Impact of Introducing Material Flow Cost Accounting: A Comparative Review of Supply Chains and Individual Companies

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***Abstract*—This paper systematically organizes cases of material flow cost accounting (MFCA) compiled so far and compares the impact of its introduction on supply chains and individual companies. Several key differences were revealed between supply chain cases and individual company cases. For instance, opportunities to improve on losses related to in-process recycling were higher in the case of individual companies, while in the case of supply chains, there was a strong trend toward discovering significant losses in the application fields of processing and assembly models, such as electronic and electrical machinery production, fields where the loss rate is low for individual companies. These findings are expected to be useful to companies and supply chains newly introducing MFCA.**

***Keywords*—Material Flow Cost Accounting; MFCA; environmental accounting; supply chain**

I. Introduction

The impact of introducing material flow cost accounting (MFCA) has been discussed in many cases till date. MFCA has been introduced and implemented in a variety of industries and various areas, with a multitude of results. This paper systematically organizes the cases exploring the impact of its introduction, and aims to examine the nature of impact and the areas where the impact can be maximum. When introducing MFCA, the subject and processes with the maximum impact are ascertained, and it is considered that guidance can be provided at the time of introduction.

This paper tries to make clear which products or process lead maximum impact in producing MFCA, and it is considered that guidance can be provided at the time of introduction.

In addition, the scope of MFCA does not have to remain limited to one company. Rather, it can be applied to the entire supply chain, from the collection of resources to the disposal of products. Since it can significantly help in improving resource productivity, the expansion of its scope of application from a company to the entire supply chain is encouraged. However, the varied effects it shows when it is applied to the supply chain and individual companies have not yet been organized. Therefore, this paper differentiates between cases for supply chains and individual companies. The effects of introducing MFCA are compared, with focus on the relationship between the loss, improvement activities and company attributes.

II. Effects of Introducing MFCA on Individual Companies

A. Overall Trends

While there are several reports pertaining to MFCA cases in individual companies, in this section, we would like to organize their content based on the "Classification of Cases of Introductions of Material Flow Cost Accounting: Interrelationship of Loss and Improvement Activities" ［1］, which was the graduation dissertation of Kawamura Nozomu, who is affiliated to the Kobe University Kokubu Research office. Kawamura analyzed 77 instances, based on the reports of the Japan Management Association Consulting［8］［9］［10］［11］［12］［13］［14］ and the Japan Environmental Management Association for Industry［6］ cited in the bibliography section, targeting cases that have been adopted and publicly offered in the MFCA model project implemented from fiscal years 2000–09 by the Ministry of Economy, Trade and Industry; the Organization for Small and Medium Enterprises and Regional Innovation; and the Tohoku Bureau of Economy, Trade and Industry.

These cases are depicted in Table 1, which has been segregated into "Loss Rate" and "Application Field." The application fields are based on the 14 types of MFCA fields of application as mentioned in the report of the Ministry of Economy, Trade and Industry ［2］. These fields comprise forming process, machining process, chemical reaction process, mixing and filling package process, paper processing, food & beverage manufacturing, electronic & electrical machine production, and surface treatment. Several cases with a 1–10% loss rate were observed, with the chemical reaction process field having a higher loss rate. This suggests that losses indicated from the chemical reaction process which highest because of the character of chemical reaction process which use much auxiliary materials like water.

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TABLE I. Percentage Of Loss Rate in Each MFCA Field of Application (numbers indicate number of cases)[1]

loss rate \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	Others	Sum
above 50%	0	0	2(29%)	0	0	1(11%)	0	0	0	3(4%)
40-less than50%	1(7%)	0	1(14%)	0	0	0	1(10%)	1(25%)	0	4(5%)
30-less than40%	3(20%)	3(25%)	0	0	1(13%)	0	0	0	0	7(9%)
20-less than30%	2(13%)	1(8%)	3(43%)	0	2(25%)	3(33%)	2(20%)	1(25%)	1(17%)	15(19%)
10-less than20%	3(20%)	3(25%)	1(14%)	1(17%)	1(13%)	1(11%)	0	0	2(33%)	12(16%)
1-less than10%	6(40%)	5(42%)	0	4(67%)	4(50%)	4(44%)	5(50%)	2(50%)	1(17%)	31(40%)
less than 1%	0	0	0	1(17%)	0	0	2(20%)	0	2(33%)	5(6%)
sum	15(100%)	12(100%)	7(100%)	6(100%)	8(100%)	9(100%)	10(100%)	4(100%)	6(100%)	77(100%)

