

Introducing Material Flow Cost Accounting and Creating Visibility

–Analyzing MFCA in practice based on a longitudinal case study–

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ABSTRACT

Environmental management accounting (EMA) is a calculation technology that connects environmental problems to the economy. Many researchers have studied the technological development of EMA. However, few studies have examined how the visibility created by EMA affects organizations' activities. Therefore, this paper focuses on the visibility by material flow cost accounting (MFCA) as one EMA tool and aims to clarify the interaction process between MFCA and organizations for about ten years in one company. In particular, we analyze roles of actors involved with MFCA descriptively.

One Japanese company introduced MFCA as an environmental management tool to overcome operating losses. After the first successful trial of MFCA at one of its plants, it was extended to company-wide and systematized by heterogeneous actors. In this process, not only was MFCA affected by actors but also MFCA actively affected to the actors. Over the years, the systematization of MFCA progressed and the actor network surrounding MFCA changed. Additionally, the definition of MFCA was changed and its activities themselves became stagnant. This case study illustrates the transformation of MFCA through changes in the actor network and that the basic concept of MFCA was maintained in both different networks.

1. Introduction

Coordinating economic activities with the reduction of environmental impacts and constructing a management mechanism to realize this coordination have become major issues for companies planning to introduce environmental management.

Environmental management accounting is expected to be one of the solutions to this coordination challenge (Burritt, 2004). Material flow cost accounting (MFCA) is a method that has attracted significant attention recently. MFCA was published as ISO14051 in 2011. In about these ten years, MFCA has been introduced in Japan, German, South Africa and other countries (see, for example, Herzig *et al.*, 2012; Kokubu and Nakajima, 2004; Onishi *et al.*, 2008; Wagner and Enzler, 2006; Jasch, 2009 and METI, 2011).

Traditional studies on MFCA focus mainly on technological aspects such as its differences from and coordination with existing management accounting and production management methods, expanded application to the supply chain, and possibility of coordination with environmental assessment (Nakajima, 2010). The development of environmental management accounting tools make it possible to create new visibility in organizations and to motivate organizations to address environmental management. However, the new visibility created by environmental management accounting doesn't always correspond with business activities bringing profit (Kokubu and Kitada, 2012).

In accounting journals such as *Accounting, Organizations and Society (AOS)*, *Accounting Auditing & Accountability Journal (AAAJ)* and others, many researchers have studied the active role of accounting as calculation (e.g. Briers and Chua, 2001; Chua, 1995; Robson, 1992). These studies examine that visibility which accounting creates affect organizations and society, and the accounting change process in the context where accounting is embedded (Hopwood, 1987). Additionally, the number of studies that employ actor-network theory to examine the active role of accounting has been increasing (Justesen and Mouritsen, 2011). In environmental accounting research, there are a few studies that focus on the active role of environmental accounting (e.g. Kitada, et.al., 2012). But there are few studies that illustrate the interaction process between environmental accounting and organizations for a long period.

This paper aims to clarify MFCA's introduction and transformation processes for about ten years by using a longitudinal case study. Especially, we focus on the actor-network related to MFCA and the active role of MFCA as calculation.

2. Method

This paper selected Company A (not named to maintain anonymity) for case analysis. Company A introduced MFCA in 2003 and later expanded to company-wide continuous application. It is one of the most advanced companies in terms of the application of MFCA. Accordingly, it is the most suitable company to consider for the analysis of introduction and transformation of MFCA in a company.

The authors conducted unstructured interviews with Company A's employees and top managers including the president from 2003-2012. The divisions and persons interviewed are as follows: the president, the environmental management division, the managing director of the environmental management division, Division E, Division H, the manager of Plant S, and the manager of the production

innovation center¹. The interviews were digitally recorded and transcribed. The duration of each interview was 1-1.5 hours. All the interviews were conducted in Japanese. Therefore, all the quotations in this paper have been translated into English with attention not to change the meaning.

Additionally, We utilized several different types of data, i.e. annual reports, environmental reports, in-house magazines, scripts of managers' speeches and interviews. We descriptively analyzed the practice of Company A's MFCA based on these data.

