The Role of Accountants in Controlling Sustainability Information

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FOREWORD

WARM WELCOME TO THE EMAN-EU CONFERENCE 2013

Managing material and energy flows has been one of the core issues of environmental management in research and practice for decades and consequently resource and energy efficiency in companies has been improved steadily. Nevertheless the analyses were often restricted to single projects; mostly the focus of the research was on physical flows, sometimes followed by a monetary evaluation. In order to support companies in better understanding both the environmental and financial consequences of their material and energy use the International Organization for Standardization has developed a standard on Material Flow Cost Accounting (MFCA), that was released in September 2011. In order to motivate research on this topic the conference theme of The Environmental and Sustainability Management Accounting Network in 2013 hosted by the Chair of Environmental Management and Accounting at Technische Universitaet Dresden in Germany is "Material Flow Cost Accounting".

We are happy to welcome scholars from all over the world, e.g. Japan, Malaysia, Thailand, South Africa and India, and a variety of European countries. Most of the contributions are dedicated to our conference theme and thus analyze Material Flow Cost Accounting from different angles such as management control systems, the supply chain, accounting systems, waste, people, allocation, process, implementation, energy efficient industries, financial performance, life cycle thinking and software solutions.

The scientific research results are embedded in presentations by practitioners both from companies and professional organizations:

Matthias Kuenzel (demea, German Agency for Material Efficiency): *Increasing the Efficieny of Modern Manufacturing - The Innovation Voucher Approach for Material Efficiency in SME*

Anke Niebaum (VDI center resource efficiency GmbH): *VDI framework guidelines on resource efficiency: an attempt for standardisation of resource efficiency analysis*

Bernhard Schwager (Robert BOSCH GmbH): *Signals from Management Control for enhancing Sustainability: The Case of Bosch*

Jochen Reinschmidt (ZVEI, German Electrical and Electronic Manufacturers´ Association): *The ZVEI-tool for Life Cycle Cost Evaluation*

Fritz Jaeckel (Secretary of State, Saxon State Ministry for the Environment and Agriculture): *300 years of Sustainability in Saxony*

Baerbel Schwarzer (Deutsche Lufthansa AG, Head of Financial Risk Controlling): *Implementing a political vision: The impact of the European Emission Trading Scheme on an Airline Group*

Edeltraud Guenther (Technische Universitaet Dresden, Chair of Environmental Management and Accounting): *Implementing a standardization vision: The impact of the ISO 14051 on research and practice*

We are looking forward to interesting discussions and impulses for further research!

I would like to thank Anne Bergmann and Klemens Andreae for the farsighted and professional organization of the conference. Special thanks to Alexandra Schmidt.

Prof. Dr. Edeltraud Guenther

Conference Chair

EMAN Steering Committee

Plenary Sessions in HSZ Room H04		
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Plenary Session I	Matthias Kuenzel (demea, German Agency for Material Efficiency)	*Increasing the Efficieny of Modern Manufacturing - The Innovation Voucher Approach for Material Efficiency in SME*
	Anke Niebaum (VDI center resource efficiency GmbH)	*VDI framework guidelines on resource efficiency: an attempt for standardization of resource efficiency analysis*
Plenary Session II	Bernhard Schwager (Robert BOSCH GmbH)	*Signals from Management Control for enhancing Sustainability: The Case of Bosch*
	Jochen Reinschmidt (ZVEI, German Electrical and Elec-tronic Manufacturers´ Association)	*The ZVEI-tool for Life Cycle Cost Evaluation*
Plenary Session III	Baerbel Schwarzer (Deutsche Lufthansa AG)	*Implementing a political vision: The impact of the European Emission Trading Scheme on an Airline Group*
	Edeltraud Guenther (Technische Universitaet Dresden, Chair of Environmental Management and Accounting)	*Implementing a standardization vision: The impact of the ISO 14051 on research and practice*

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The Discipline of Environmental Management Accounting. A Bibliometric Literature Review

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Abstract: **Purpose – The paper investigates the body of literature on environmental management accounting (EMA) and provides a quantitative overview of the academic as well as the professional literature constituting the field. By doing so, the paper discusses whether EMA has developed as a discipline.**

Based on a database containing 814 (396 of them published in academic journals) publications in English, German and French with a publication date prior to 2012 a bibliometric analysis is conducted. Data on the publications, journals, authors and citations were collected, double-checked and examined by applying bibliometric measures.

