period of time. During collection, data should be meaningful, reliable, and usable. In some MFCA project, time period is indicated as monthly, half-year, or a year most common.

Step 4: Allocation of Costs

MFCA divides costs into four; material, energy, system, and waste management cost. Material, energy, and system costs are allocated to the product based on the input and loss proportion. The cost of each input and output in the QC is calculated by multiplying the unit price of the material and physical material amount. While energy, system and material costs are proportionally distributed to products and losses, all the cost of waste management are charged to losses. If the costs for each QC is unknown or difficult to calculate, then these costs must first be distributed to each quantity center and then distributed to product and material losses. An appropriate distribution criterion must be selected as machinery hour, volume of production, number of employee, work hour, number of jobs performed, etc.

Step 5: Evaluating MFCA Results

MFCA increases the visibility of material loss throughout the process, using overall material costs, including energy and system costs associated with material losses and material quantities that do not turn into products. Thus, it provides opportunities for businesses to

identify and solve problems. Managers, who have knowledge about the economic loss and its reasons, can identify opportunities to increase efficiency and improve firm's performance. This situation is overlooked in traditional cost accounting. Most businesses monitor the rate of efficiency related to the material used in the process.

Step 6: Improvement of the Processes and Reducing Material Loss Through MFCA

Businesses may explore opportunities to improve environmental and financial performance once they have a good understanding of the magnitude, trigger factors and consequences of material use and loss with MFCA analysis. To achieve these improvements, substitution of materials, R&D activities related to process modification, production lines or products should be considered. Moreover, cost-benefit analysis can be performed with MFCA data. The MFCA application also creates opportunities for improvements in the accounting and information systems of businesses.

In this section, the definition of MFCA, some studies in the literature, its emergence, relationship with EMA, elements, differences from traditional cost accounting systems and implementation steps were mentioned. In the fourth section, case analysis will be performed.

CHAPTER IV

CASE STUDY

4.1. Aim of the Study

The purpose of this thesis is to reveal the differences of MFCA method with the traditional method in a production enterprise, to explain the application stage of MFCA, its contribution and to examine whether the waste generated during the production process is reduced. For this purpose, a case study is performed in a steel pipe producing company operating in Istanbul.

4.2. Sample Selection

In the fourth chapter where the case study takes place, a steel pipe manufacturing company is selected which is registered İstanbul Chamber of Industry and listed in the top 50 industrial company. The enterprise has several production lines, this analysis is based on a specific production line. Therefore, data were collected only from this production line.

4.3. Limitations of the Study

Since the research was conducted on a company operating in the steel pipe industry, it only reflects the results from that company and its specific production line.

4.4. MFCA Application Methodology

In this study, 2018 and 2019 year production cost figures of the sampled enterprise are obtained from the cost accounting information system to determine the benefits of the MFCA method for a production enterprise. The example selected enterprise adopted the ISO 14051 standard in 2019 and aimed to reduce waste according to this standard for the first

time in production processes, and waste management processes were implemented according to the ISO 14051 standard.

The reason for comparing 2018 and 2019 in the study is that production tonnages, raw material unit prices and exchange rates are similar.

4.5. Implementation on a Manufacturing Company

This section describes how the process works. For the development of cost accounting in the production enterprises that will implement MFCA, firstly, certain data should be collected and a plan should be made.

4.5.1. About Business Nature

The company (hereafter referred to as "Company X") has established in 1958 in Turkey. Company X continues its activities as a reliable world brand with its 1,945 employees and more than 4,000 product types. It is one of the leading manufacturers in Europe and the world in the steel pipe sector with 7 plants on 3 continents and a high sales volume.

Currently, company has ISO 9001, ISO 14001, ISO 10002, ISO 45001, and ISO 5001 certifications. Also, lean six sigma philosophy has established in 2002 to reduce costs and error rates in business processes, while increase efficiency and customer satisfaction with continuous improvements.

4.5.2. Description of the Manufacturing Process

Material flow starts with the delivery of inputs to the factory warehouse area where the materials are accepted and checked throughout the manufacturing process (steel coils). The manufacturing process involves several steps itself.

Steel pipe production line can be listed as cutting steel band in the desired length, wrapping in accumulation, integrating the band with the welding process after shaping

through the rollers, stripping the inner and outer burrs formed during the welding process by burr pen after conversion to the pipe, cutting and packaging of the pipe according to the customer's request.

