BUSINESS, MANAGEMENT AND EDUCATION
ISSN 2029-7491 print / ISSN 2029-6169 online
2011, 9(1): 5–18
doi:10.3846/bme.2011.01

MATERIAL FLOW COST ACCOUNTING (MFCA) – TOOL FOR THE OPTIMIZATION OF CORPORATE PRODUCTION PROCESSES

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Received 18 November 2010; accepted 15 January 2011

Abstract. The paper focuses on the Material Flow Cost Accounting method (hereinafter the "MFCA"). It presents an application of the MFCA within a manufacturing plant of the largest manufacturer of ceramic tiles in the Czech Republic – the company Lasselsberger. It shows the importance of data acquired from the MFCA system as well as their application for an optimization of manufacturing processes for specific conditions of a manufacturing plant of the company.

Keywords: material flow, cost accounting, material flow cost accounting, production, material costs.

Reference to this paper should be made as follows: Hyršlová, J.; Vágner, M.; Palásek, J. 2011. Material Flow Cost Accounting (MFCA) – tool for the optimization of corporate production processes, *Business, Management and Education* 9(1): 5–18. doi:10.3846/bme.2011.01

JEL classification: M11, M41.

1. Introduction

The MFCA represents the key tool of the management approach referred to as the flow management, the objective of which is, in particular, to manage manufacturing processes with regard to the flows of materials, energy, and data so that a manufacturing process can proceed efficiently and in compliance with any set targets (Fichter *et al.* 1999; Jasch 2001, 2009).

In flow management, enterprise is understood as a system of material flows. On the one hand, this system contains material flow relating with value added generation (from purchase of input materials through particular processing stages to distribution of products to the customers). On the other hand, inseparable part of material flows is formed by material losses that occurred in the course of corporate processes (for example, defective products of poor quality, scrap, waste, damaged products, products with expired term of consumption, etc.). This means that materials leave enterprise in the form of undesirable residues – undesirable from both economic and environmental viewpoints. As a matter of fact, these are waste flows of all states (solid waste, waste water and emissions to the air).

Within MFCA, emphasis is primarily laid on transparency of material flows and on the relating costs. Thus, there are created basic conditions for proposing measures that are connected with significant material and cost savings. Measures aiming to reduce consumption of materials are associated also with cost savings in the area of handling the materials as well as in the area of waste disposal.

The paper focuses on MFCA. It characterizes MFCA as material flow management tools and points out the significance of MFCA information for the optimization of production processes. The aim is to present MFCA system outputs on example of a company manufacturing ceramic tiles and show the importance of data acquired from the MFCA system for the optimization of manufacturing processes.

2. MFCA – a tool of material flow management

The principal concept of the MFCA is based on the chart shown in Fig. 1. Any and all inputs (materials, energy, water, and other inputs) and outputs (primary products / byproducts, wastes, wastewaters, emissions) are determined within a quantity centre, and a calculation is carried out in respect of material, energy, and system costs incurred for products and material losses. The term product refers to any product transferred to the next manufacturing stage (a quantity centre) as suitable and/or leaving the company as a final product. In terms of the MFCA, the term material loss is not only seen in the narrow sense, but it refers to any and all invested materials, energy, and other economic resources, which were not transformed into products and leave unused as wastes.

The MFCA concentrates on material flows and associated costs. Not only does the system provide data in physical units, it also shows the value of individual materials flows. Material costs are an important part of the material flow costs; these costs represent an important cost item in manufacturing companies. The usage of materials is monitored in physical units and it is also shown in monetary units (material costs) within the MFCA. The material flows are reconstructed within a quantity centre, and data are ascertained in order to determine which part of the materials is flowed to products and which part of the materials leaves as material losses.

The MFCA also monitors energy costs, i.e. costs of all energy sources used within the respective quantity centre. Furthermore, system costs are allocated to products and material losses. The system costs are defined as any and all costs, which are incurred when handling material flows within a company (e.g. personnel costs, depreciation costs). Each material flow of a company may be treated as a carrier of system costs – whether it concerns raw materials, work in progress, products, or material losses. The system costs are always allocated to output flows, and they are retransferred to subsequent flows and stock of materials. Material losses, which leave a quantity centre, must also be allocated waste disposal costs.