The bibliometric analysis identifies trends in EMA research publications which show that EMA has developed as a young discipline, but is still faces challenges to get better established in mainstream accounting and management research. Although the publication number is growing, a substantial part of the publications have been published outside mainstream accounting journals in non-accounting journals, books and reports. A recent trend towards establishing specialised environmental (and sustainability) accounting journals is also rendered apparent. The low number of highly cited publications of few authors, however, indicates that EMA is still to become a mainstream field of research.

The paper discusses with the help of bibliometric analysis and measures whether EMA has developed as a discipline and whether it has become part of mainstream accounting research.

I. INTRODUCTION

The significance of acceptance of EMA research as an acknowledged accounting discipline should not be underestimated. As 'mainstream' science, EMA research would be found within the current professional scientific discussion and thus in specialized as well as mainstream professional peer reviewed journals. Whereas specialized journals support in depth investigation and specialized knowledge development, mainstream journals support the broader acceptance of topics and methods in the professional community and the integration in broader accounting research developments. Clearly, there are also other modes of exchange such as conferences, workshops, books, and private exchanges between researchers by email. However, these cannot be examined and analysed reliably and reproducibly.

Another feature of an acknowledged discipline and mainstream science is scepticism as a part of the scientific discussion [1]. When exercised through formal scientific circles such as the peer review process, scepticism is essential for the functioning of science as it yields an erratic path towards eventual truth. By keeping topics or a discipline outside mainstream journals, i.e. by choosing to not exercise legitimate scientific scepticism in widely acknowledged discussion fora and journals, other researchers block this path.

It needs to be noted, though, that 'mainstream' cannot be equated with 'consensus' [2]. A vitally important part of mainstream science is the recognition of 'odd' ideas by isolated individuals that get tossed into the mix. Mostly they do not work out and eventually get discarded; sometimes they become established and move into what is effectively a professional consensus. Sometimes contrasting ideas remain a focus for consideration for a long time before later developments eventually bring a resolution; and there are many open questions not yet resolved. Thus, controversial discussions may become mainstream as such, without being subject to consensus between the researchers.

It is also important to shed light on the controversy between (rather than within) EMA and mainstream accounting and management research. Following the disputes among researchers in the field over the validity of preliminary (i.e. untested) data, hypotheses, and (tentative) models delivers additional detail on the development of EMA as these matters need further study to determine their reliability.

This paper investigates how EMA research publications by academics, practitioners and policy makers, i.e. by the accounting profession [3], have developed. Based on several comments of renowned academics who indicated that academic accounting research has become increasingly detached from practice and society [4]-[9], and given the substantial development in academic journals as well as the visible involvement of professional accounting organisations and international organisations, this paper considers both, academic and professional contributions to EMA.

This literature review takes a systematic approach by applying acknowledged bibliometric methods [10]-[13] to analyse past developments and to serve as a basis for recommendations for future research.

The paper is structured as follows: After a short description of the scope of research, i.e. what EMA encompasses, and a discussion of the few existing literature reviews on EMA and the remaining gap for a systematic review (Section 2), the chosen bibliometric approach is explained in Section 3. Section 4 reviews the descriptive statistical results with regard to the development of the number and type of publications, authorship, and citations. This analysis is supported by bibliometric evaluation based on Bradford´s law [14], Garfield´s law [10], [12] and the Ortega hypothesis [15] as well as a contents analysis of the publications and investigations of collaboration, regions of origin, topics covered and type of studies. Section 5 discusses the results, analyses them and draws conclusions for further research.

II. Environmental management accounting

1. *Extensive investigation of EMA research*

This literature review covers English, French and German publications which explicitly deal with environmental management accounting (EMA). As a part of the broader concept of accounting EMA describes a corporate environmental information management approach to support company-internal management decision making on environmental and economic performance issues by means of accounting [16]-[19]. Given the diversity of different management decision situations EMA encompasses a broad set of accounting tools including monetary accounting methods such as environmental cost accounting, environmental investment appraisal, budgeting or financial planning and methods focusing on physical measures such as material flow accounting, eco-budgeting, etc. [20].