Subsequently, taking reference from Shimogaki ［7］, the losses revealed by the MFCA analysis were divided into i) processing yield loss; ii) loss due to defects; iii) in-process recycling loss; iv) conversion loss; v) inventory disposal loss; vi) auxiliary materials loss, and vii) disposal loss. Results analysis relationship with the application fields are shown in Table 2. Since there were several instances of multiple losses occurring in a single case example, the total number of losses is greater than the total number of case examples. A trend of significant processing yield loss was observed in each field, with the percentages being particularly high in machine processing and paper processing. There were fields, such as the paper processing field, which only indicated losses due to processing yield and defective product, and there was a trend of specialization of losses in this field. In addition, processing yield loss is most frequent in the chemical reaction processing field, which has a high loss rate; hence, we can see a point for improvement here.

TABLE II. Classification of Loss Discovered in Each MFCA Field of Application (numbers indicate number of cases)

Classification of loss \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	Others	Sum
processing yield loss	8(32%)	8(62%)	5(38%)	0	7(50%)	3(30%)	6(38%)	2(25%)	1(9%)	40(34%)
loss due to defects	5(20%)	3(23%)	0	2(22%)	7(50%)	1(10%)	5(31%)	1(13%)	1(9%)	25(21%)
in-process recycling loss	7(28%)	0	2(15%)	2(22%)	0	0	0	0	0	11(9%)
conversion loss	1(4%)	1(8%)	3(23%)	2(22%)	0	0	0	0	2(18%)	9(8%)
inventory disposal loss	0	1(8%)	0	0	0	2(20%)	1(6%)	0	3(27%)	7(6%)
auxiliary materials loss	4(16%)	0	3(23%)	0	0	2(20%)	1(6%)	2(25%)	1(9%)	13(11%)
disposal loss	0	0	0	0	0	0	0	2(25%)	1(9%)	3(3%)
others	0	0	0	3(33%)	0	2(20%)	3(19%)	1(13%)	2(18%)	11(9%)
sum	25(100%)	13(100%)	13(100%)	9(100%)	14(100%)	10(100%)	16(100%)	8(100%)	11(100%)	119(100%)

Next, five factors ［5］ comprising on-site improvement, raw material change, product design change, production method and plan change, and equipment change were cited as the methods of improving the revealed losses; improvement through loss recycling, and others were also added. Table 3 shows these classifications and the results of the analysis. It also includes proposals for improvements, in addition to actual improvements. Since there are multiple improvements and proposals for improvement

[1] Table 1, 2, and 3 are based on ［1］, with partial revisions made by the author.

for each loss, their total number is greater than the total number of losses. When we look at Table 3, we see there is a high degree of improvement due to changes to raw material in the machine process field. This indicates that losses due to trimming and cutting are significant in this field, and therefore losses have been reduced through specification changes of raw material. A major characteristic of the chemical reaction process field is that while it conducts few on-site improvement activities, it carries out several changes pertaining to product design and equipment. This is considered to be a characteristic of the chemical reaction process field which is dependent on devices. In addition, the food & beverage production field conducts significant improvement activities due to loss recycling, such as inspections of processed new products that generated a loss.

TABLE III. The Scope of MFCA Application and Improvement Activities (numbers indicate the number of cases)

improvement activities \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	Others	Sum
comprising on-site improvement	12(33%)	8(31%)	1(10%)	3(30%)	7(39%)	5(50%)	5(29%)	1(25%)	5(35%)	47(32%)
raw material change	3(8%)	7(27%)	1(10%)	2(20%)	1(6%)	2(20%)	4(24%)	1(25%)	1(7%)	22(15%)
product design change	5(14%)	0	3(30%)	1(10%)	2(11%)	0	3(18%)	0	2(13%)	16(11%)
production method and plan change	5(14%)	1(4%)	2(20%)	1(10%)	0	1(10%)	0	0	1(7%)	11(8%)
equipment change	10(28%)	7(27%)	3(30%)	3(30%)	6(33%)	1(10%)	4(24%)	2(50%)	3(20%)	39(27%)
improvement through loss recycling	1(3%)	0	0	0	0	0	0	0	2(13%)	3(2%)
others	0	3(12%)	0	0	2(11%)	1(10%)	1(6%)	0	1(7%)	8(5%)
sum	36(100%)	26(100%)	10(100%)	10(100%)	18(100%)	10(100%)	17(100%)	4(100%)	15(100%)	146(100%)

B. Relationship between Effects of MFCA and Methods of Production

Of the MFCA-introduction case studies that were analyzed, classifications of “low variety, mass production” and “wide variety, low production” were specified in 22 cases, with 7 cases of low variety and 15 of wide variety. On analyzing their loss costs as a percentage of the total, it was found that about 60% of the cases of “wide variety, low production” had a loss cost percentage of over 20%. Since 40% of “low variety, mass production” had loss costs of over 20%, it was understood that “wide variety, low production” showed a higher percentage of loss costs. Furthermore, in “wide variety, low production,” the percentage that accounts for material costs was seen to be generally higher compared with system costs and energy costs.

