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Introduction of material flow cost accounting (MFCA) to the supply chain: a questionnaire study on the challenges of constructing a low-carbon supply chain to promote resource efficiency

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1. Introduction

Efficient environmental management is becoming more important for enterprises. In order to achieve governmental reduction goals for greenhouse gas emissions set for every industry in Japan, many Japanese enterprises are carrying out technology development for “energy and resource conservation”, and are marketing “environmentally friendly products”.

Under such circumstances, enterprises are not only developing more environmentally friendly products, but are also working on the reduction of environmental impacts with measures of environmental management. Material flow cost accounting (MFCA) had been promoted in Japan since the year 2000 in order to increase resource productivity, originally based on a German idea (Strobel

and Redmann, 2000, 2001).¹ MFCA is an environmental management accounting method that simultaneously pursues the reduction of environmental impact and reduction of cost. MFCA has been globally used and recognized as one of the most useful environmental management accounting method (see Burritt and Saka, 2006; Onishi et al., 2008; Herzig et al., 2012; Schmidt and Nakajima, 2013; Fakoya and Margaretha van der Poll, 2013). Public recognition in Japan and abroad has grown since the publication of the international standard on MFCA, ISO 14051, in September 2011 and its Japanese adaption, JIS Q14051,² in March 2012 (ISO, 2011). Since then the concept of MFCA has been further developed both theoretically and methodologically. Its scope has been widened from MFCA procedures within individual enterprises to the extended accounting of material flows along entire SCs (supply chains) (METI, 2011, 109–122).³

Public awareness and political programs to reduce environmental burdens presently focus strongly on the reduction of CO₂

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¹ In the Japanese METI projects to develop environmental management accounting, MFCA methodology was introduced individually into Japanese enterprises. The METI project continued for about 10 years from 2000, and some reports were published in Japanese (e.g. http://www.meti.go.jp/policy/eco_business/mfca/MFCA-summaryEng.pdf). MFCA has been developed in European countries based on regional perspectives (FEM and FEA, 2003; Wagner and Enzler, 2006; Jasch, 2009).

² JIS stands for “Japanese Industrial Standards”, and Q stands for “Management System” on JIS.

³ MFCA has begun to be implemented not only to industrial organization but also nonprofit organization (e.g. Papaspyropoulos et al., 2012). In the Japanese METI projects, MFCA has been introduced into hospital, restaurant and hotel, too. And MFCA approach has been applied to other research fields. (e.g. Low et al., 2014).

emissions, pinpointing emissions of CO₂ and other greenhouse gases as (one of) the dominant factors of environmental impact. A major challenge therefore seems to be to promote environmental management systems that target a low-carbon economy. While MFCA in its initial stages concentrated mainly on the analysis of, and measures within, single companies, it is also expected today to find additional, perhaps even higher potentials for carbon reduction along the SC (supply chain) by making use of synergetic optimization and cooperation within the SC network.

The present paper therefore evaluates, first, existing SCs from the perspective of a low-carbon approach, by applying MFCA, and investigates management mechanisms targeting a low-carbon SC. The present paper will try to define the requirements for a low-carbon SC, including the upstream and downstream enterprises in the scope of the evaluation, along with one's own company, by sharing CO₂ emission information among these enterprises (Kokubu et al., 2012). The paper will discuss how low-carbon SCM (supply chain management) might be planned, executed, and controlled in order to construct a low-carbon SC.

First, the relationship between buyers and suppliers with respect to low-carbon SCM is examined. Subsequently, the challenges in introducing MFCA in SCM are identified based on a questionnaire study carried out with domestically listed Japanese companies in February 2012. Finally, the implications and challenges for future research are discussed.

2. Relationship between buyers and suppliers

2.1. Visualizing material losses

MFCA quantifies material loss in relation to a product or a production process. MFCA carries out a cost evaluation of that material loss using production cost information, and is used as management accounting information to increase resource productivity. The reduction of material loss simultaneously decreases environmental impact and cost, and decreasing the amount of input material or the amount of energy used can help construct a low-carbon SC. MFCA is

therefore not only a cost control tool, but also an environmental impact control tool.

According to previous research, the material losses assessed by MFCA can be classified into the two types shown in Fig. 1.