In spite of the methodological diversity and although EMA as a term is used in the extant literature to refer to different areas (e.g. carbon accounting, material flow cost accounting, environmental investment appraisal), a fairly common understanding of EMA has developed for the last two decades. A major influence on this common understanding has been exerted by publications of the UN Division on Sustainable Development (UNDSD). UNDSD invested considerable resources in disseminating knowledge in the area by involving many experts and stakeholders in the field [19], and by the widely spread international guideline published by IFAC [21]. Also widely cited academic publications which do not differ substantially in their definitions of EMA such as Gray and Laughlin's seminal paper on Corporate Environmental Accounting [17] or the book by [18] can be said to have had some influence on shaping this common understanding.

2. *Previous literature reviews*

With the development of EMA, few literature reviews have been conducted to date. Whereas most of these reviews are based on a small selection of the existing body of literature (e.g. publications in top accounting journals), some authors have attempted to conceptualise a framework to map their findings [22]. The identified literature reviews, however, face some limitations which have motivated the following literature review.

Although various qualitative review studies have been conducted by Mathews [22]-[28] and others no comprehensive quantitative reviews of the EMA literature exist so far.

An analysis of the existing literature reviews published until 2011 reveals that they do not fully capture the current (state of) development of EMA, as they either deal with environmental accounting on a general (as opposed to a management level) and even national level, or have in the meanwhile become outdated [22]-[24] given the rapid development in more recent years. The first published systematic review paper was completed by Mathews [22], who covered twenty-five years of social and environmental accounting research, which, however, was characterized by very few publications until then. Mathews classified the contributions by periods, and whether they were "empirical studies", "normative statements", "philosophical discussions", "radical/critical literature", "non-accounting literature", "teaching programmes and textbooks", "regulatory frameworks" and "other reviews of the literature". Subsequently, Mathews [23] took his approach one step further by developing a matrix approach of categorization with the perceived underlying philosophies.

III. Scope of research and methods

1. *Scope of research*

The scope of the following literature review on EMA publications encompasses all management accounting approaches which are explicitly used in EMA (e.g. environmental cost accounting, key performance indicators, the balanced scorecard, etc.) thus considering a broad range of company-internal environmental accounting methods ranging from full cost accounting to total cost assessment, material flow cost accounting, life-cycle costing, and accounting tools dealing with corporate environmental investments, natural equity accounts of companies, etc.. Also considered are papers focusing on specific issues such as carbon accounting [29], natural capital/biodiversity accounting, water accounting, or material flow and waste accounting, etc. as long as they have a clear focus on supporting company-internal management decisions.

In addition to publications in peer-reviewed journals, EMA contributions published in professional body journals, as conference papers, working papers, books, PhD-dissertations or reports by NGOs, professional bodies, or governments are included in the following literature review. The identified authors are either associated to the academic community in accounting and/or management studies and/or environment sciences, or sometimes publish for the business community (such as the "Big Four" accounting firms), for NGOs (such as the World Resource Institute) or international organizations (such as the UN). The decision to take such a broad range of authorships and publications is based on the acknowledged strong influence of international, political and professional organisations and their publications [19], [21].

2. *Methodological approach*

The bibliography on EMA was compiled starting with nearly one hundred papers on EMA found in earlier literature reviews and complemented by more recent publications in journals and by academic book publishers who have already published in the area of EMA. The search focused on publications on the corporate level and

EMA. Publications in the three major (globally and in Europe) languages – English, French and German - were considered, covering a total of 44% of the population of the European Union member states and 41% of the population in the OECD countries. By means of snowball sampling the references of these first one hundred publications were reviewed to identify further EMA publications. This way 497 journal articles, working papers, reports and books were collected.

As a result of this literature search, a robust bibliographic database of English, French and German publications between 1973 and (including) 2011 was collected. The bibliographic database comprises i) 814 EMA publications in total, including peer-reviewed journal papers, reports, books, and book chapters, ii) written by 658 authors. iii) Of the 814 publications iv) 396 are journal papers, v) published in 89 peer-reviewed and academic journals, vi) of which only 17 have been published in the Financial Times list of highly recognized management journals: vii) 14 publications in Accounting, Organizations and Society, and 3 publications in the Journal of Business Ethics.