The production flow chart for the steel pipe production process can be seen below.

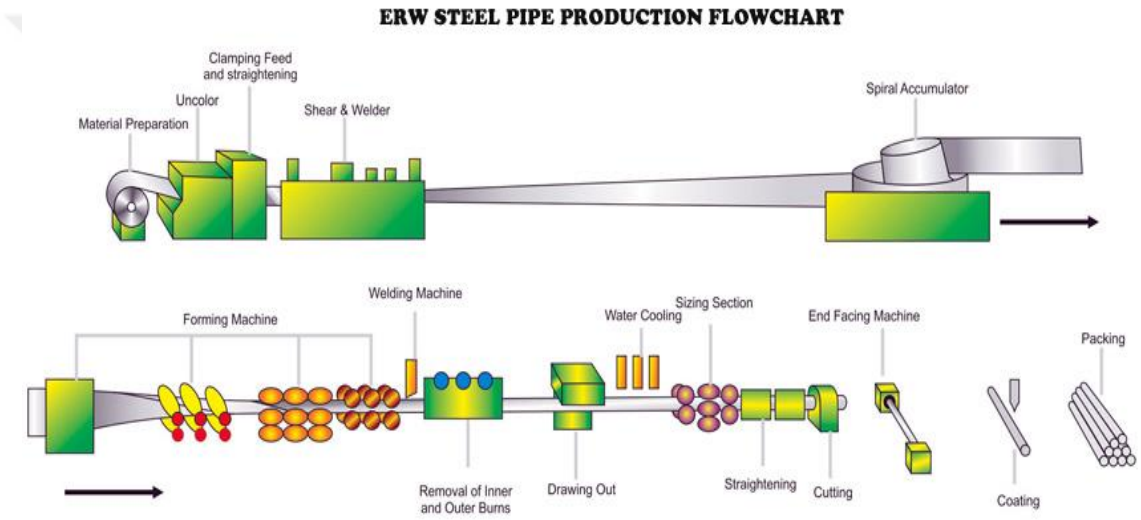

Figure 1: Steel Pipe Production Process Flow Chart

Source: (http://www.steels-supplier.com/processing-technoloy/production-process/)

The parts of the pipe machine process can be counted as respectively where the slitted bands are loaded, accumulation where line supply is made, end welding where the production flow is carried on by boiling the end and head of the bands, form rollers that shape steel and sword rollers that prepare steel for welding, high frequency welding generator that melts and adheres the steel, caliber spools measuring to the pipe within the tolerances of final outer diameter and wall thickness, straightening rollers where the straightness of the pipe is provided, length cutting line where the pipe is cut to the desired length, and as a last the packaging line.

Accumulation: Bands with end welding are collected in accumulation. In order to avoid band-induced stance, continuous production is provided by accumulation.

Rollers: Bands coming out of the accumulation start to take shape in the form rollers for the first time. The band starts to roll by bending the edges of its with the rollers made of cold work tool steel.

High Frequency Welding: The band which is rolled is melted with high frequency welding without any filling material and is welded from both ends of the tape.

Cutting: Pipes with welded and final geometrical adjustments are made cut with the help of saw in desired length and sent to the packaging line.

Packaging: Pipes which are came from cutting line are packed and taken to inventory areas.

These are the general processes of pipe production. Whole manufacturing processes are completed by a categorization of manufactured products. After that, final products are divided into two class; I. quality class, II. Quality class, and losses.

The whole production process is divided four main cost centers in the company's accounting system (Fig. 2).

- Slitting: The bands are sliced according to the predetermined widths for each pipe size in this process. This cost center mainly uses basic material (steel band).
- Welding: The band, which is rolled, is melted with high frequency welding without any filling material and is joined from both ends.
- Cutting: Welded pipes are cut with the help of saw in desired length and sent to the packaging line.
- Packaging: Pipes cut to the desired length are packed as desired in the packaging line.