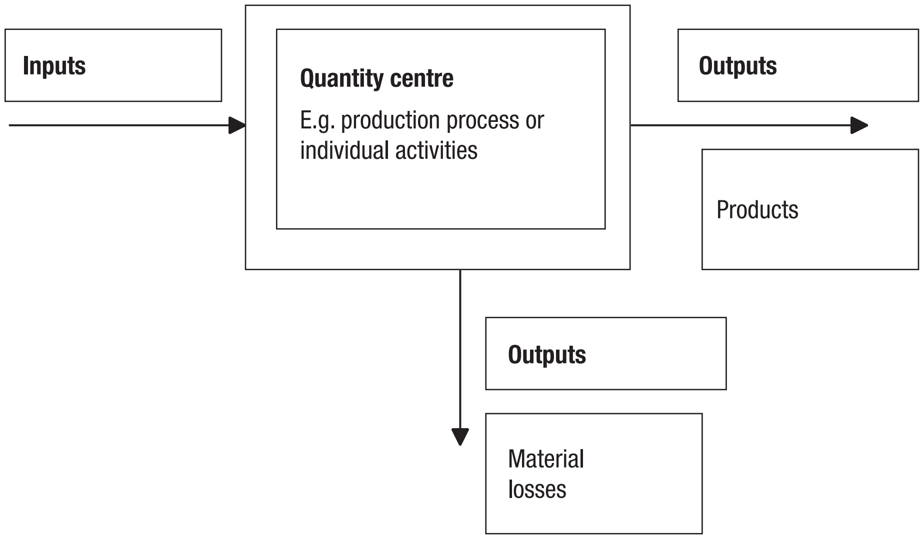

Fig. 1. MFCA chart (Source: Palásek 2009)

The MFCA represents an accounting method that provides the management as well as other stakeholders with absolutely new data, which can be used in support of the decision-making – see e.g. (Hyršlová *et al.* 2008; Hyršlová, Kubáňková 2009; Kokubu, Nakajima 2004; Kokubu, Nashioka 2005; Strobel, Redmann 2001; Strobel 2000; Wagner, Enzler 2006). Using the MFCA data, it is possible to seek "corrective actions" for material flows and to propose measures that might lead to a higher efficiency of manufacturing processes.

MFCA belongs to very important methods of environmental cost accounting and thus also of environmental management accounting (Schaltegger, Burritt 2000; Nakajima 2006). In the recent years, various approaches to the conception of environmental accounting were gradually developing (Bennett, James 1998; Burritt *et al.* 2002; EPA 1995; Gray 1993; Gray *et al.* 1996; Gray, Bebbington 2001; Jasch 2002; Schaltegger, Burritt 2000; Schaltegger, Stinson 1994; Schaltegger *et al.* 1996). Environmental cost accounting is defined as the identification and assessment of environmental costs and their allocation to the processes, operations, products or centres (IFAC 1998). A very important category of environmental cost accounting is formed by environmental costs. The basic definition specifies corporate environmental costs as environmental protection costs (Fichter *et al.* 1997). Nevertheless, to specify corporate environmental costs, also material and energy flows can be taken as a basis. Environmental costs then can be defined as a sum of all costs relating, directly or indirectly, with the use (consumption) of materials and energies and with environmental impacts resulting therefrom (Fichter *et al.* 1997). The difference between both conceptions is shown on Fig. 2. Methods used within environmental cost accounting can be divided into groups which stem from the definition of environmental costs and from methods used in cost accounting. The cost analysis applied always depends on the problem which is to be addressed; for different purposes it is necessary to start from different approaches to classification of costs. Of high significance for corporate processes management is primarily the application of material and energy flow-based methods. MFCA so belongs to very important methods of environmental and economic performance management.