IV. Results and discussion

1. Historical development of EMA publications

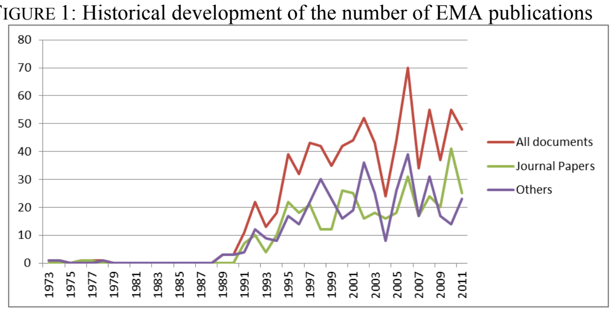
Environmental accounting can be considered a "rare orchid" topic playing a negligible niche role until 1990 in terms of academic publications, although the first books and papers (in AOS) were published in the 1970s. Figure 1 shows the development of the total number of EMA publications split up in journal and other publications (including books, book chapter, working papers and reports).

In terms of the number of publications the field remains negligibly small until 1990 (below 3 publications per annum) and then "explodes" with a strong increase until 1997 (up to more than 40 publications per annum) and a much smaller average increase between 1997 and 2011. Since 1997 the development has been characterized by strong outlays with lows particularly in 2004, 2007 and 2009 and with peaks in 2002, 2006, 2008 and 2010.

Although a chart depicting the number of publications cannot show a cause and effect relationship, the rapid development of EMA research and the turning point (when the number of EMA publications started to grow substantially) can be identified after the publication of the Brundtland Report in 1987 as well as the book by David Pearce (in 1989) and Rob Gray's [16] response to it.

Despite disruptions and the changing gap between the number of journal papers and other publications, a correlation analysis provides a correlation factor of 0.78 (level of significance 0.05), suggesting a strong correlation in the number of academic and other publications for the period between 1973 and 2011. As Figure 1 shows, the years until 1989 are without any EMA publications and thus distorting the correlation result. A correlation analysis for the period between 1989 and 2011 shows a correlation factor of 0.51 (level of significance 0.05) with only a weak correlation between the research published in scientific journals and research in other media such as books, book chapters, reports or working papers. Thus no general quantitative indication could be found that the number of academic journal papers is related to or driving other publications. This may indicate that publications by professional institutions, books, contributions in books, working papers, etc., although expectedly also being influenced by journal publications, still develop their own dynamism and thus deserve attention as contributions to the emergence of a new research field.

FIGURE 1: Historical development of the number of EMA publications



2. Journals contributing to EMA

Academic journals play an important role in the development of a discipline as they reflect topical priorities of academic discussion and fundamental research as well as the acknowledgement in the respective scientific community. The only accounting journal in the Financial Times list of highly acknowledged journals which has published on environmental accounting until 2011 is Accounting, Organizations and Society with 14 publications between 1976 and 2011. Among the top ranked journals (A or A* qualified) the Accounting, Auditing and Accountability Journal (AAAJ) has published most on environmental management accounting, followed by Accounting Forum and Critical Perspectives on Accounting. AAAJ has issued several special issues on the subject (1991, 1997, 2002, 2007, 2010), contributing substantially to the peak of literature in those years (see Figure 1).

3. Authorship

Authors in any field of research have an impact of how this field is shaped. According to the Ortega hypothesis [15] scientific progress is based on the work of a small percentage and number of researchers and authors in each field. For the research field of EMA, only 15 (2.2%) out of 658 authors contribute towards 341 (42%) publications out of the 814 publications. The proportion of authors to the overall contribution to the field remains similar when only journal publications are analysed. Again, 15 (3.8%) authors contribute to 172 (44%) of the 396 academic publications. This can also be attributed to the high number of "one-off" authors who conduct their research in related areas and often have one single publication in the field of EMA.

Several further observations can be made by looking at the major contributors in the field. The order of the authors with most journal papers is somewhat counterintuitive. Since this review focuses on environmental management accounting literature, it appears surprising that Rob Gray and Jan Bebbington are in the lead group, given that their work deals broadly with the critical perspective of social accounting. This observation can, however, be explained with Gray and Bebbington's earlier work, when they produced numerous environmental accounting publications with case studies within various organisations and the analysis of company-internal processes and approaches.