A significant processing yield loss was frequently observed in both “low variety, mass production” and “wide variety, low production.” The considerably higher defective product loss was also a characteristic of “mass variety, low production.”

As for the relationship with proposed improvement activities, any characteristic points could not be seen for “low variety, mass production” or “wide variety, low production.” However, a significant percentage (80%) of improvement activities in “wide variety, low production” were triggered by changes in product design, which shows that product design was relatively important because of the

wide variety produced.

C. Relationship between Improvement Activities, Loss and Range of MFCA Application

From the results described above, it was ascertained that different kinds of losses are likely to be discovered in each range of MFCA application. For example, in-process recycling loss was often found in the forming process, changing loss[2] was found in mixing and filling package processing, and auxiliary materials loss were identified relatively high in chemical reaction processing and surface treatment. It was also revealed that the more the case example had the attribute of producing a wide variety, the more identified significant loss.

Of the case examples examined, 27 specified that they implemented an improvement plan, with improvement measures for the processing yield loss being the most frequent. The in-process recycling loss was notable and eight of the 11 companies in the case examples that were measured as having a major loss implemented improvement measures for it. In-process recycling is frequently admitted as good for not disposing but recycling, and it is rarely targeted for improvement. The fact that in-process recycling loss was evident through MFCA, and there were many companies implementing improvement measures for it shows that it is one of the important effects of MFCA.

As far as improvement proposals and improvement activities actually implemented are concerned, it was found that case examples where improvements were actually implemented were slightly higher the loss distribution rate was compared with total cases. This indicates that the larger the discovered loss, the more likely the case example was to conduct improvement activities. In addition, many improvements that were implemented were pertaining to on-site improvements and changes to product design, such as increasing the number of products made from one material. This indicates that the case examples preferred improvement activities with minimal costs.

III. Effects of Introducing MFCA into the Supply Chain

The analysis of the effects of introducing MFCA into the supply chain took place over three years, from fiscal year 2008 to fiscal year 2010, and used the 58 case examples adopted for the Supply Chain Resource Saving Partnership Promotion Project commissioned by the Ministry of Economy, Trade and Industry. [3] The medium of analysis were the Ministry of Economy, Trade and Industry industries compiled from the case examples during the three-year project. In this section, improvement activities,

[2] Changing loss: losses which recognized when changes production lines. Test production or setting cost are the example.

loss classification, and fields of MFCA application are extracted and their relationships are shown, as was done for individual companies. However, characteristics of supply chain, multiple companies and factories are included in a single case example. Therefore, there are multiple fields of application for one case example, and as a result, the total for fields of application in the subsequent analysis is greater than the number of case examples.

TABLE IV. Relationship between the application field in the supply chain and the loss rate (numbers indicate the number of cases)

loss rate \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	textile processing	Sum
above 50%	4(29%)	7(23%)	1(50%)	0	0	0	4(57%)	2(18%)	0	18(21%)
40-less than50%	0	2(6%)	0	0	0	0	1(14%)	1(9%)	0	4(5%)
30-less than40%	2(14%)	12(39%)	0	0	3(30%)	0	1(14%)	6	0	24(28%)
20-less than30%	3(21%)	3(10%)	0	2(50%)	2(20%)	0	0	0	0	10(11%)
10-less than20%	1(7%)	4(13%)	0	0	1(10%)	1(50%)	1(14%)	1(9%)	3(50%)	12(14%)
1-less than10%	2(14%)	3(10%)	0	1(25%)	3(30%)	1(50%)	0	1(9%)	3(50%)	14(16%)
less than 1%	2(14%)	0	1(50%)	1(25%)	1(10%)	0	0	0	0	5(6%)
sum	14(100%)	31(100%)	2(100%)	4(100%)	10(100%)	2(100%)	7(100%)	11(100%)	6(100%)	87(100%)

When we look at Table 4, we see that just as in the case of individual companies, a characteristic for supply chains is that the distribution in the 1–10% range is high, but the distribution above 30% is high as well. In particular, companies with a loss rate of 50% or more account for more than half in electronic and electrical machinery production. This again can be said to be a characteristic of supply chains. In case of individual companies, electronic and electrical machinery production mainly pertains to assembly work, and hence losses do not appear often. However, the loss rate is high for supply chains.