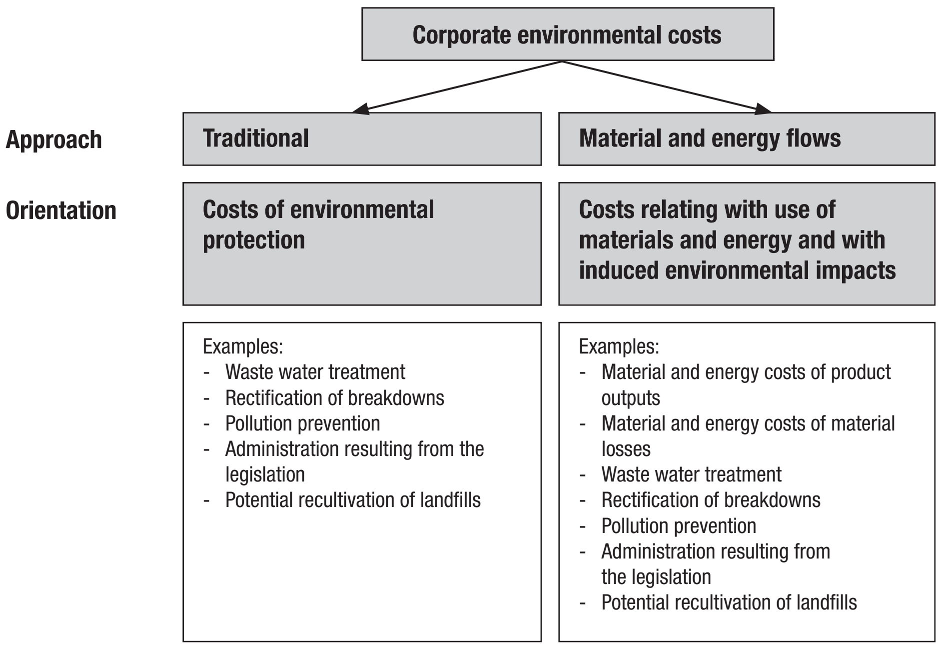

Fig. 2. Corporate environmental costs (Source: prepared by authors)

3. Case study: Application of the MFCA method in a company manufacturing ceramic tiles

The company Lasselsberger currently presents the largest manufacturer of ceramic tiling in the Czech Republic, and it is one of the major players on the European markets. The company has been maintaining and developing the historical traditions of the ceramic manufacturing. The brand RAKO represents comprehensive sets of wall and floor tiles, including extensive range of bathroom, kitchen, and house interior floor accessories. From the perspective of lifestyle, the company targets end users with high demands in the area of design and utility value of offered materials.

The MFCA method has been applied in the manufacturing plant RAKO III, which is part of the company Lasselsberger. This plant manufactures interior ceramic tiles, which are mainly characterized by a variety of sizes and designs. Application of the MFCA method took places in three stages: preparation, data collection, and calculation. The costs of products and material losses were monitored for the period of 12 months (the 2008 calendar year).

3.1. Description of the manufacturing process

The flow of materials throughout the manufacturing process starts with the delivery of inputs (several types of ceramic clays and raw kaolin) into covered storage boxes, where the materials are accepted and their parameters are checked. The manufacturing process itself involves several stages. The initial stage is the pulverization and homogenization of inputs, using the wet grinding process. The homogenized ceramic deposits are pumped from drum mills into storage tanks, from which they are subsequently piped to spray driers. The drying process results in granulate of about 5.5% humidity, with defined granulometry. From the drying plant, granulate is transferred to a reservoir via a belt conveyor. The next manufacturing stage involves the pressing process. Granulate is transformed into the final product – tile – with the required shape and size. After passing through a tray drier, the semi-finished tiles – pressings – are transferred to another manufacturing process stage via conveyors. This next stage involves glazing, which is performed on the so-called glazing lines. Engobe as well as a layer of glaze are applied onto the pressings. This manufacturing stage mainly requires a high level of cleanliness of input semi-finished products, because any dust applied together with the glaze results in defect products during the next (fifth in total) manufacturing stage – i.e. burning process. Overall, the aforementioned manufacturing stages (pressing and glazing) result in wastes of approximately 2% area of the total production. The production is monitored in both m^2 and tons, specifically for the plant producing such wastes.

The glaze and engobe applied on glazing lines are prepared during a separate manufacturing stage called the glaze preparation. The inputs (frit and washed kaolin) are first grinded and then transformed into a suspension, which is applied onto a face side of tiles during the glazing process. The amount of wastes is not monitored during the process of glaze preparation. It is estimated at about 9.5% of glazes and engobes input in mills and subsequently 5% of suspensions produced in a glaze preparation plant.

Another manufacturing stage, which follows after the glazing stage, is the above mentioned burning process. It takes place in gas roller kilns and it is characteristic by high energy consumption. The time of burning and the firing curve depend on the tile size and the applied glaze type. The whole burning process lasts for about 40–50 minutes.