We illustrate MFCA's introduction and transformation processes for about ten years in a company in the next chapter. Especially, we focus on the interaction between visibility by MFCA and actors. This chapter has five parts - (1) Prior to the introduction of MFCA, (2) The introduction of MFCA, (3) Company-wide deployment of MFCA, (4) Coordination between MFCA and production innovation, (5) Change in the concept of 'loss cost'.

3. The introduction and transformation of MFCA at Company A

(1) Prior to the introduction of MFCA

Company A has traditionally been sensitive to environmental issues because it is a chemical company. It established its environmental management division as early as 1970's and began undertaking activities to achieve an ISO 14001 environmental management system in 1996. It also started to work toward zero emissions in about 2000.

The company had a great turning point financially in the latter half of 1990s when it recorded an operating loss. During this period, Company A reviewed its business and reformed its organization. During these hard times, Mr. X became president. He consolidated the business and transformed the organization's system from the existing divisional system to the in-house company system in 2000. Immediately before taking over the presidency, while still vice-president, he created the phrase "environment creation company" for the first time in a business plan. The objective was to achieve social value with a view to consolidating employee awareness. He tried to overcome this crisis through becoming "environment creation company".

At this point, however, the company did not have any specific direction on how to become an environment creation company, and many employees shared the feeling that it would cost too much to address environmental conservation. Then, the company established an environment management project (for six months) to discuss how to raise the level of environmental conservation activities to the management level, and report the results of the discussion at management meetings.

Mr. P, then leader of this project, recalled the discussion as follows:

"Employees of Company A cannot easily erase the feeling that environmental conservation is costly. If environmental conservation activities are directly linked to management and profit, environmental management will accelerate. Then, we discussed what environmental management we should achieve, what missions we should perform to achieve the expected environmental management, and what we could get from it."

As part of this project, participants discussed how to approach raising the level of environmental management to the management level using three methods: integrating the vectors, creating a business

characterized by environmental conservation, and increasing management efficiency through environmental conservation. The discussion results were reported to the board of directors. Adopting the proposal from the environmental management project, Company A established its environmental management division to promote environmental management in the former half of 2003.

(2) The introduction of MFCA

Mr. P, who became manager of the environmental management division, was looking for ways to link environmental conservation activities to company profit and what methods and strategies the company should use. In the spring of 2003, he heard about MFCA at a symposium and felt intuitively that this was the environmental management method he had been seeking.

He immediately tried to introduce MFCA to Company A on a trial basis. He asked the manager of Plant M to introduce MFCA, and the two men decided to introduce it at one of the production lines at Manufacturing Division T.

Mr. P made a presentation about the introduction of MFCA to the President X before introducing it on a trial basis. President X said, "MFCA is interesting. I have never thought of it before, but please promote MFCA by specifying specific targets if it can improve the soundness of the plant site."

Despite the president's affirmative opinion, the manufacturing floor still had a strong negative response to MFCA. Manufacturing Division T was very proud of its high yield rate. The division manager said, "Our plant has well-organized data and we know our defective fraction. What else do we need?" Responding to this opinion, Mr. P tried to persuade the plant staff, saying, "Let's try this. MFCA is not for checking results but for analyzing the production process." MFCA was then introduced on a trial basis.

The process of introducing MFCA begins with collecting data. Data were collected through a repetitive trial and error method. In the course of data collection, rules about how to handle such things as data about materials recycled in the production process and energy cost were determined through discussion each time such issues arose. Furthermore, Mr. P measured the necessary data unavailable from the existing production and accounting database himself using measuring instruments. He remembered that this measurement was a toilsome job.

Later, several staff members from Company G, one of Company A's subsidiaries, participated in the introduction to provide consultation on production technology. One of the participating staff members was well versed in the accounting system, and data were collected and analyzed in consultation with him. It took about six months to move from data acquisition to data analysis. Back then, few companies were introducing MFCA in Japan, and there were scarcely any cases to use for reference. Mr. P said, "The scarcity of references helped us proceed with the introduction. We processed easy-to-use data and designated them as Company A's MFCA."