As shown in Fig. 1, material losses visualized by MFCA can be classified into material losses that can be reduced and improved immediately at the production site and material losses that require further medium-to long-term studies or other financial or technical measures. While the former can be tackled directly by the production department itself, the latter requires cooperation outside the production department. For example, when MFCA shows that a change of production method or of product design is required in order to reduce material losses, it will be necessary to seek cooperation from multiple functions within the organization, such as the production technology department, the product development department, the research and development department, etc. Furthermore, it is possible that material loss can be reduced only by obtaining the cooperation of suppliers beyond one's own company. In that case, the purchasing department must take the initiative and seek the cooperation of suppliers. Accordingly, when targeting a low-carbon SC the relationship between a buyer and supplier has to be examined closer.

2.2. Relationship between a buyer and supplier introducing MFCA

The concept of SC has been discussed from different angles looking at the transportation and distribution of goods, value chains, etc. However, it is often treated in a narrow sense as the singular responsibility of a procurement department. If, on the other hand, the material flow along the entire SC is followed, and the construction of an optimum low-carbon SC is considered, the other departments, such as product development, production, sales, and logistics, must be involved, too.

Cooper and Yoshikawa (1994), focusing on cost management in the Japanese automotive industry, illustrated the wide scope of SCM in order to satisfy needs of a specific customer group, regardless of the enterprise, political, or geographical boundaries; all the steps related to the movement of a product from the supply

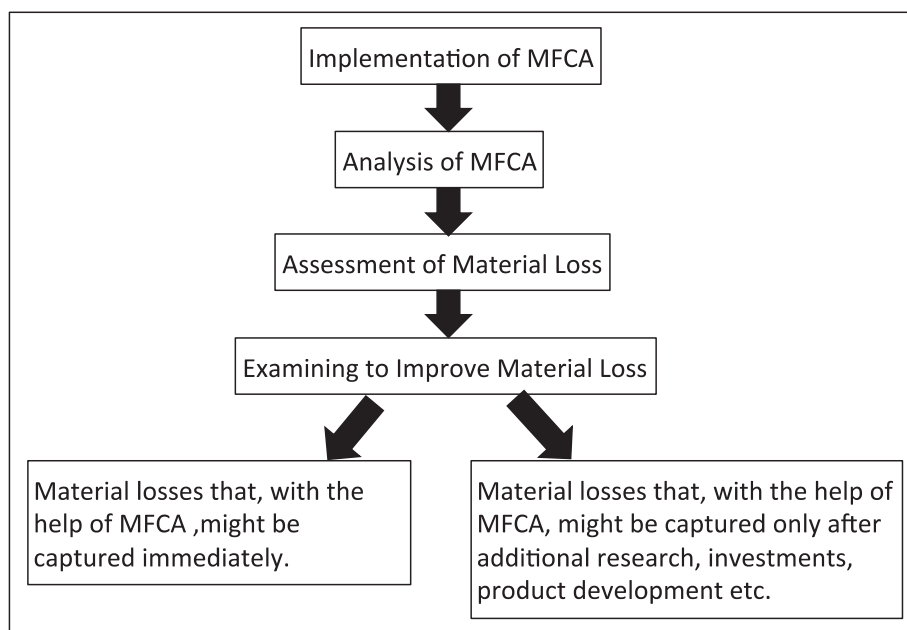


Fig. 1. Classification of material loss reduction in MFCA.
Source: Revised Nakajima and Kimura, 2012, p. 16.