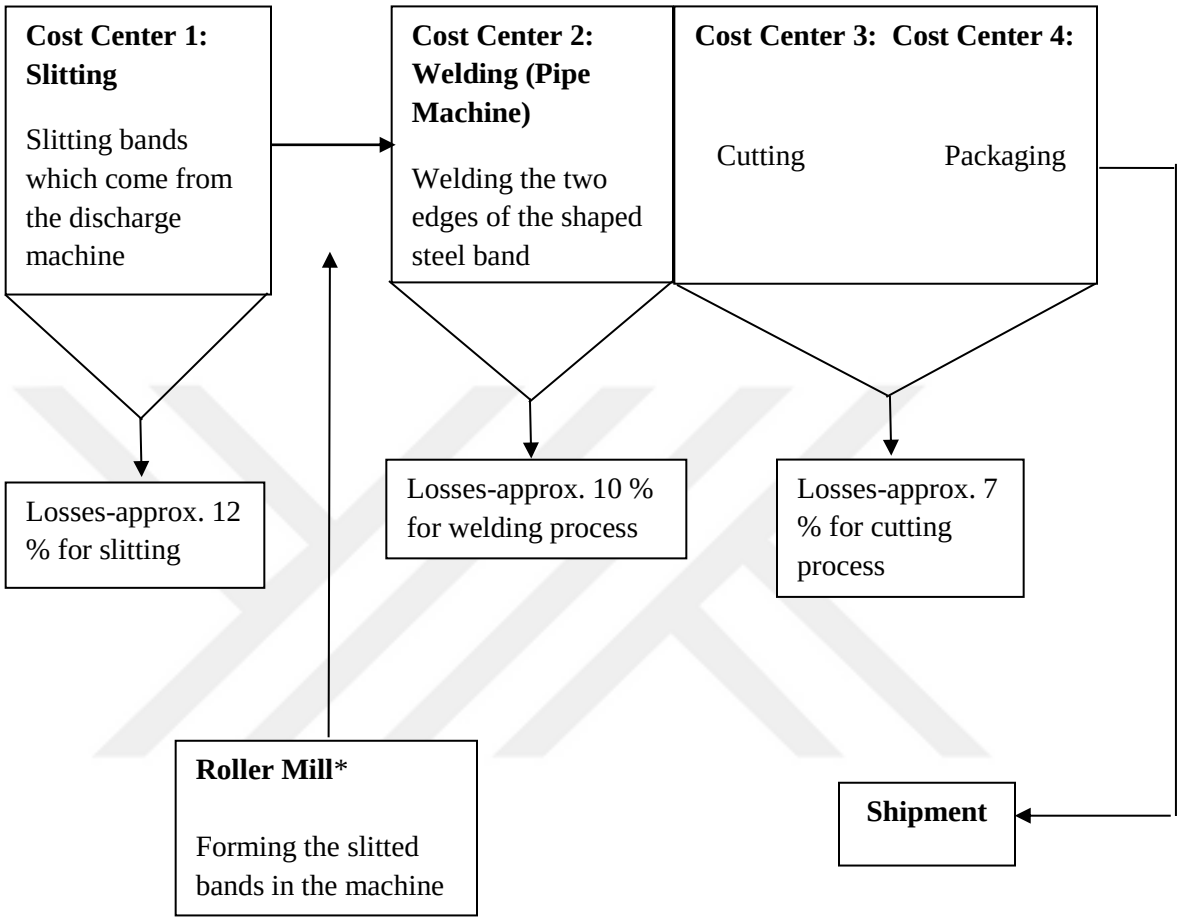

Figure 2: Manufacturing process chart with individual cost centers in 2018 (The data in the figure is adapted to the flow diagram of (Palasek, 2009).)

*Roller Mill is a cost center, but this center has least lost in the production process. Therefore, it doesn't add in cost centers and flow charts.

MFCA not only consider the cost center also consider quantity center through the production process. Company X divides its quantity center (QC) into four centers. (Fig. 3)

- Slitting: Steel band coils in the stock area are peeled and entered to flattener rolls. Meanwhile, bands are slitted in pipe machine.
- Welding: Slitted bands are welded in pipe machine with high frequency.
- Cutting: After welding process, pipes are transferred to cutting with saws.
- Packaging: Cutted pipes are packed with carton boxes or plastic bag and labeled.