The results of the trial introduction in Plant M were presented to President X in December 2003. It was clear that material losses from Plant M accounted for a large part of Company A's losses. Losses at Plant M had not been seen as a major problem because it was commonly recognized that salvage loss occurs naturally in the production process, and it is put back into the production line. Workers at Plant M

were very surprised at the results, and they were against disclosing the values outside of the plant. Mr. P, however, persuaded them to make the values public, saying, “They are not used to find points of accusation but to show points of improvement.”

Based on the results of the trial introduction, Mr. P said to President X, “Even though the company suffers from deficit operations now, it is more important to reduce material losses than to reduce the workforce because Company A is a manufacturing company.” Mr. P recalled saying, “Because Plant M is Company A’s major plant, the results obtained there were very instructive. If we had obtained results from a small process in a small plant, people would have assumed that we succeeded only because the trial was conducted on a small process in a small plant. The plant manager was very surprised at the amount of material losses at Plant M of Manufacturing Division T.”

Looking back to that time, then-President X said the following:

“(One of) the decisive factors in my mind that made me interested (in environmental management) is that the company adopted MFCA’s perspective and conducted the actual condition survey on a production line at Plant M in 2003. I learned that about 25% of the difference between input and output for the production line disappeared. What does the disappearance of 25% of the input amount mean? Because the survey results were very shocking to me, I decided to incorporate production innovation in the next midterm business plan. I think MFCA led to the innovation of production in my mind. I think that we can streamline production considerably by locating the source of that 25%.”

(3) Company-wide deployment of MFCA

Having confirmed that MFCA could reduce environmental impacts and costs simultaneously through the trial at Plant M, Mr. P selected model plants from each three in-house companies for company-wide deployment of MFCA. This, however, was the “beginning of the hardship” for Mr. P.

Mr. P went to the model plants with a certain degree of support from President X, but he faced the same opposition at each plant as he had at Plant M. He also found distrust of the new MFCA method among plant workers, who asked questions such as what they could get from this new method, whether there was any need to conduct analysis using such an unfamiliar method, and what the differences were between MFCA and the existing cost accounting? In particular, Mr. P was asked to explain in detail the difference between MFCA and the existing cost accounting. At the worksite, cost accounting was a tool to calculate cost, and it was not linked to improvement activities. At the worksite, workers address improvement activities on a daily basis from three viewpoints: manpower, working hours, and productivity. They asked him to explain the differences between MFCA and their daily improvement activities.

Responding to this resistance, Mr. P told the workers at the plants, “the focus of MFCA is not part of the process, but it is a tool to see the material flow of the entire process. Because it is an activity to understand the material flow, we have to coordinate it with company-wide activities for better management results.” Mr. P consistently persuaded the workers, saying, “If we succeed in reducing production costs by coordinating our activities to reduce waste and carbon dioxide (CO₂) from the environmental perspective, our activities will be assimilated with those of the entire plant.” Discussions

were also conducted on how to utilize the values calculated by cost accounting in the worksite. At the same time, efforts were focused on how to visualize the material loss rather than how to perform accurate calculations.

Mr. P. faced several issues in the course of the company-wide deployment. One of them was what MFCA would mean for Company A. One of the factors that raised this issue was that the promoters of MFCA's introduction were somewhat hesitant about the environmental management division introducing an accounting method instead of the financial division or the accounting division. At the same time, worksite staff asked about the relationship between the existing cost accounting and MFCA, showing objection to the new accounting method. Then, it was decided to address the issues by introducing the new process as "material flow activities"² instead of using the name MFCA. Therefore, MFCA was positioned as the calculation of material loss, independently from cost accounting.

The material loss measured by MFCA was called 'loss cost' at Company A. The loss cost includes raw material cost, energy cost, system cost (labor cost, depreciation cost, and other administrative costs), and waste disposal cost.