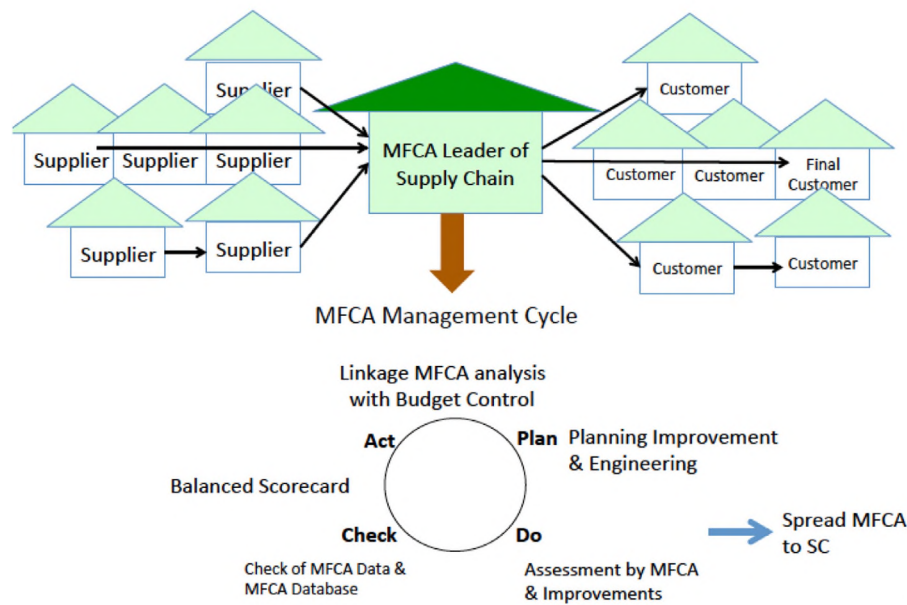


Fig. 2. Positioning of an MFCA leader in a low-carbon SC.

of materials to the end users are planned, supervised. Also, Tanaka (1998) stated that SCM tunes the flow of raw materials to meet the customer's demand for service. As is apparent from these definitions, SCM must plan and control the series of material flows from the starting point of resource extraction, to the manufacturers of materials and parts, to the end customer and final disposal.

Asanuma (1997) discussed the changes in internal organization and inter-enterprise organization of the automotive and electrical and electronic equipment industries of Japan from the perspective of comparative system analysis.⁴ In considering changes in the inter-organizational relationships outside the enterprise, Asanuma focused on the "Core enterprise", which functions as the core of a network, and is the organizer of the network from parts production to the end customer. The core enterprise is generally in charge of the final product, and while it also produces some of the essential parts, it purchases a substantial proportion of parts from suppliers. The core enterprise is also largely responsible for sales. This means that the core enterprise referred to here is in a business relationship with both suppliers and customers and, in terms of SCM, the core enterprise is the main constituent of the SC network.

⁴ The network referred to here is the network of enterprises created through an enterprise, which assigns a brand to durable goods that are sold in large quantities, entering into a business relationship with many other enterprises (Asanuma, 1997, 154).

⁵ According to Cooper and Slagmulder (1999), inter-organizational cost management is an approach that is organized to reduce the cost of the entire network by coordinating the activities of the enterprises participating in the supplier network.

⁶ For example, Cooper and Slagmulder (1999) divide the supplier network in which lean enterprises procure parts from suppliers into the three types of kingdom, barony, and republic, depending on the number of core enterprises. For the kingdom type, a single company plays a central role in dominating the network, and the suppliers etc. that constitute the corresponding network work with the objective of supporting the core enterprise. Also, although not explicitly stated by Cooper and Slagmulder (1999), it is thought that the core enterprise becomes a lean leader in supply chain like MFCA leader in supply chain, mentioned in this paper. The lean leader actively manages the three elements of performance, quality, and cost fundamental for the survival of the enterprise, and should make strategy to be shared with suppliers.

Cooper and Slagmulder (1999) discussed the series of material flows between buyer and supplier targeting low cost and high quality while introducing lean manufacturing, particularly in the Japanese automotive industry, as an inter-organizational cost management concept.⁵ They also assumed that the core enterprise plays a major role in the relationships between suppliers and buyers in order to achieve lean manufacturing.⁶

Based on the research mentioned above, the position of an MFCA leader and his essential role in the extension of MFCA to the SC is shown in Fig. 2.

In Fig. 2, an MFCA leader is placed as the promoter at the center of the SC network in order to introduce MFCA. Referring to the initially calculated material losses, the MFCA leader coordinates communication between suppliers and customers in order to resolve medium-to long-term issues that require a certain amount of cooperation and time to resolve. The MFCA leader recommends and supports the introduction of MFCA among suppliers and customers.

Referring to the types made by Cooper and Slagmulder (1999) between buyer-driven and supplier-driven types of inter-organizational improvements in cost management, the MFCA leader might approach both suppliers and buyers along the entire SC network in order to reduce material losses. However, for buyers with a certain amount of market and purchasing power, one can observe advantages to obtain willingness in mutual cooperation (see Gosman et al., 2004).