The whole manufacturing process is completed by a checkout and sorting of manufactured products. Products are divided into three categories, in line with EN CSN 14411 – i.e. quality class I, quality class II, and wastes. According to the company, the inspection process results in losses of approximately 5% of the total area of final production. The sorting process is followed by packaging and transfer into the final products storage.

The ceramic manufacturing is characteristic of a nonexistence of material losses. The entire solid component of material losses is recycled and used as input in the first production stage. Due to this, the costs associated with material losses in traditional management accounting methods only refer to disposal costs of the packaging used to transfer the glazes.

The whole manufacturing process is divided into three cost centres (Fig. 3) within the existing company management accounting system:

- Preparation of Materials. The costs associated with this centre are incurred in connection with grinding and homogenization of inputs, their subsequent drying and the production of granulate. This cost centre uses the basic materials; however, not the most important expensive materials;
- Preparation of glazes. The centre handles the preparation of glazes, which are applied using glazing lines during the manufacturing process. The important cost items include energy costs and costs of inputs (raw materials). Since different types of glazes are required for various tiles, the preparation of glazes takes places discontinuously – a special type of glaze is prepared for each tile type. Estimated losses of materials associated with this cost centre amount to approximately 9.5% of the materials used in mills. Other material losses result from the need to wash out mills, filter presses, and tanks before each batch of glaze;
- Manufacturing. This centre ensures the pressing of materials arriving from the cost centre Preparation of Materials, glazing performed on glazing lines, burning of tiles, and subsequent sorting and packaging.

The MFCA method has been applied to the complete manufacturing process of the RAKO III plant. Six manufacturing formats were selected for the purpose of monitoring; each in both matte and glossy glaze. The whole manufacturing process was subdivided into four quantity centres:

- Preparation of Materials. This quantity centre corresponds to the cost centre Preparation of Materials; therefore, the identification and allocation of energy and system costs will be based on the profit and loss statement of this centre. Almost all material losses consist of water evaporated during the drying process;
- Preparation of Glazes. This centre, similarly as the previous quantity centre, also fully corresponds to the cost centre Preparation of Glazes. The centre is not too large, and it is thus suitable for the monitoring of material flows within the MFCA method. The identification and allocation of energy and system costs will be based on the profit and loss statement of the cost centre as well;
- Pressing and Glazing. This quantity centre does not correspond to the cost centres created within the existing management accounting. The reason for its formation is the need to acquire a more realistic view of the material flow corresponding to the assessment of arising material losses;

– Burning, Sorting, and Packaging. The reason for the formation of this quantity centre is the need to specify the monitoring of material flows. The only material loss of the burning process is the water evaporated from the pressings; other material losses result from the sorting process on sorting lines.

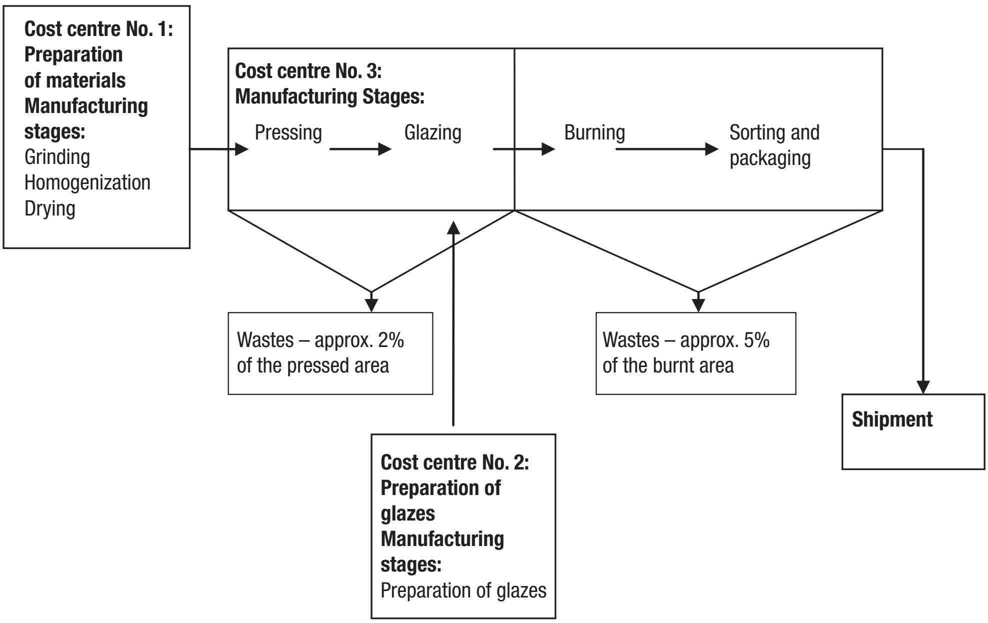

Fig. 3. Manufacturing process chart (including individual cost centres) (Source: Palásek 2009)

Fig. 4 shows a simplified chart of material flows in the RAKO III manufacturing plant.