After the loss cost was clarified, a proposal for reduction and the feasibility of the proposal were discussed. During this process, staff members from the plant's manufacturing division, those working in production technology, and the production technology consultants from Company G discussed the feasibility of the proposal. Subsequently, each production plant made a list describing the breakdown and content of the loss along with issues and specific measures for reduction based on the analytical results. This list was used as the basis for a meeting of company managers, plant managers, working group members, and office members. Then, each in-house company prioritized activities for loss reduction and set target values for loss reduction activities. In this way, the plan-do-check-act (PDCA) cycle for loss reduction was established. Even staff at the plants saw the results of these activities.

The manager of Plant S said, "When we started MFCA, we were very confused. Because staff on the plant knew instinctively where and what waste was produced in the process, we were not able to find the significance of setting indices by calculating values with an electronic calculator. However, we found that we did not know how much value the loss had, and we were induced to make capital investments considering the loss value. This is the greatest result we achieved by introducing MFCA."

A representative of Company E said, "We traditionally considered the material losses produced in the process stage as unavoidable. Although we tried to reduce these losses by improving technology, we were somewhat wary of trying to reduce these losses. However, MFCA allowed us to locate points producing major material losses. Then, we tried to work out solutions starting with these points. This is one of the good results that initiated the introduction of MFCA. From the calculated values, we learned that we could manage to reduce losses. Without MFCA, we all knew where waste was produced. However, we were surprised to see how effective MFCA is because it allows us to specify the points producing waste. Listing material losses motivates us to take action. If we had started just to look for inefficient points without much thought, we could have given up and easily concluded 'we cannot do that.'"

Analysis based on MFCA was completed in every plant by the second half of 2005, and the results were presented at a management meeting. The results surprised President X. Later, production innovation

was built into the midterm business plan that started in 2006, and a midterm plan was made for reduction of the 'loss cost' clarified by MFCA.

The next issue was how to proceed with reducing the clarified 'loss cost'.

(4) Coordination between MFCA and production innovation

As mentioned above, MFCA is a method for clarifying material flow including material loss, namely 'loss cost' in Company A, in physical and monetary units. Production workers involved in the measurement will have a great sense of futility if MFCA cannot help them reduce loss cost. Naturally, they cannot achieve the original objective to create profit by using an environmental method. Accordingly, activities to reduce material losses are very important for a company that introduces MFCA.

In deploying MFCA to company-wide, a big issue arose for Company A. The environmental management division, with which Mr. P. was affiliated, had been promoting MFCA from the introduction to the company-wide deployment. Although it could visualize material losses through MFCA, it did not have methods or the knowledge to reduce material losses.

The team promoting MFCA had been staffed by Mr. P and a few employees of Company G since MFCA was introduced in 2003. While aggregating data and information for MFCA, Mr. P explored ways to build a department for improvement activities. He submitted a direct request for backup resources to his superior, Executive Managing Director Z, who was in charge of environmental management, and presented a proposal to establish a department focusing on improvement activities at the management policy meeting. He recalled that he had the hardest time during this period, that is, between 2005 and 2006.

At this time, Mr. Y, the managing corporate director in charge of research and development, tried to establish the Production Innovation Center within the Research and Development Division in order to address other problems. He was worried mainly about two aspects of Company A's production activities.

One of his concern was that those production activities aimed to achieve the target of cost reduction calculated by the traditional approach and ended up solving only some parts of the problem. When he visited an automobile manufacturer's plant, he saw that staff there worked on Kaizen and tried to remove many types of wastes (ex. waste of over-production, waste of transportation, waste of processing, waste of inventory etc.) thoroughly. He recognized the importance of the underlying philosophy of production activities and felt the need to envision an ideal production line and use innovative production activities to approach the ideal production line.

Another issue was how to clarify the contribution of production activities to management. The introduction of the in-house company system strengthened the autonomy of each in-house company. As a result, each in-house company addressed production improvement activities independently and reported their results to managers using their own separate indices. That is, the president and top managers wasn't able to compare each in-house company's production activities and the results.