TABLE V. Classification of loss discovered in each field of MFCA application in the supply chain (numbers indicate the number of cases)

Classification of loss \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	textile processing	Sum
processing yield loss	11(50%)	29(58%)	2(50%)	2(50%)	7(47%)	1(20%)	7(78%)	9(50%)	3(43%)	71(53%)
loss due to defects	6(27%)	8(16%)	0	0	3(20%)	1(20%)	2(22%)	3(17%)	0	23(17%)
in-process recycling loss	2(9%)	2(4%)	0	0	0	0	0	1(6%)	0	5(4%)
conversion loss	0	3(6%)	0	1(25%)	1(7%)	0	0	1(6%)	1(14%)	7(5%)
inventory disposal loss	0	0	1(25%)	0	0	0	0	0	1(14%)	2(1%)
auxiliary materials loss	2(9%)	6(12%)	1(25%)	1(25%)	4(27%)	2(40%)	0	4(22%)	2(29%)	22(16%)
disposal loss	1(5%)	2(4%)	0	0	0	1(20%)	0	0	0	4(3%)
sum	22(100%)	50(100%)	4(100%)	4(100%)	15(100%)	5(100%)	9(100%)	18(100%)	7(100%)	134(100%)

Table 5 shows the results of the loss classification conducted in each field of application. It shows that processing yield loss is high regardless of the field, and defective product loss is also increasing, with a particularly high percentage in paper processing. Overall, auxiliary material loss is comparatively high. On the other hand, the in-process recycling loss is not very high. All seven companies in electronic and electrical machinery production said they had incurred a processing yield loss. This trend differs from the analysis of individual companies, which shows a trend of hardly any materials loss since typically only parts are assembled in the final set maker. However, in fact, this is consistent with the finding that a significant loss occur when producing these materials and parts ［4］.

TABLE VI. Improvement Activities and Fields of MFCA Application in the Supply Chain (numbers indicate the number of cases)

improvement activities \ application field	forming	machining	chemical reaction	mixing and filling package	paper	food & beverage manufacturing	electronic & electrical machine production	surface treatment	textile processing	Sum
comprising on-site improvement	2(6%)	9(%)	0	0	0	0	0	3(12%)	2(22%)	16(9%)
raw material change	9(27%)	18(50%)	2(33%)	1(17%)	2(12%)	0	6(55%)	6(23%)	0	44(25%)
product design change	6(18%)	7(19%)	0	0	4(24%)	0	0	3(12%)	0	20(11%)
production method and plan change	4(12%)	12(33%)	2(33%)	1(17%)	4(24%)	1(17%)	0	6(23%)	3(33%)	33(18%)
equipment change	6(18%)	7(19%)	1(17%)	2(33%)	3(18%)	1(17%)	2(18%)	4(15%)	2(22%)	28(16%)
improvement through loss recycling	3(9%)	3(8%)	1(17%)	0	1(6%)	1	0	1(4%)	1(11%)	11(6%)
others	3(9%)	8(22%)	0	3(43%)	3(18%)	3(50%)	3(43%)	3(12%)	1(11%)	27(15%)
sum	33(100%)	64(100%)	6(100%)	7(100%)	17(100%)	6(100%)	11(100%)	26(100%)	9(100%)	179(100%)

Table 6 shows the relationship in terms of how losses revealed by the application of MFCA to the supply chain were controlled. Several case examples cited changes to raw materials. In particular, half of the case examples, including forming process and machine process, submitted improvement proposals of changes to raw material. While equipment changes were not that high overall, the results indicated that within forming processing, there were a comparatively high percentage of improvements through equipment changes. This suggests that it is possible to examine equipment investment comparing negative product costs and costs necessary for equipment introduction by measuring the loss rate through the introduction of MFCA.

IV. Comparison of Benefits of Introducing MFCA to the Supply Chain and Individual Companies

Although we have seen that the impact of introducing MFCA into supply chains an individual companies varies, we will now take a more detailed look at this aspect. Table 7 is a comparison of the loss rates in supply chains and individual companies. Since case examples of supply chains include multiple fields of application, its total is greater than the overall number of case examples.