4. Publications by countries

Another bibliometric approach to analysing the development of EMA as a discipline deals with "geographic hotspots" of EMA research. This was done by counting the number of authors for each country in which the institutional affiliation of the researcher is located. For the analysis only authors with two or more publications were considered in order to exclude authors with a marginal attachment to EMA research.

5. Most cited EMA publications

Citations are a measure of how often a publication has been referred to and thus how influential it is. A higher citation score shows that the contents of the publication have been received and discussed intensely in the scientific community. As of March 2012, 15 documents have been cited over a 100 times in Google Scholar. The citation scores of ISI Web of Knowledge and Scopus were also collected in March 2012.

The two most cited publications are books written by the four most active contributors to the field of EMA. Considering the authors, the most influential author in environmental and social accounting is Rob Gray, who has five publications among the fifteen top cited publications on EMA. This is even more obvious when considering journal papers only.

V. Conclusion

This paper analysed the initially posed question whether EMA research has developed as a discipline and become mainstream with a bibliometric analysis of EMA publications. The overall results clearly indicate that EMA has become an acknowledged accounting discipline although some aspects reveal that the discipline is still young and not fully established in mainstream accounting research.

As a historical development measure the rate of "knowledge growth" (measured by the increasing number of related publications) shows that EMA research is enjoying a wide recognition. Both, academic journal publications as well as books, reports of professional and international organizations are increasing. As the quantitative development in journals and other publications is not strongly related a certain own dynamism may exist in different publication communities. Differences in publication outlets also exist when comparing the geographical origin of authorship where New Zealand, Australia and the UK favour journals for their EMA publications whereas Japan, France, Austria, the Netherlands, and Germany focus on other publication formats.

Examining the development with regard to journals shows that particularly the uptake by mainstream accounting and management journals has increased steadily. Bradford's law on the ratio between core and related journals could be confirmed. As a sign of early disciplinary development though, EMA publications have so far found their way into mainstream accounting journals mainly by means of special issues. A stronger representation in current issues of mainstream journals is still to be achieved.

The mostly recent establishment of specialised journals as outlets for EMA research can be seen as an indication of the establishment of the discipline. Nevertheless, the fact must be considered that these journals are not solely dedicated to EMA research, but cover reporting and sustainability accounting more broadly. In fact, the number of EMA publications in these makes up only a fraction of their total output.

From an authorship perspective the Ortega hypothesis stating that a small number of authors shape the field is confirmed. At the same time the number of authors is increasing strongly, however, with may authors only contributing with one or few publications, indicating that the core authors are involving young researchers. Although the research community is growing, a large number of publications are produced by authors and co-authors, involved in a single or very few publications only. This fragile pattern could also be interpreted as an indication of the uncertainty of these (younger) authors as to whether the community is developing and likely to achieve mainstream status. However, this interpretation should be discussed again and examined in a couple of years because of the relative novelty of EMA (with a strong increase of publications only since 1991) and since the development and acceptance of a new academic discipline can come slowly [30].

Another key observation is the geographical spread of the authors who have influenced the literature as well as the countries where the EMA discussion is flourishing: the UK, Germany and Australia. This shows that the topic of environmental and sustainability accounting is mainly discussed in a small part of Europe and Australia. More recently, however, especially Asian academics have started to deal with EMA, too. It has to be noted that EMA research has been conducted in developing countries too, mainly through empirical research, but most of these researchers are still located in Europe or Australia. The geographic location of EMA research hot spots shows that a further geographical development is needed before EMA can be considered global mainstream. The fact that the USA are under-represented might be interpreted or reflect the political situation or a general laggard position with regard to environmental matters but is particularly revealing since the majority of mainstream research is managed from within the US.

In conclusion, a comprehensive literature review of various kinds of academic and qualified practitioner-oriented publications on EMA shows that the area is developing with a high speed, involving an increasing range of authors and regions. Most of the analysed bibliometric measure show that EMA has become an acknowledged discipline, however, still being young, has various challenges to become fully established in the mainstream accoutning and management reseach.