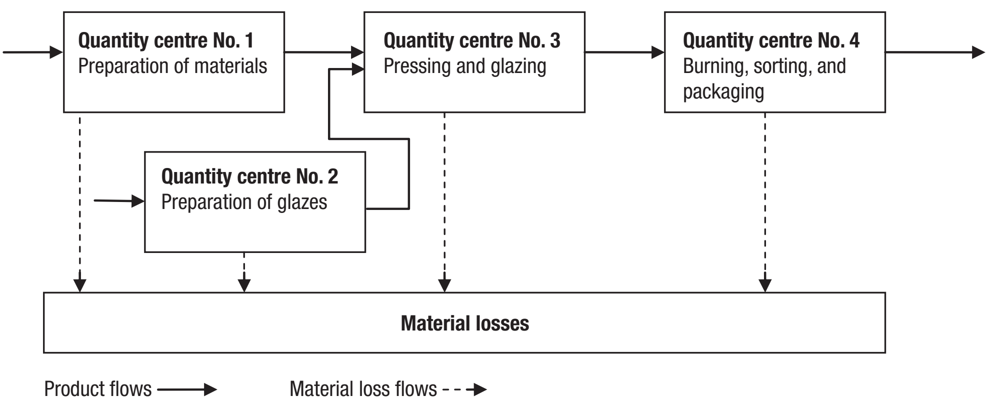

Fig. 4. Basic chart of material flows (Source: Palásek 2009)

3.2. Data collection

During the data collection process, it was necessary to perform the reconstruction of material flows by individual quantity centres (weight units). Some data required for the MFCA method had to be calculated based on the knowledge of the manufacturing process and using the company formulas.

However, the reconstruction of material flows on the part of individual quantity centres in the units of weight only represented the first stage of the data collection process that had to be performed. The knowledge of the material flows and the prices of raw / other materials were then used to determine the material costs of products and material losses – i.e. the prices of materials, which leave for other quantity centres (or to customers) as part of products or as part of material losses – waste flows. It applies than the material costs of products equal to the material costs of products produced in the last quantity centre. The material costs of material losses were obtained as the sum of costs of material losses throughout the whole manufacturing process (i.e. for all quantity centres).

During the data collection stage, it was also necessary to identify and determine energy and system costs incurred by individual quantity centres during the period in question.

The second stage of the MFCA method application resulted in the material balances of all quantity centres and the whole manufacturing process – both in the units of weight and in CZK (see Tables 1–3) – and in the data on energy and system costs for individual quantity centres (see Table 4).

Table 1. Materials within the MFCA method (Source: company data and own calculations)

Item	Quantity centre No. 1	Quantity centre No. 2	Quantity centre No. 3	Quantity centre No. 4
Products (total materials in t)	85 838	11 464	95356	86 803
Share in the total usage of materials in the centre	66%	90%	98%	91%
Material losses (total materials in t)	44 282	1 292	1 946	8 553
Share in the total usage of materials in the centre	34%	10%	2%	9%

The overall balance of material flows of the RAKO III plant is based on the following logical assumption: Products of the RAKO III plant (i.e. the whole manufacturing process, for which material flows were monitored, and to which the MFCA method was applied) correspond to the products of the last quantity centre (i.e. the centre Burning, Sorting, and Packaging). Material losses amount to the sum of the material losses incurred in all quantity centres (see Table 3).