Therefore, in the present paper we consider primarily an MFCA leader in the position of a buyer. This also is because, in order to realize a low-carbon SC, it is believed that focus should be given especially to the areas where the effects of MFCA introduction are expected to be highest. If, for example, a buyer, as assembler of multiple parts from multiple suppliers, is the MFCA leader, it can be assumed that he has a major impact on the entire SC, starting from its rights concerning product design in general, and possibilities of influencing resource productivity at the production stage, in addition to the design and prototyping stages. That is, it is believed that the attempts to reduce environmental impact and cost at the production site of the MFCA leader who is the assembler may impact

Table 1
Industry breakdown of the enterprises that were contacted and responded.

Industry	Respondent enterprises		Sent enterprises	
	No. of enterprises	Composition ratio	No. of enterprises	Composition ratio
Transport machinery	26	7.3%	103	6.6%
Non-ferrous metals	8	2.2%	38	2.4%
Electrical equipments	73	20.5%	283	18.1%
Electricity and gas	3	0.8%	22	1.4%
Steel	9	2.5%	54	3.5%
Textile	7	2.0%	58	3.7%
Petroleum and coal products	2	0.6%	13	0.8%
Precision machinery	15	4.2%	50	3.2%
Food	19	5.3%	131	8.4%
Metal products	24	6.7%	94	6.0%
Machine	70	19.7%	236	15.1%
Chemicals	54	15.2%	209	13.4%
Pharmaceuticals	7	2.0%	56	3.6%
Pulp and paper	5	1.4%	24	1.5%
Other products	19	5.3%	107	6.9%
Rubber products	6	1.7%	19	1.2%
Glass, soil and stone products	9	2.5%	64	4.1%
Total	356	100.0%	1561	100.0%

the entire product's life cycle from first supplier to end consumer. In that sense, the decision-making of the MFCA leader determines the success or failure of optimizing a low-carbon SC, with consideration for the entire SC network.

In addition, there is a great possibility that the introduction of MFCA will contribute to the competitive edge, in areas such as cost reduction etc., even for suppliers. According to [Takahashi et al. \(2010\)](#), buyers that account for 10% or more of sales, raise the sales cost ratio using their price negotiation power, and, on the other hand, reduce the sales ratio by improving operational efficiency, thus offsetting the operating margin for the corresponding buyer. In addition, it has also become apparent that the turnover ratio of the inventory for the corresponding buyer is high. That is, although suppliers are provided with efficient transactions by buyers with high amount of sales, it is found that they face difficulties in production cost reduction. This also means that if suppliers can reduce production cost by reducing material loss through MFCA, and by sharing the medium-to long-term challenges with the buyer introducing MFCA, both sides – buyer and supplier – might profit from a win–win situation (see [Takahashi et al., 2010](#)).

For the buyer as MFCA leader and suppliers to collaborate and perform cost reduction activities, information sharing is essential. To efficiently increase resource productivity through MFCA, close information sharing is a must. For the buyer and suppliers to maximize the reduction of material loss in the SC it is desirable that they share material flow model and cost information based on material loss accounting. However, according to a survey by [Sakaguchi \(2003\)](#), while buyers might in general be aware of the production process, production facilities, the existing quality

Table 2
Test of the difference between the average values related to the enterprise size (sales) of the respondent and non-respondent enterprises.

	Respondent			Non-respondent			t Value
	Average	SD	Median	Average	SD	Median	
<i>Listed company of the first section of TSE</i>							
Sales	353,409	1,055,892	96,768	352,992	1,054,020	74,981	1.384
<i>Listed company of another section of the stock exchange</i>							
Sales	17,486	21,540	11,807	17,640	21,576	11,478	0.737

Table 3
Priorities of criteria in selecting a supplier.

	Number of responses
Environment	4
Delivery	13
Cost	104
Quality	225
No response	4
Other (invalid)	6
Total	356

management system, and quality-related information etc., suppliers, on the other hand, have no access to detailed cost information. In view of price negotiations with buyers, it seems only natural that suppliers will try to avoid providing cost information. However, it has been pointed out that collaboration with business partners seems to be easier if information sharing is restricted to only quantitative information at the time of MFCA introduction ([Kokubu and Shimogaki, 2007](#); [Higashida, 2008](#)). If MFCA is also a management method to enhance joint cost reduction activities in terms of increasing resource productivity, it is believed that the barriers for information sharing will be lower than other cost-related inquiries.