Managing Director Y was worried about these problems and was thinking about how to set up a new department for production activities. At the same time, Mr. P was considering the construction of a mechanism to associate MFCA with activities to reduce material losses. Under these circumstances,

Managing Director Y (in charge of the Research and Development Center), Executive Managing Director Z (in charge of the environmental management division), and Mr. P got together to decide which of the two alternatives to select: establishing an MFCA task force within the environmental management division or establishing a new department for MFCA. Managing Director Y made the final decision and proposed establishing the Production Innovation Center staffed with specialists in production technology and entrusting this new department with MFCA. It was decided that Mr. P, who took the initiative to introduce MFCA, would be transferred to the Production Innovation Center in 2006.

The environmental management division was no longer directly tied to MFCA because both Mr. P and the MFCA implementation were transferred outside of the division. However, Mr. P asked members of the environmental management division not to be indifferent to MFCA, despite his departure.

However, members of the environmental management division seemed to have taken it for granted that MFCA would be transferred to the Production Innovation Center. This can be assumed from the comments of the manager of the environmental management division. He said the following:

“It is unnatural that the environmental management division is involved in the activities to incorporate MFCA into production technology, because MFCA is in a sense a production innovation. The environmental management division started to introduce MFCA because it focuses primarily on the environment, but MFCA is actually an issue involved in production technology.”

The following promotion system related to MFCA was established after MFCA was transferred from the environmental management division to the Production Innovation Center.

While the Production Innovation Center took on the administrative work, MFCA and material loss reduction was promoted by a working group that included the division of production technology and members from each production line in each in-house company. When it faced activities that it could not perform independently, staff from the Production Innovation Center would go to the worksite as needed.

The Production Innovation Center set production innovation indices when it was established in 2006 to clarify the contribution of production activities to management, one of the issues Managing Director Y was concerned with. These comprised five items: external loss cost (the amount to settle product complaints), internal loss cost (the amount involved in the disposal of defective products produced in the production process), productivity improvement cost (the amount to improve raw materials and labor costs used for production), safety loss cost (the amount incurred from equipment-related disasters and labor accidents), and environmental cost (the amount to dispose of waste produced inside the plant and the energy necessary for the disposal). The target reduction value was set for each of the five items and assigned to each in-house company. Staff from the Production Innovation Center joined the staff of each in-house company and addressed cost reduction together. The amount of cost reduction showed how much it affected the operating profit of the company as a contribution to management.

When transferred to the Production Innovation Center, MFCA was positioned as a method to help achieve the target values for the production innovation indices. Company A identified the costs involved in material losses clarified by MFCA as “loss cost”. As mentioned above, loss cost includes raw material cost, energy cost, system cost, and waste disposal cost. That is, reducing these ‘loss costs’ leads to achieving the production innovation index targets, especially internal loss cost, productivity improvement

and environmental cost, and contributes directly to company profit as a form of cost reduction. MFCA became important because it was associated directly with production innovation indices.

President X said, “We set up a target value for how much production innovation contributes to the increased operating profit. We have to incorporate the concept of material flow cost in setting the targets.”

Each in-house company was entrusted with the operation of MFCA around 2008. Although MFCA was deployed company-wide, the progress of MFCA operations varied by in-house company and plant. Mr. P also came to think that the MFCA activities should be focused on plants with large material losses. Site staff members like the production section manager and the production department manager were assigned the MFCA calculations. At the same time, each worksite explored the possibility of improving loss cost and activated the PDCA cycle in the worksite. Staff from the Production Innovation Center extended their support, but each production site essentially performed its MFCA-related activities by itself throughout the process.

After MFCA was transferred from the environmental management division to the Production Innovation Center, it came to be led by production departments, Company A faced radical changes in the external environment surrounding its production activities: a steep rise in the cost of raw material and the economic depression caused by the Lehman shock starting around 2007. How to achieve profits became a major issue in a situation that did not allow for sales to increase, as did how to address the skyrocketing raw material cost in stagnant business conditions. This increased the importance of production innovation greatly inside the company.

This situation motivated the company to position production innovation as one of the three columns, together with business development and human resource development, in its midterm five-year business plan starting in 2009, as it was in the preceding five-year plan. The target reduction value of loss cost for the period between 2009 and 2012 was set, and MFCA continued to be positioned as the major method for this midterm business plan.