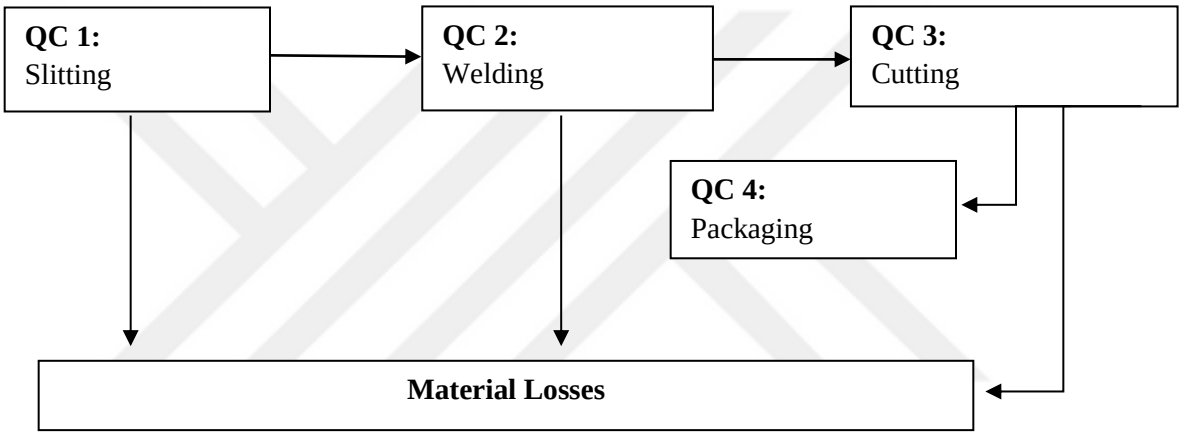

Figure 3: Quantity Centers in Manufacturing Process (The data in the figure is adapted to the flow diagram of (Palasek, 2009).)

4.5.3. Data Collection

The process started with product-loss analysis conducted at the end of 2018 within the enterprise. In the report, which shows the product balance that entered and exited the production process during 2018, attention was drawn to the loss rates that occurred during the year. (Table 2 shows a summary of this analysis.) There upon, what improvements and methods should be used to reduce losses were discussed in enterprises. In order to contribute to internal reporting, it was decided to apply MFCA method within the enterprise. Before starting, the application was set out on the basis of the plan-do-check-act cycle.

During the planning phase, some preview meetings were arranged to inform all departments which introduced the MFCA method by management. In order to implement the method, support was received from experts. Experts are selected as staff consisting from the accounting department and ISO consultants. In order to understand the elements of MFCA, the staff who will take part in the application process were trained by experts. Then, the limitation of the application and the time period were determined. Cost centers and quantity centers were determined and a material flow map was drawn up to see where the losses were mostly given. Production departments and engineers took part in the creation of the material flow map (Figure 2 and 3).

It was determined that which products consist of inputs and outputs that provide flow in quantity centers during the do phase. These data are recorded to the system by weighing of the raw material that entered into production process, and wastes exiting from production process. In addition, the energy and system costs consumed for each processes were calculated. After calculating these costs, the product-loss rate was chosen as the appropriate criterion for allocation. According to this rate, waste management cost calculated as the total cost of negative products.

In control phase is the phase that results were obtained after the application and data set were summarized.

The act phase of the application, lastly, consisted of defining improvements and evaluating development opportunities. These processes were described in detail below.

The first step of the data collection process represents the direct material flows on the part of QCs in the units of weight (tons). Second, the cost of raw material is determined. Thirdly and lastly, direct labor costs and manufacturing overhead costs are indicated. The data of the classical cost accounting method applied by the company in 2018 and the MFCA method applied in 2019 were collected and analyzed comparatively in dollars.

Table 2 shows the material flows according to the cost accounting method used by the company in 2018. In traditional method which company uses, no value is assigned to lost material cost. The cost of the lost materials that arise in the process are added to the final product of each QCs. Losses are calculated by measuring the balance of inputs and outputs within the enterprise. These data are calculated by weighing the products entering and leaving each process at the production site.

Operations	Materials Used	Material Losses
1.Slitting		
Steel Band	88.809 ton	10.657 ton
Total in $	9.058.518 $	0
Total Share in Materials	100%	12%
2.Welding		
Steel Band	76.953 ton	7.695 ton
Total in $	8.772.642 $	0
Total Share in Materials	100%	10%
3.Cutting		
Pipe	69.758 ton	4.883 ton
Total in $	8.510.476 $	0
Total Share in Materials	100%	7%
4.Packaging		
Pipe	64.875 ton	0
Total in $	8.368.875 $	0
Total Share in Materials	100%	0%

Table 2: Direct Material Cost Data from 2018 (Data were taken from company's production-cost analysis, cost accounting info. system and balance sheet accounts)

The table shows only the costs of the materials entering production and the physical values of the materials exit as output. The performance of the production cannot be measured because of the treatment way of traditional costing. For this reason, the actual cost of the final product remains hidden. In this case, the company considers that it can cover the cost of waste products with sales.