If the MFCA leader and suppliers successfully engage in collaborative information sharing and introduce MFCA into the SC, it is believed that the resource productivity of the entire SC will increase. However, some questions are still open and some of the present preconditions of existing SCs for MFCA introduction are not clear. Accordingly, in the next section, the actual conditions and properties of existing SCs are investigated based on questionnaire research and the challenges for MFCA introduction are identified.

3. Overview of the questionnaire research

In Japan, initial research on low-carbon SCs has been conducted by [Kajiware and Kokubu \(2012\)](#), according to whom the status and form of the business relationship between buyer and supplier and the purchasing department's goals have a major impact on the promotion of low-carbon SCM. In their survey, [Kajiware and Kokubu \(2012\)](#) were first able to show the determining factors of low-carbon SCM. The results of their study thus served as a fundamental information to the present paper, which was carried out to clarify awareness and identification of the challenges of SCs experienced by buyer and suppliers, the status of introduction of MFCA, and also the status of information sharing and collaboration.

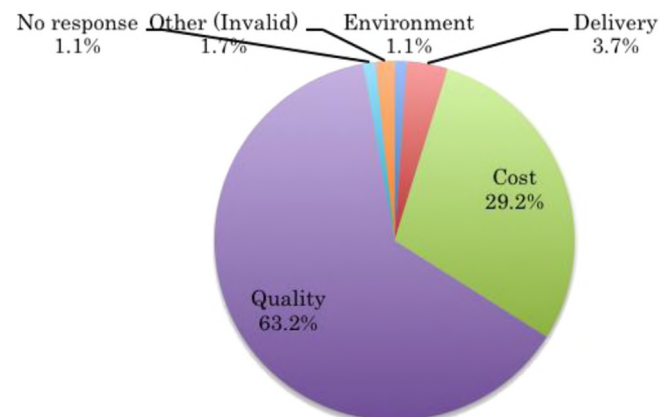


Fig. 3. Priorities of criteria in selecting a supplier.

Table 4
Obstacles to reach procurement goals.

	Number of responses
Delay of delivery	45
Rise of procurement cost	230
Unstable quality	65
Negative impact on the environment	3
Others	10
No response	3
Total	356

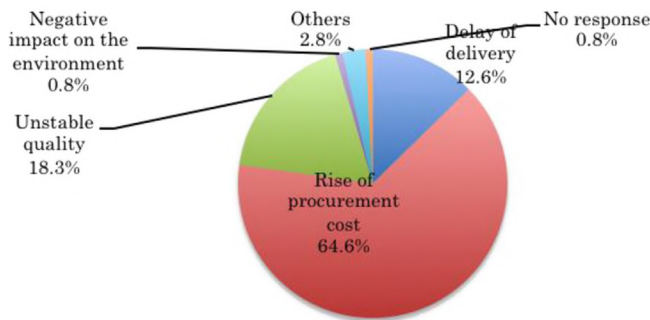


Fig. 4. Obstacles to reach procurement goals.

To carry out the survey, questionnaires were mailed to purchasing personnel (purchasing department, materials department, etc.) of listed enterprises (1,561 companies in the manufacturing industry). Sakaguchi (2003) focused on assemblers of machinery, precision equipment, etc. In the studies by Asanuma (1997) and Cooper and Slagmulder (1999), the enterprises referred to were generally assumed to be assemblers involved in the production of end products. However, in the MFCA introduction case studies collected so far by METI (Ministry of Economy, Trade, and Industry, Japan), enterprises that manufacture rubber or curtains were also included, without being limited to assemblers (METI, 2011). Other studies were carried out on the introduction of MFCA to the energy industry (Nakajima, 2006). The present survey targeted all the listed companies belonging to the manufacturing industry, not just assemblers.

The questionnaire was sent to the listed industrial enterprises (1561 enterprises) in Japan on 4 February 2012. The deadline date was on 29 February 2012. The response rate was 22.8% (356 questionnaires received). The breakdown of the industry sectors of the respondent enterprises is presented in Table 1. Also, as shown in Table 2, it is insignificant of *t*-test for variance of average of sales between there respondent enterprises and non-respondent

Table 5
Selection of materials with differences in environmental impact.