Comparison of Loss Rates[3]

[3] Since all supply chain case examples did not publish their loss rates, its total number is smaller than the total number of case examples. In the supply chain case examples, in principle, the target was "the negative cost" rate which the part of not become products of the entire supply chain. However, according to the case study, there were some that only published the value of the individual organization in the supply chain, and in these cases, the highest value was used. In such cases, the values differ from the values in the results of the analysis in the preceding section

object / ross rates %)	individual companies	supply chain
above 80%	3(4%)	1(2%)
70～less than80%		5(10%)
60～less than70%		2(4%)
50～less than60%		4(8%)
40-less than50%	4(5%)	3(6%)
30-less than40%	7(9%)	11(22%)
20-less than30%	15(19%)	6(12%)
10-less than20%	12(16%)	6(12%)
less than10%	36(47%)	11(22%)
sum	77(100%)	49(100%)

It was evident that "less than 10%" is the largest percentage for both individual companies and supply chains. In particular, roughly half of the individual companies fell in this category. On the other hand, when the scope is expanded to the supply chain, the "less than 31–40%" loss rate is as high as the "less than 10%" rate. In addition, a high loss of over 50% is commonly cited in case examples of supply chains. In other words, the results indicate a higher loss rate when introducing MFCA into the supply chain.

TABLE VII. Comparison of Loss Categories

object / Classification of loss	individual companies	supply chain
processing yield loss	40(33.6%)	71(53%)
loss due to defects	25(21%)	23(17%)
in-process recycling loss	11(9.2%)	5(4%)
conversion loss	9(7.6%)	7(5%)
inventory disposal loss	7(5.9%)	2(1%)
auxiliary materials loss	13(10.9%)	22(16%)
disposal loss	3(2.5%)	4(3%)
others	11(9.2%)	0(0%)
total	119	134

Table 8 is a comparison of the categories of loss revealed after introducing MFCA. The analysis of individual companies shows a high loss for in-process recycling, in addition to defective product loss and processing yield loss. On the other hand, although the high processing yield loss did not change when MFCA was applied in the supply chains, the results did show low auxiliary material loss and low defective product loss in in-process recycling. When we analyze this according to supply chain units, it suggests that there is a trend toward frequent loss reduction due to processing yield and auxiliary materials, since there are several case examples that include a machine-processing process. On the other hand, in recycling, there are few cases implemented at individual supply chains, but many cases of open recycling or of only in one company.

TABLE VIII. **Improvement plans examined for loss**

object / improvement activities	individual companies	supply chain
comprising on-site improvement	47(32%)	16(9%)
raw material change	22(15%)	44(25%)
product design change	16(11%)	20(11%)
production method and plan change	11(8%)	33(18%)
equipment change	39(27%)	28(16%)
improvement through loss recycling	3(2%)	11(6%)
others	8(5%)	27(15%)
total	146	179

When we look at the improvement plans examined for loss in Table 9, we see that the highest percentage is for on-site improvements in case examples of individual companies. Conversely, in the analysis of supply chains, the biggest percentage is for changes to raw material. As previously stated, the biggest losses were found to be in processing yield for both individual companies and supply chains, although differences can be seen in their respective improvement plans. This indicates that changes to raw material that were unmanageable in individual organizations have become manageable in the supply chain by applying MFCA. When we have a look at each case example, we frequently see descriptions of communication between various companies regarding the examination of improvement plans based on the results of the MFCA analysis. It was thus considered that loss which could not be avoided was possibly tampered with.

V. CONCLUSION

The results indicate that the impact of introducing MFCA in supply chains is different from the effect of its introduction in individual companies.

In particular, it can be said that high loss rates in supply chains is a significant effect of the introduction of MFCA in fields where low loss rates were seen in individual companies, such as electronic and electrical machinery production. In addition, the analysis showed there is significant potential to improve losses by changing the raw material in the supply chain. These factors indicate that introducing MFCA in the supply chains has proved to be beneficial so far.

On the other hand, in the case of individual companies, the fact that hidden losses, such as the in-process recycling, are pointed out by MFCA, coupled with examples of several cases implementing

improvements to control the losses, is an important knowledge for the potential introduction of MFCA. This shows a new perspective for MFCA, of indicating where there is room for improvement, rather than ending at the point when the in-process recycling is completed.

In addition, it can be said that the characteristics of each application field include major suggestions for the introduction of MFCA in the future.

ACKNOWLEDGEMENT

This paper is part of the results of the Ministry of Environment's Environmental Research and Technology Development Fund (1E-1106) and this research is supported by the Japan Society for the Promotion of Science (grant number 25285138).

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