Considering table 2, 88.809 ton of steel bands were entered production as raw materials in the enterprise. The unit price of steel is 102 $/ton. The amount of QC 1 (slitting) operation is 9.058.518 $. 10.657 tons of waste measured in the slitting process as material loss. During the welding process, 69.258 tons were transformed into steel pipes and 7.695 ton of the steel band became loss. The unit price of welded pipe is 114 $/ton. Total cost of the QC 2 is 8.772.642 $. After welding process, pipes are sent to cutting. 69.758 tons pipes entered in cutting process and amount is 8.510.476 $. Unit price is 122 $/ton. QC 3 has 4.883 ton loss. For the last quantity center QC 4, there is no waste in 64.875 ton. Unit price is 129 $/ton for finished goods and the amount is 8.368.875 $.

Cost Data	Slitting	Welding	Cutting	Packaging
Direct Labor Costs	798.583	3.699.524	605.131	499.807
Manufacturing Overhead Costs	32.678	684.027	39.624	24.652
Total ($)	831.261	4.383.551	644.755	524.459

Table 3: Direct Labor and Manufacturing Overhead Cost Data of 2018 (Source: Company's Accounting Info. System)

Table 3 shows the direct labor costs and manufacturing overhead costs incurred in the quantity centers throughout 2018. Direct labor costs consist of the expenses of workers working in production. Manufacturing overhead costs consist of auxiliary materials, overtime wages, depreciations and expenses such as rent, insurance, tax.

In the classical cost accounting method in 2018, it was revealed that the waste costs were not considered by the managers since they were not presented in monetary terms. Due to the high loss rates and higher unit prices of the manufactured product, business and production managers decided to apply the MFCA method.

By the end of 2019, only one year later, as a result of the implementation, material waste rates and costs were reduced. (See Table 4)

Operations	Materials Used	Negative Output	Positive Output
1.Slitting			
Steel Band	86.427 ton	7.778 ton	78.649 ton
Total in $	8.469.846 $	762.244 $	7.707.602 $
Total Share in Materials	100%	9%	91%
2.Welding			
Steel Band	78.649 ton	5.505 ton	73.144 ton
Total in $	8.415.443 $	589.053 $	7.826.408 $
Total Share in Materials	100%	7%	93%
3.Cutting			
Pipe	73.144 ton	2.926 ton	70.218 ton
Total in $	8.484.704 $	339.416 $	8.145.288 $
Total Share in Materials	100%	4%	96%
4.Packaging			
Pipe	70.218 ton	-	70.218 ton
Total in $	8.707.032 $	-	8.707.032 $
Total Share in Materials	100%	0%	100%

Table 4: MFCA Application in 2019 (Source: Company's production-cost analysis data, cost accounting info. system)

Considering Table 4, 86.427 tons of steel coils were entered production as raw materials in the enterprise. The unit price of steel is 98 $/ton. The amount of QC 1 (slitting) operation is 8.469.846 $. 7.778 tons of steel band measured as waste in the slitting process

were negative output and the monetary expression of this was determined as 7.778 tons x $ 98 = 762.244 $ while the positive was calculated as 78.649 tons x $ 98 = 7.707.602 $. As a percentage, 91 % of the steel band used is a positive product and the remaining 9 % is a negative product cost.

During the welding process, 5.505 tons of negative 73.144 tons of positive product output was calculated from 78.649 tons of steel band. 73.144 tons were transformed into steel pipes. The unit price of welded pipe is 107 $/ton. Total cost of the QC 2 is 8.415.443 $. 5.505 tons of waste measured in the welding process were negative output and the monetary expression of this was determined as 5.505 tons x $ 107= 589.053 $, while the positive was determined as 73.144 tons x $ 107 = 7.826.408 $. As a percentage, 93 % of the steel band used is a positive product and the remaining 7 % is a negative product cost.

After welding process, pipes are sent to cutting. 73.144 tons pipes entered in cutting process and amount is 8.484.704 $. Unit price is 116 $/ton. QC 3 has 2.926 ton (2.926 x $ 116 = 339.416 $) wastes as negative output while 70.218 ton (70.218 x $ 116 = 8.145.288 $) is positive output. As a percentage, 96 % of the steel band used is a positive product and the remaining 4 % is a negative product cost.