In 2009, the Production Innovation Center was reorganized to deal with the above-mentioned steep rise in the cost of raw material as well as strengthen production innovation and the Production Innovation Center started to cooperate with purchasing groups.

Looking back to the day of the Production Innovation Center’s reorganization, Mr. Q, then its head, said, “The Production Innovation Center faced adverse conditions in the initial stages. However, it created a company-wide project and achieved great results in the long run. The Production Innovation Center would not have achieved results without MFCA. If MFCA had not been introduced, an increase of raw material cost would automatically increase the production cost.”

Recalling the MFCA introduction in Company A, Mr. P gave the following comment.

“MFCA is highlighted because it is a tool to reduce ‘loss cost’. If it had been a tool to focus on waste only, it would not have motivated the company to this extent.

“It would have been impossible to achieve such remarkable results if the introduction of MFCA had ended at Plant M and if the environmental management division had remained the only promoter of MFCA. In this sense, we were continuously blessed with good luck. The manager at Plant M agreed with introducing MFCA, Executive Managing Director Z followed up the introduction, Managing Director Y

supported the introduction from his position in production activities, and (then-)President X publicly announced the introduction of MFCA. As a matter of fact, I think that the success of the MFCA introduction was due to a series of coincidences because the right people got involved whenever required.”

(5) Change in the concept of ‘loss cost’

President X resigned at the end of the 2000s. Then, a new five-year midterm business plan began with the inauguration of a new president in 2009. The new business plan took on halving the energy costs and doubling the productivity as the major issues for production innovation. The company initially intended to promote the two new issues by coordinating them with MFCA.

To halve energy consumption, in particular, it was planned to clarify energy waste using MFCA and reduce energy consumption using the eco-just-in-time (ECO-JIT) method. Reducing energy consumption using MFCA was seen as another trial for the development of MFCA. Furthermore, the goal of doubling productivity included not only hourly productivity and labor productivity but also reducing waste with the help of MFCA.

In 2011, however, two great changes occurred in the network promoting MFCA. One is that Mr. P, who had taken the initiative to introduce and promote MFCA, left the company, and the other is that Managing Director Y, manager of the Production Innovation Center who had decided to implement MFCA, left his office.

Before these two changes, however, the network promoting MFCA had been changing gradually. One of the changes involved the execution system for MFCA as described above. Each in-house company and plant took the initiative in performing the PDCA cycle involved in the measurement of material losses and improvement activities, and the Production Innovation Center mainly played a supporting role in the activities for reducing ‘loss cost’. This was a natural process because the Production Innovation Center was not able to take the lead in implementing MFCA indefinitely itself.

Although each in-house company was entrusted with its own implementation of MFCA, the connection reducing ‘lost cost’ with the production innovation indices was maintained. At the same time, because the production innovation indices were kept active, MFCA would supposedly continue to be utilized as the method to achieve their targets. But, as result, each in-house company became strongly aware of the cost involved in collecting information on the material flow once it was entrusted with the utilization of MFCA.

Because staff collected information unavailable from the existing company accounting database and production management database manually, reducing the data collection cost was an issue. Company A planned to construct an information system to solve this issue and to foster the implementation of MFCA within the company, but this plan was not realized.

Mr. P, who had been promoting MFCA, left the company amid such developments as entrusting MFCA to each in-house company, adding doubling productivity and halving energy consumption as major goals of production innovation, and introducing a method to achieve the targeted productivity and energy consumption.

Although the midterm objective of reducing waste to zero was maintained, new targets like doubling productivity and halving energy consumption were added to midterm business plan. As a result, the new targets attracted more attention than reducing loss cost, and as MFCA had been entrusted to each in-house company, its use gradually declined.

In the midst of the changes in the network surrounding MFCA, the concept of 'loss cost' was revised in 2011. The revised concept was defined as the value obtained by multiplying the difference between the rate of material loss of the preceding year and that of the current year by the material cost of the current year. The 'loss cost' is the ratio of wasted material loss to used material.