	Number of responses	Percentage
If procurement cost of material X is higher, we will not select material X (low CO ₂ emissions)	257	72.2%
Procurement cost of material X is 5% higher than others	53	14.9%
Procurement cost of material X is 6–10% higher than others	10	2.8%
Procurement cost of material X is 11% or more higher than others	2	0.6%
No response	28	7.9%
Other (invalid)	6	1.7%
Total	356	100%

Table 6
Average business years with suppliers.

	Number of responses	Percentage
Less than 1 year	0	0.0%
1 year to less than 3 years	1	0.3%
3 years to less than 5 years	11	3.1%
5 years to less than 10 years	53	14.9%
10 years to less than 15 years	275	77.3%
No response/other (invalid)	16	4.5%
Total	356	100%

Table 7
Awareness of the material yield related to the materials ordered from suppliers.

	Number of responses	Percentage
Aware	146	41.0%
Unaware	198	55.6%
No response/other (invalid)	12	3.3%
Total	356	100%

enterprises. We've not found significant variance between the two parties. Therefore, all the responses were targeted for analysis and discussion.

4. Aggregated results and findings of the questionnaire research

4.1. Performance evaluation indicators of the purchasing department

First, the priorities of criteria to select suppliers were considered. The previously considered criteria on delivery, cost, and quality were completed by an additional performance indicator on environment. According to Table 3 and Fig. 3, quality clearly ranked top as a performance indicator to select a supplier, while the number of enterprises that select according to environmental performance was negligible.

While the purchasing departments declare quality to be the most important performance indicator when selecting a supplier, this does not necessarily mean that quality is always the top priority or that it always determines purchasing decisions. When asked which are the most important obstacles to reach procurement goals (Table 4), 64.6% of the companies refer in first place to the rise of procurement cost (Fig. 4).

Also, as in Table 5, if material X to be purchased is of the same quality and same delivery timeframe, but lower environmental impact (CO₂ emissions), 72.2% of the enterprises would not select material X if the purchasing cost is higher.⁷

4.2. Information sharing and improvement activities with suppliers

The requirements to which importance was attached in traditional inter-organizational cost management should probably be examined in relation to MFCA, which also acts as a cost management method. According to previous research, buyers in Japan realize cost reduction through collaboration with suppliers (Asanuma, 1997; Cooper and Slagmulder, 1999). It has also been noted that they perform information sharing, and also have a

⁷ Prior to this question, companies were asked how they would choose between materials of high and low environmental impact if the cost, quality, and delivery time were identical. The response was that 90.4% (322 companies) stated that they would choose materials with a low environmental impact.

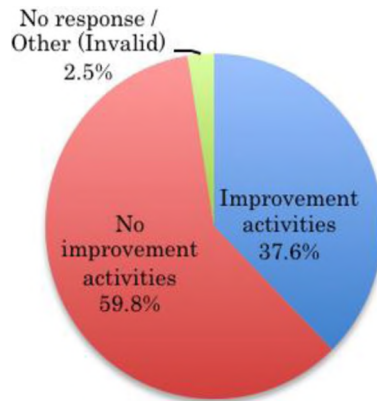


Fig. 5. Material yield improvement activities with suppliers.

Table 8

Material yield improvement activities with suppliers.

	Number of responses
Improvement activities	134
No improvement activities	213
No response/other (invalid)	9
Total	356

tendency to do business over the long term. However, since these previous studies targeted Japanese enterprises in the 1970s and 1980s, and since they are mainly case studies, it has been pointed out that these previous studies' findings do not apply to current Japanese enterprises (e.g. Kato, 2000; Sakaguchi, 2003, 2004).

For example, while Sakaguchi (2003) is affirmative about the buyer building a long-term relationship with suppliers, on the other hand, points out that the buyer make a cautious approach towards continued assurance of future business because some information from the buyer has not been understood positively by suppliers.