For the last quantity center QC 4, there is no waste in 70.218 ton. Unit price is 124 $/ton for finished goods and the amount is 8.707.032 $.

Cost Data	Slitting	Welding	Cutting	Packaging
System Costs	706.746	3.266.023	547.187	452.032
Energy Costs	28.901	674.027	33.951	21.987
Total ($)	735.647	3.940.050	581.138	474.019

Table 5: System and energy costs of 2019 (Source: Company's Accounting Info. System)

Energy costs are allocated according to the ratio of material flow balances. Energy cost includes electricity, natural gas, fuel oil. Energy cost calculation is made individually for every quantity center. First, a measurement device is identified, and power consumption

measured in each QC. Then energy consumption cost is calculated using Equation (1) (Cecílio, 2017).

$$Energy\ Cost_{QC} = Energy\ [kWh]_{QC} \text{ x } Unit\ Cost/kWh_{QC} \quad (1)$$

System cost is allocated similarly to energy cost. It includes employee costs, depreciation cost, and equipment cost. Equation (2) represents the calculation of system cost (Cecílio, 2017).

$$System\ Cost_{QC} = \sum Employee\ Cost_{QC} + Depreciation\ Cost_{QC} + Equipment\ Cost_{QC} \quad (2)$$

Employee cost includes all the cost of each employees in the production system. Allocation should be made based on the material flow ratio (positive product and negative product ratio) in QC. Depreciation cost is the cost of machines and places used in the production process. These costs calculated with a chosen criterion (straight-line method, double declining method etc.) and assigned every quantity center. Equipment cost is the cost of materials which is used indirectly production such as burr pen, saw, conveyor belt etc. It is measured according to amount of usage for each QC and allocated the ratio of material flow balance.

Items	Slitting	Welding	Cutting	Packaging
Positive Product				
Share in the total materials usage in the center	91%	93%	96%	100%
Material Costs	7.707.602	7.826.408	8.145.288	8.707.032
System Costs	643.139	3.037.401	525.300	452.032
Energy Costs	26.300	626.845	32.593	21.987
Total Costs	8.377.041	11.490.655	8.703.180	9.181.051
Negative Product				
Share in the total materials usage in the center	9%	7%	4%	0%
Material Costs	762.244	589.035	339.416	-
System Costs	63.607	228.622	21.887	-
Energy Costs	2.601	47.182	1.358	-
Total Waste Management Costs	828.452	864.839	362.662	-

Table 6: Allocation of Cost through MFCA for the year 2019

According to MFCA, the allocation of costs to all items that consist the product cost are made according to the product-loss ratio that entered production. In that case, energy and system costs are distributed according to the positive and negative product output rate of the quantity centers where it takes place. Waste management costs are the total negative product costs of each cost centers (See Table 6)

QC 1 (slitting) has a system cost of 706,746 $. The distribution of this system cost is made to 91% positive product (706,746 $ x 0.91 = $ 643,139), to 9% negative product (706,746 $ x 0.09 = $ 63,607). Also, energy cost is distributed at the same rate on positive product (28.901 $ x 0,91 = 26.300 $) and negative product (28.901 $ x 0,09 = 2.601 $).

QC 2 (welding) has a system cost of 3.266.023 $. The distribution of this cost is made to 93% positive product (3.266.023 $ x 0.93 = 3.037.401 $), to 7% negative product (3.266.023 $ x 0.07 = 228.622 $). Energy cost is distributed on positive product 674.027 $ x 0,93 = 626.845 $ and 674.027 $ x 0,07 = 47.182.

QC 3 (cutting) has a system cost of 547.187 $. The distribution of this cost is made to 96 % positive product (547.187 $ x 0.96 = 525.300 $), to 4% negative product (547.187 $ x 0.07 = 21.887 $). Energy cost is distributed on positive product 33.951 $ x 0,93 = 32.593 $ and 33.951 $ x 0,07 = 1.358 $.

Since there is no waste in QC 4 (packaging), all costs incurred here are assigned to the positive product.

4.5.4. Findings and Evaluation of Data

In the data collection section, 2018 traditional cost accounting and 2019 MFCA data are presented. The financial part of data was obtained from the cost accounting budget and reporting department, and the physical part was obtained from the planning and production department of the selected company.