That is, the purview of MFCA became smaller than the area it originally covered, as MFCA now applied only to the loss cost of the materials-to-waste ratio. However, the calculation of the material loss cost included not only the material-to-waste ratio but also the material-to-use ratio. This shows that the strategy to increase resource efficiency by considering input material was different from the waste reduction and zero emission activities that the company implemented before the introduction of MFCA. At the same time, evaluating the ratios of input material and output material in monetary units was intended to motivate the staff to reduce material loss in the same vein as MFCA.

Stated another way, the spirit of MFCA, which tried to improve resource efficiency in light of the difference between input and output and to offer an incentive for an approach to improving resource productivity, was passed on, though the definition of 'loss cost' was revised and the area of material to cover was changed. This is because the coordination between MFCA and production innovation indices was maintained.

4. Discussion

In this section, we analyze the transformation of the MFCA network by focusing on the features of its calculation.

The introduction and deployment of MFCA in Company A was initiated because of two problems that the company faced. One was that it had decided to designate environmental management as one of the bases of its efforts to recover from an operating deficit. The company aimed to create profits by promoting environmental management, but it did not have a method to do so. In search of a method for environmental management, the manager of the environmental management division, Mr. P, heard about MFCA. Because MFCA leads directly to cost reduction, it satisfied Company A's wishes to increase profits in through environmental management.

The major material losses clarified by the company-wide deployment of MFCA were presented at a management meeting and created impact for managers. This prompted Company A to incorporate production innovation in the midterm business plan in 2006, and the activities to reduce material losses were substantial. Then, another problem came to the surface.

Mr. P of the environmental management division promoted the introduction of MFCA, but he and the environmental management division were not able to get directly involved in the reduction of material losses because they did not have knowledge to reduce material losses. Even if the introduction of MFCA clarified material losses, a company cannot find any significance in introducing MFCA if it cannot then

reduce the material losses.³ In addition, the material losses that can be reduced through existing improvement activities is restrictive, and it is necessary to address modification of the manufacturing method, design, and materials for getting greater improvement results (Kokubu, 2011). A cross-divisional approach is also necessary for this modification, and it is necessary to appoint a responsible person who can supervise all issues involved in the introduction (Higashida, 2011). That is, the introduction requires a company-wide approach and an organization that supports it.

Then, Company A transferred MFCA from the environmental management division to the Production Innovation Center. This decision was not solely because Mr. P and MFCA required MFCA to be transferred. MFCA fit well with the ideas of Managing Director Y, who was in charge of research and development planning and wanted to strengthen production activities and set evaluation indices. Traditionally, each in-house company performed activities independently within Company A, and Company A did not have unified indices for company-wide evaluation of activities that each in-house company performed independently. In addition, the approach taken up to this point was conducted within the existing production mechanism and activities, and a philosophy on which production activities could be based did not exist. Managing Director Y planned to establish a new organization to solve these issues and strengthen the company-wide production activities. The introduction of MFCA fit well with solving these issues.

Reviewing the introduction of MFCA and the process of its deployment in Company A indicates that three key actors were responsible for its introduction and deployment: Mr. P, who was the promoter of MFCA; Managing Director Y, who agreed to let the Production Innovation Center take charge of MFCA; and then-President X, who placed environmental management at the core of the management targets.

Not only these actors affected the deployment process of MFCA, visualizing by MFCA allowed to integrate these actor's needs. This is why MFCA was maintained in a different form even after the departure of the strong promoter and supporters.

What should be noted here are the characteristics of MFCA as an accounting method. They can be divided into the input aspect, or information collection, and the output aspect, in which indices are presented as calculation results such as material loss. The influence of these two aspects on the introduction and change of the MFCA process within Company A needs to be analyzed.

The input aspect relates to the challenge of engaging production management from a shared point of view, because each in-house company managed production based on individual company rules. This problem was resolved by providing each in-house company with material flow information. Each in-house company possessed material flow even if the type of materials were different. If some factories used the same material, they could collaborate to reduce material loss from the same point of view.