Accordingly, here the presence or absence of a long-term relationship with suppliers will be considered first. As can be seen from Table 6, 77.3% of the purchasing departments have maintained a business relationship of 10 years or more with their suppliers. There is no significant difference from the 74.8% shown by Sakaguchi (2003), which indicates that many purchasing departments presently build relationships over the long term with suppliers.⁸

Next, the modalities of information sharing and collaboration between organizations were considered. In the present survey, information sharing is being assessed according to whether or not the buyer knows the material yield of the supplier, and the presence or absence of collaboration is judged according to whether or not the buyer is improving material yield by collaborating with the supplier.

Material yield information is essential to understand the technological strength of the production process of the corresponding enterprise. It is very likely that low material yield correlates directly with failure cost of the production process. That is, in an enterprise with a low material yield, the production process is improvable and the buyer might curb procurement costs by actively supporting suppliers in achieving higher material yields.

As shown in Table 7, more than 55% of buyers are not informed about material yield from the suppliers' side.

Fig. 5 (Table 8) shows that almost 60% of buyers do not cooperate with suppliers in order to increase material yields. On the other hand, more than 37% do already undertake improvement activities targeting a higher material yield jointly with suppliers.

As shown in Table 9, 32.3% of the companies are aware of the material yield at the suppliers and undertake improvement activities to increase the material yield jointly with suppliers. In addition, most of the enterprises (76.9%) that are aware of the suppliers' material yield are carrying out collaborative improvement activities. Also, more than half of the companies (51.6%) that are unaware of the material yield do not undertake improvement activities. Of the enterprises that are unaware of the yield information, 88.9% do not cooperate. These results support the trend that enterprises that are informed about the material yield of their suppliers undertake improvement activities while enterprises that are not informed do not undertake improvement activities.

4.3. Realities of MFCA introduction

Finally, we examine the degree of MFCA awareness and introduction in the purchasing departments. As shown in Table 10 and Fig. 6, only 24.7% of the companies are familiar with the concept of MFCA. In addition, 18% of the purchasing departments answered that they "Do not know" whether MFCA has been introduced in their own company. Although this seems only natural regarding the low degree of recognition of MFCA, this is believed to be a high-priority issue. Considering that the purchasing departments play a central role in introducing MFCA into the SC, it will be necessary to find ways of making purchasing departments familiar with the concepts and effects of MFCA.

While 24.7% of the companies claimed familiarity with the concept of MFCA, only 2.0% have actually introduced it; 2.8% claim they have studied MFCA, but have not introduced it, as shown in Table 11 and Fig. 7. This raises an interesting question for further research: why do companies not introduce MFCA even though they are aware of the concept and must know about the possible competitive advantages?

5. Closing remarks

The present questionnaire study found that the costs of purchased material are seen as the dominant performance indicator by purchasing departments when dealing with suppliers. Also, it is clear that under the present conditions companies tend to build up long-term relationships with suppliers, and enterprises that have information on the suppliers' material yield often undertake improvement activities by collaboration.

This sets the framework when introducing MFCA into SCs with the objective of constructing a low-carbon SC and points to the necessity of raising awareness of environmental issues and encouraging information sharing with suppliers, mainly their purchasing departments. This study shows that purchasing departments at present are not prepared to deal with environmental issues, be it carbon emissions or other environmental impact factors. This corresponds with the observation that cost is being given priority in suppliers' performance evaluation and hardly any consideration is being given to indicators related to environmental performance. In fact, as shown in Table 5, hardly any enterprises that responded to the questionnaire selected suppliers because of a lower environmental impact when higher costs were involved. This again, as also proposed by Kajiwara and Kokubu (2012), is related to the challenge of increasing the motivation to deal with environmental issues and environmental management and to include

⁸ However, the questionnaire of Sakaguchi (2003) differed in many ways in terms of the survey methods. For instance, it was designed with a 3-point Likert scale and only assemblers were surveyed. A simple comparison is therefore not possible.

Table 9

Cross tabulation of awareness of material yield information and improvement activities.

		Awareness of material yield information				Total
		Aware		Unaware		
		Number of responses	Percentage	Number of responses	Percentage	
Improvement activities for material yield	Being done	110	32.3%	22	6.5%	132
	Not being done	33	9.7%	176	51.6%	209
	Total	143	41.9%	198	58.1%	341

Table 10

Degree of recognition of MFCA.

	Number of responses
Know MFCA	88
Do not know MFCA	262
Other (invalid)	6
Total	356

Table 11

Introduction status of MFCA.