In the application, it was observed that all departments within the enterprise contribute to the process actively. Comparative tables (Tables 7 and 8) are created with the information recorded during and after the application. In the tables, the costs are classified and summarized in the accounting system. As a result of the implementation, the decisions taken within the company and the improvements made in the production processes are explained below.

2018 Traditional Cost Accounting Data			2019 MFCA Data		
Operations	Materials Used	Material Losses	Materials Used	Negative Output	Positive Output
1.Slitting					
Steel Band	88.809 ton	10.657 ton	86.427 ton	7.778 ton	78.649 ton
Total in $	9.058.518 $	0	8.469.846 $	762.244 $	7.707.602 $
Total Share in Materials	100%	12%	100%	9%	91%
2.Welding					
Steel Band	76.953 ton	7.695 ton	78.649 ton	5.505 ton	73.144 ton
Total in $	8.772.642 $	0	8.415.443 $	589.053 $	7.826.408 $
Total Share in Materials	100%	10%	100%	7%	93%
3.Cutting Pipe	69.758 ton	4.883 ton	73.144 ton	2.926 ton	70.218 ton
Total in $	8.510.476 $	0	8.484.704 $	339.416 $	8.145.288 $
Total Share in Materials	100%	7%	100%	4%	96%
4.Packaging					
Pipe	64.875 ton	0	70.218 ton	0	70.218 ton
Total in $	8.368.875 $	0	8.707.032 $	0	8.707.032 $
Total Share in Materials	100%	0%	100%	0%	100%

Table 7: Traditional Cost Accounting VS. MFCA

	2018		2019	
	Direct Labor Cost ($)	MOH ($)	System Cost ($)	Energy Cost ($)
Slitting	798.583	32.678	706.746	28.901
Welding	3.699.524	684.027	3.266.023	674.027
Cutting	605.131	39.624	547.187	33.951
Packaging	499.807	24.652	452.032	21.987

Table 8: Comparison of Other Costs in 2018 and 2019

- In traditional cost accounting, see in table 7, raw material losses in the production are expressed only physically. The cost of material losses is shown in the output exiting from the quantity center. Therefore, the cost of the main product has increased since the cost of the waste product remains hidden. In MFCA, compared to the traditional cost accounting, the output from the quantity center is classified as positive and negative output. Negative output is waste. Positive outputs are products that pass from one center of quantity to another. Here, it is emphasized that this negative output has a monetary value.
- Table 8 is presented to show the differences between the cost components of traditional method and MFCA method. In traditional cost accounting, costs are classified as direct material costs, direct labor costs and manufacturing overhead costs. In MFCA, costs are classified as material, system, energy and waste management costs. The reason such classification is to distribute the costs to the lost product collectively, not separately and present these costs for internal purposes (In table 8).

- Unlike the traditional method, the MFCA assigns monetary value to waste, draws attention of production managers to inefficient places, and serves as a tool to help reduce both waste and production costs.
- In this study, the production line examined in the enterprise producing steel pipes consists of four quantity centers and four cost centers. The material loss and monetary value in each quantity center are reported by MFCA and it leads production managers and engineers to inefficient points, helps to prepare the ground for improvements.

	Waste Costs Comparison in %	
QCs	2018 (Before Implementation)	2019 (After Implementation)
Slitting	12	9
Welding	10	7
Cutting	7	4
Packaging	0	0

Table 9: Comparison of Waste Cost in Percentage

- The high rate of waste calculated in the information provided in 2018 (see Table 9) by the cost accounting department encouraged engineers to make improvements to lower this rate. The improvement process according to the MFCA method, which started to be implemented in 2019 by company, is explained below.

a) Slitting, the first step in the production process, had a 12 % material loss in 2018. The reason for these losses was the size of the band purchased from the supplier was standard size, so that most of the material became waste while slitting process. In addition, during the cutting process, losses occurred due to reasons such as inexperienced workers' error and poor quality of the auxiliary materials used. To reduce these wastes, firstly, the purchasing department has agreed with the supplier to purchase the band in the desired size. Secondly, engineers and team leaders in the factory observed their staff for the errors which arose from human, during working hour and shift changing. Thirdly, a new machinery investment was made to reduce

the cost of auxiliary equipment. After these improvements, the wastes fell to 9 % in 2019.

b) Welding process is the process that determines the quality of the pipe. The losses in the welding process in 2018 were 10 %. These losses consist of burrs that appear in the welding process of the pipe and cannot be prevented by the nature of the process but can be reduced. The burr pens used as auxiliary materials in the welding process were imported at high prices. A low-cost burr pen was designed by engineers and production managers, and waste costs were reduced to 7 %.

c) Cutting process has the least lost among all quantity centers. Most of the losses that occurred in 2018 were due to personnel errors and equipment poor quality. The new machine investment in the slitting process contributed also in the cutting process and reduced the waste here from 7% to 4%.

d) In packaging process, no waste has been generated within both year.