Table 2. Material costs within the MFCA method (Source: company data and own calculations)

Item	Quantity centre No. 1	Quantity centre No. 2	Quantity centre No. 3	Quantity centre No. 4
Products (material costs in CZK)	48 376 652	82 838 388	128 590 739	137 265 624
Share in the total material costs of the centre	92%	87%	98%	92%
Material losses (material costs in CZK)	4 064 707	12 671 519	2 624 301	11 533 808
Share in the total material costs of the centre	8%	13%	2%	8%

Table 3. Materials and material costs within the MFCA method (the RAKO III plant) (Source: own calculation)

Item	Total materials (t)	Share in the total usage of materials	Material costs (CZK)	Share in the total material costs
Products	86 803	61%	137 265 624	82%
Material losses	56 073	39%	30 894 335	18%

The data about energy and system costs were obtained from the profit and loss statements of individual cost centres. The system costs did not reflect all the costs items that were reported in the statements of individual cost centres, but only the costs immediately relating to the material flows. Table 4 summarizes the data on energy and system costs for individual quantity centres during the period under review.

Table 4. Energy and system costs (in CZK) (Source: Company data and own calculations)

Item	Quantity centre No. 1	Quantity centre No. 2	Quantity centre No. 3	Quantity centre No. 4	Total
Energy costs	50 442 411	1 347 688	27 618 558	81 386 446	160 795 103
System costs	30 799 108	6 493 541	49 955 013	49 357 003	136 604 665
Total	81 241 519	7 841 229	77 573 571	130 743 449	297 399 768

3.3. MFCA calculation

During this stage, it is necessary to allocate the material, energy, and system costs to products and material losses, and to determine the total costs associated with individual material flows. The allocation must be performed within each quantity centre based on the ratio of the material content in products and material losses. The MFCA calculation is easier for the first two quantity centres (Preparation of materials / Preparation of glazes). These centres do not use the input in the form of products of other centres – the energy and system costs of the previous manufacturing stages do not have to be considered in the calculation. On the other hand, the calculation of the other two centres must consider the energy and system costs incurred in connection with the products in the previous quantity centres. The material flows, which result from the previous manufacturing stage (i.e. the output of the preceding quantity centre), are the carriers of the energy and system costs allocated to them based on the ratio of the material content in products and material losses making up the output of such preceding quantity centre. The energy and system costs, which were incurred during the following manufacturing stage (quantity centre), must be allocated based on the ratio of the material content in products and material losses making up the output of the given manufacturing stage.

Table 5 shows the allocation of energy and system costs to products and material losses leaving from individual quantity centres as well as the determination of their total costs.

Table 5. Costs of products and material losses (in CZK) (Source: own calculation)

Item	Quantity centre No. 1	Quantity centre No. 2	Quantity centre No. 3	Quantity centre No. 4
Products:				
Share in the total usage of materials in the centre	66%	90%	98%	91%
Material costs	48 376 652	82 838 388	128 590 739	137 265 624
Energy costs	33 276 091	1 211 204	60 863 736	129 491 204
System costs	20 317 703	5 835 923	74 586 466	112 826 493
Total costs	101 970 446	89 885 515	264 040 941	379 583 321
Material losses:				
Share in the total usage of materials in the centre	34%	10%	2%	9%
Material costs	4 064 707	12 671 519	2 624 301	11 533 808
Energy costs	17 166 321	136 484	1 242 117	12 758 977
System costs	10 481 405	657 618	1 522 173	11 116 976
Total costs	31 712 433	13 465 621	5 388 591	35 409 761

3.4. Findings resulting from the MFCA method application in the RAKO III plant

Economic results achieved by the RAKO III plant in 2008 are mainly attributable to the technology used for the manufacturing of tiles. In total, the plant produced 86 803 tons of products and 56 073 tons of material losses during the period under review; the costs associated with the material losses amounted to approximately CZK 86 million.

Based on the MFCA calculation, it is possible to recommend to the company to mainly concentrate on the processes taking place within the quantity centre Preparation of Materials, which produced the majority of material losses. Material losses mainly occur during the manufacturing process of drying, and they result from the method of processing raw materials at the beginning of the material flow. In 2008, the existing initial stages of the manufacturing process resulted in 44 282 tons of material losses; the production of the material losses is directly associated with costs of approximately CZK 32 million. The recommendation relates to the method of processing raw materials, i.e. the method of grinding of raw materials. One solution would be to replace the discontinuous mills with continuous mills. The use of continuous mills should lead to a lower consumption of water, which is the main component of the material losses. Even though the material losses are recycled within the company, the energy and system costs incurred in connection with their production are irrecoverably lost. The remaining quantity centres work very well, with only a small potential for improvement. Specifically the quantity centre Pressing and Glazing is highly effective.