On the other hand, the output aspect leads to the solution of the lack of an underlying production philosophy and the lack of uniform performance indicators to clarify the contribution of production activities to the company. MFCA calculates material loss as the difference between the input amount and the output amount, and no artificially created concept such as standard value or benchmark exists. This facilitated the creation of a production philosophy.

Before the launch of the Production Innovation Center, Managing Director Y said that he visited an

automaker's plant and was impressed with the attitude that even one single process mistake should be improved. At the same time, he felt keenly that Company A was lacking a philosophy to eliminate mistakes and wastes and increase productivity as much as possible. Company A set up targets of zero defective products, zero accidents, and zero waste in its midterm business plan starting in 1996 as part of its development of a philosophy for production activities. Then Company A tried to nurture the philosophy of production activities by addressing 'loss cost'. Because addressing the reduction of 'loss cost' is directly associated with achieving the targets of zero defective products and zero waste, MFCA and activities to reduce 'loss cost' are assumed to have affected the development of the philosophy for production activities. This cannot be realized only by regarding MFCA as a tool for reducing material loss. Company A successfully achieved results because it introduced MFCA as the major method for supporting its production innovation activities.

Looking back to the activities during the three years starting in 2006, Managing Director Y said, "Staff at the worksite improved their awareness greatly as a result that they were engaged in activities to create a philosophy for each production line."

Additionally, another factor of output aspects is 'loss cost' in monetary units. This index was closely associated with production innovation indices as well as being the midterm target in the environment management plan. To be specific, the internal loss cost, environment cost, and reduction of raw material cost in production management indices were directly affected by the reduction of 'loss cost'. Besides, they are directly linked to the profit in the profit and loss statement. That is, reducing 'loss cost' that is visualized by MFCA is closely connected with production innovation indices and the profit. Therefore, material loss or 'loss cost' calculated by MFCA has affected Company A's activities from both the ecological and economical point of view.

As mentioned above, MFCA is assumed to have spread within Company A because it provided all in-house companies with a uniform framework both for the input aspect of collecting material flow information and for the output aspect of setting indices for calculation results. MFCA's concept of material loss developed into the philosophy of production activities for Company A.

The network surrounding MFCA greatly changed and the MFCA activities themselves became stagnant after 2011, because the staff that promoted the introduction and spread of MFCA had left. Under these circumstances, however, MFCA's basic concept of the input and output of materials and evaluation of them in monetary units to inspire resource efficiency improvement remained in the company despite the changed model of MFCA. This is because MFCA's calculation method contributes to the development of a production philosophy and because the production innovation indices are maintained in coordination with MFCA.

This case study shows that MFCA is affected by human actors' network and is kept as calculation method in a company.

5. Conclusion

In this paper, we descriptively analyzed that the introduction and transformation process of the visibility by MFCA within a company and showed that the absence of an environmental management

method leading to profit acquisition and the absence of a department for reducing material loss built momentum in the transformation process of MFCA.

Additionally, there were people who promoted the introduction and supported the resolution of these problems. Of course, the human actors are important, but other actors also played an important role in the transformation of MFCA. They are the Production Innovation Center, production innovation indices, and the midterm business plan. MFCA transformed through its association with the company's core mechanism to support overall corporate management and production activities. This is assumed to have allowed the core concept of MFCA to stay alive within the company in coordination with production innovation indices and in association with the philosophy of production activities, even after the use of MFCA become inactive and the concept of 'loss cost' changed.

In brief, we clarified that not only MFCA was affected by the context where MFCA was embedded, but also MFCA affected and created the context. This shows the process that the environmental problem had been incorporated in a company through a calculation.

Notes

- ¹ The affiliations and job titles of interviewees are those at the time of interview. All a company name, division names, and personal names are anonymous.
- ² In this paper, the term "material flow activities" is not used; the term "material flow cost accounting" (MFCA) is used uniformly.
- ³ Responding to these issues, Nakajima (2011) proposed that MFCA should be utilized not only for reducing material loss but also for the management index of resource productivity.

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