CONCLUSION

Enterprises, whose aim is to make profit, have become aware of their environmental responsibilities with the pressure of stakeholders over time. Although production techniques are developed, due to the nature of production, consumption of environmental resources, environmental damage and waste can occur. Businesses must also consider the environmental aspects of their activities due to the increasing importance of environmental issues on a global scale, legal regulations and pressures of environmentally conscious consumers hold businesses responsible for the negative effects on the environment. For this reason, businesses have included concepts such as environmental accounting, sustainability reports and socially responsible businesses in their managerial processes.

It is seen that the concept of environmental management accounting has emerged due to the insufficient physical and monetary aspects of environmental issues in the cost accounting applied by the enterprises in order to follow the production processes. Environmental management accounting carries out the classification, recording and reporting of the effects of businesses on the environment. However, it can be stated that MFCA has emerged due to the insufficiency of environmental management accounting in establishing the monetary dimension of the effects of businesses on the environment. As a more concrete step of EMA, MFCA is a system that includes determining the negativities resulting from the environmental interactions of the businesses, recording and reporting their monetary dimensions. In a broader sense, MFCA plays an important role in reducing these aspects while revealing the negative effects of businesses on the environment. MFCA undertakes activities such as process improvement and cost reduction. It aims to improve the factors that cause negative effects and product losses to the environment and informs business managers about the inefficiencies resulting from production.

In this study, acting with the concept of environmental accounting, which is the environmental approach of accounting science, environmental wastes were investigated over

monetary and physical values through MFCA. Firstly, the importance, objectives and modernization of the concept of cost accounting for businesses are mentioned. Next, the importance, elements, and objectives of environmental management accounting concept is emphasized at the macro level in the historical process. As the importance of the environment increases based on the foundations of sustainable development, the interest in environmental management accounting has also increased. Environmental protection activities, which are a requirement of social responsibility, are taken into consideration by the private sector as well as awareness of individual and corporate. As businesses began to shape their business models with environmental awareness, the need to obtain environmental information emerged. Collecting this information on accounting basis in terms of reliability and validity and distributing it to the relevant parties has great importance for both business profitability and environmental protection. In this context, many improvements have been made in the field of accounting. One of them is the emergence of material flow cost accounting.

In third chapter, concept, historical development, elements, and implementation process of MFCA is explained. MFCA is a new tool that guides business activities and innovations in production to achieve tangible results at the same time, such as reducing the environmental impact of enterprises, improving the economy and reducing costs. This method considers the cost accounting system from an environmental point of view and not only the products produced but also the waste appeared during the production process, as opposed to traditional cost accounting. For this, it is recommended to get support from product experts and engineers in order to design products and processes. So, it will be possible to use the materials more efficiently and significant cost savings will be achieved with the products and processes designed to support waste reduction.

In the study conducted in the fourth section, the data obtained from 2018-2019 in an enterprise producing steel pipes were examined and waste costs were calculated. While the classical method used in 2018 only follows the losses physically, in 2019, the costs incurred for these wastes are revealed with the MFCA application. According to this method, waste costs calculated through accounting are reported, and helped to develop improvements by

drawing attention to the point where the costs are high. In the study, the improvements were made by the enterprise for waste materials showed its effect in 2019 and there was a certain decrease in waste rates. With the effective participation of all departments within the company, this process was carried out and a waste budget for 2020 was prepared to continue the success achieved.

In conclusion, businesses should design their production processes in the globalizing world, considering the use of resources in addition to their profit targets. Moreover, for future work, it can be recommended to apply in multi-process production lines in large and medium-sized companies. Most importantly, system integration may be needed due to the large data set in big sized companies. For the companies with more raw and auxiliary material requirements, applying MFCA on the supply chain can increase the positive return.

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