The manufacturing of ceramic tiles represents a traditional production with a familiar manufacturing process. In general, it is very difficult to propose any improvements for these technologies, because they tend to be very sophisticated from the perspective of technology. The MFCA method could contribute to the development of new technologies, which would eliminate or mitigate deficiencies of traditional technological processes. It is apparent that it is not possible, for various reasons, to completely prevent the production of material losses. However, it is useful to try reducing the value of material losses as much as possible while preserving the product quality desired by customers.

4. Conclusions

The MFCA method represents one of the management accounting methods. Unlike traditional methods, the MFCA monitors materials flows and costs associated with products and material losses. In case of material losses, it does not only target the disposal costs of such "negative" products, but any and all economic resources, which were expended (used) in connection with material losses. The data acquired during the process contribute to the fact that management is able to propose such measures, which would lead to more effective production and lower volume of material losses. Such measures increase the economic effectiveness of production and, at the same time, positively affect the environment. MFCA improves the current accounting approaches in two levels:

1. Economic level. MFCA primarily focuses on material costs. In manufacturing enterprises they represent a very significant cost item; in comparison with them, costs relating with, for example, waste management, are insignificant. Traditional accounting systems do not provide sufficient information on material costs, in enterprises there is not available detailed information on how particular materials pass through enterprise. Within MFCA, the data in physical units are interconnected with the data expressed in monetary units. The progress of materials through enterprise is identified, it is evident what part of materials is put in a product and what part of materials leaves enterprise in waste flows (and the system provides not only information in physical units, but also the value of particular material flows is expressed).

The acquired information can be used to support decision-making processes. Ways are searched to "rectify" material flows and measures are proposed, leading to a reduction of consumption of materials and to increased efficiency of production processes – for example, material handling is improving to avoid their damage and wastage, waste quantities (volumes) are being reduced (for example, through new techniques within production process, and also through avoidance of completion of poor quality products), improvements are being achieved in the area of material productivity, etc.

2. Environmental approach level. MFCA focuses on reducing the costs through a reduction in quantities (volumes) of consumed materials and energies. This has also positive environmental impacts. Materials and energies are better used and waste flows burdening the environment are being reduced. MFCA so represents a very important tool for environment-oriented management and for improvements of eco-efficiency. Environmental benefits are realized even if it is not a willful intention of enterprise.

When applying the MFCA method within a plant manufacturing ceramic tiles of different sizes, colors, and glazes, the reconstruction of material flows was mainly based on the detailed knowledge of the manufacturing process and its individual stages. At the same time, data from the company information system and company formulas were used. In spite of this, the identification of the material flows in physical units did not present a simple task, especially in those manufacturing stages, which use materials already preprocessed in other centres.

The application of the MFCA method revealed that the quality of information output is mainly affected by the selection of quantity centres. For this reason, it is necessary to specify an optimum size of each quantity centre, in order to prevent losses of important data and time/money-consuming collection of the relevant data. Furthermore, the quality of obtained data is greatly affected by an identification of energy and system costs and, above all, their correct allocation to individual quantity centres.

During the application of the MFCA method, it is useful – see e.g. (Ministry of Economy, Trade and Industry, Japan 2005) – to proceed from relatively simpler processes and productions – with relatively easier improvements – to more complex processes and productions, which require more difficult implementation. In this matter, it is possible to gradually acquire experience, which is especially necessary for the correct execution of the first two stages (preparation and data collection) in case of more complex manufacturing processes.

Acknowledgements

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic under project No. MSM 6046137306.

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MATERIALIŲJŲ SRAUTŲ SĄNAUDŲ APSKAITA (MSSA): ĮRANKIS BENDRIESIEMS GAMYBOS PROCESAMS OPTIMIZUOTI

J. Hyršlová, M. Vágner, J. Palásek

Santrauka

Straipsnyje nagrinėjamas materialiųjų srautų sąnaudų apskaitos metodas (toliau „MSSA“). Šiam metodui praktiškai pritaikyti pasirinkta didžiausia Čekijos keraminių plytelių gamintoja „Lasselsberger“. Tyrimo rezultatai parodė tiek taikomo MSSA metodo specifiką, tiek šio metodo praktinį pritaikomumą, remiantis konkrečios įmonės pavyzdžiu, gamybos procesams optimizuoti.

Reikšminiai žodžiai: materialieji srautai, sąnaudų apskaita, materialiųjų srautų sąnaudų apskaita, gamyba, materialinės išlaidos.

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