	Number of responses
MFCA has been introduced	7
MFCA has not been introduced	241
While MFCA has not been introduced, there is interest in it	28
While MFCA has not been introduced, it has been studied	10
Do not know	64
No response	5
Other (invalid)	1
Total	356

environmental indicators into the performance evaluation procedures of the purchasing departments.

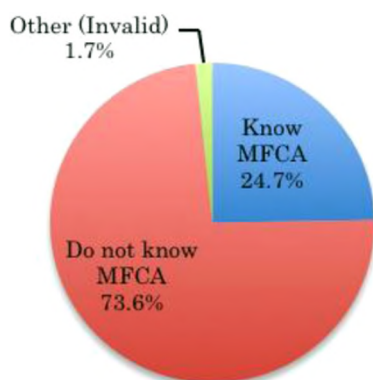
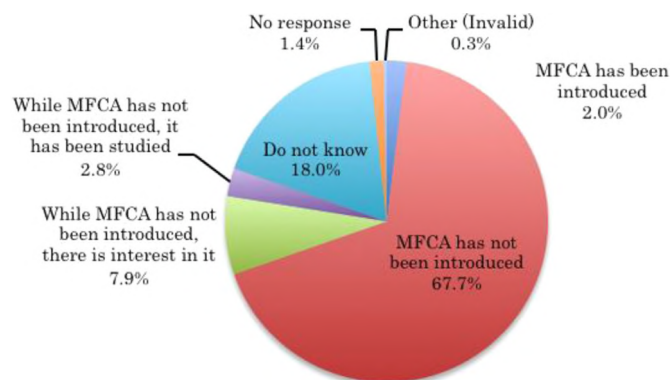
However, it will be difficult to actually introduce environmental indicators into the evaluation procedures of purchasing departments. This is due to the fact that a change of strategy and strong backing from top management will be required first in order to effect significant change on the selection of applied performance indicators. As long as the majority of enterprises attach little or no strategic importance to the management of environmental impacts, it will not be necessary for purchasing departments to recognize or apply environmental performance indicators.

On the other hand, MFCA is a method that simultaneously supports the reduction of environmental impact and costs. This means that introducing MFCA and collaborating with suppliers via the purchasing department makes it possible for a company to significantly lower purchasing costs. That is, in order to facilitate MFCA collaboration between the buyer and suppliers, as a first step towards a low-carbon SC, the cost-cutting advantages of an MFCA-guided collaboration have to be understood by the purchasing department in the first instance.

Next, in order to introduce MFCA along the SC, information sharing between buyer and suppliers has to be encouraged. This information sharing process could start by depicting the material flows in and between buyer and supplier, regarding the two companies as one business unit. Then collaboration between various management functions will be required, for instance between Production management on both sides, or between accounting,

product development, or R&D. As such a challenging collaboration is unlikely to be free of conflict, the introduction of MFCA will be greatly facilitated by the sharing of at least basic information relating to material yield and CO₂ emissions.

Finally, considering the results of the present study, the challenges for further research can be outlined. The present questionnaire study did not differentiate between domestic and foreign suppliers. It can be assumed that cooperation with suppliers located overseas has to meet different challenges than cooperation with domestic suppliers. Future research will have to examine the specific requirements of international cooperation regarding Japanese-owned enterprises overseas as well as local enterprises. Barriers to, and drivers of, material efficiency (including low carbon) guided cooperation will have to be assessed more closely, for international as well as for domestic cooperation. For example, the supportive or hindering factors of specific contract designs or capital relationships between buyers and suppliers are of interest. If a given capital or contractual relationship supports MFCA introduction, case studies or empirical evidence should be provided. Relationships between the type and amount of information sharing on the one side, and material loss or resource efficiency on the other, should be examined. For further developments, it seems to

**Fig. 6.** Degree of recognition of MFCA.**Fig. 7.** Introduction status of MFCA.

be desirable to rely on sound case studies or strong empirical data rather than purely on theoretical argumentation. The results might not only support the efficiency of inter-company cooperation targeting the win–win objective of higher material yield and reduced environmental impact for both sides, both buyers and suppliers. They might also provide a more precise basis for targeted governmental or legal measures towards a resource-efficient and low-carbon economy.

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