REFERENCES

[1] Watkins, J.W.N. (1984), Science and scepticism, Princeton, (N.J.), Princeton University Press.
[2] Lehrer, K. and Wagner, C. (1981), Rational consensus in science and society: A philosophical and mathematical study, Dordrecht, Kluwer.
[3] Evans, E., Burritt, R. and Guthrie, J. (2011), Bridgig the Gap between Academic Accounting Research and Professional Practice, Sydney, The Institute of Chartered Accountants in Australia.
[4] Guthrie, J., Burritt, R. and Evans, E. (2011), "The relationship between academic accounting research and professional practice", in Evans, E., Burritt, R. and Guthrie, J. (Eds.), Academic accounting research and professional practice, ICAA, Sydney, pp. 5-14.
[5] Hopwood, A.G. (2007), "Whither accounting research?", Accounting Review, Vol. 82, No. 5, pp. 1365-1374.
[6] Hopwood, A.G. (2008), "Changing pressures on the research process: on trying to research in an age when curiosity is not enough", European Accounting Review, Vol. 17, No. 1, pp. 87-96.
[7] Hopwood, A.G. (2009), "The economic crisis and accounting: implications for the research community", Accounting, Organizations and Society, Vol. 34, No.6-7, pp. 797-802.
[8] Baldvinsdottir, G., Mitchell, F. and Nørreklit, H. (2010), "Issues in the relationship between theory and practice in management accounting", Management Accounting Research, Vol. 21, No. 2, pp. 79-82.
[9] Malmi, T. and Granlund, M. (2009), "In search of management accounting theory", European Accounting Review, Vol. 18, No. 3, pp. 597-620.
[10] De Bellis, N. (2009), Bibliometrics and citation analysis, Scarecrow Press, Lanham, MD.
[11] De Solla Price, D.J. (1974), Little science, big science, Suhrkamp, Berlin.
[12] Garfield, E. (1955), Citation Indexes for Science: A New Dimension in Documentation through Association of Ideas, Vol. 122, No. 3159, pp. 108-111.
[13] Jokic, M. and Ball, R. (2006), Quality and Quantity of Academic Publications (in German: Qualität und Quantität wissenschaftlicher Veröffentlichungen). Forschungszentrum Jülich, Jülich.
[14] Bradford, S.C. (1985), "Sources of information on specific subjects", Journal of Information Science, Vol. 10, No. 4, pp. 173-180.
[15] Cole, J.R. and Cole, S. (1972), "The Ortega Hypothesis. Citation analysis suggests that only a few scientists contribute to scientific progress", Science, Vol. 27, No. 178, pp. 368-375.
[16] Gray, R. (1990), The Greening of accountancy: the profession after Pearce. ACCA Research Report 17, ACCA, London.
[17] Gray, R. and Laughlin, R.C. (1991), "The coming of the green and the challenge of environmentalism", Accounting, Auditing & Accountability Journal, Vol. 4, No. 3, pp. 5-8.
[18] Schaltegger, S. and Burritt, R. (2000), Contemporary environmental accounting: issues, concept and practice, Greenleaf, Sheffield.
[19] UNDSD (2002), Environmental management accounting: policies and linkages, UNDSD, New York.
[20] Burritt, R., Hahn, T. and Schaltegger, S. (2002), "Towards a comprehensive framework for environmental management accounting", Australian Accounting Review, Vol. 12, No. 2, pp. 39-50.
[21] Jasch, C. and Savage, D.E. (2009), "The IFAC International Guidance Document on Environmental Management Accounting", in: Schaltegger, S.; Bennett, M.; Burritt, R. & Jasch, C. (Eds) (2008): Environmental Management Accounting for Cleaner Production. Dordrecht: Springer, pp. 321-336.
[22] Mathews, M.R. (1997), "Twenty five years of social and environmental accounting research: is there a silver jubilee to celebrate?", Accountability, Auditing & Accountability Journal, Vol. 10, No. 4, pp. 481-531.
[23] Mathews, M.R. (2004), "Developing a matrix approach to categorize the social and environmental accounting research literature", Qualitative Research in Accounting and Management, Vol. 1, No. 1, pp.30-45.
[24] Gray, R. (2002), "The social accounting project and Accounting Organizations and Society. Privileging engagement, imaginings, new accountings and pragmatism over critique?", Accounting, Organizations and Society, Vol. 27, No. 7, pp. 687-708.
[25] Parker, L.D. (2005), "Social and environmental accountability research: A view from the commentary box", Accounting, Auditing & Accountability Journal, Vol. 18, No. 6, pp. 842-860.
[26] Parker, L.D. (2011), "Twenty-one years of social and environmental accountability research: A coming of age", Accounting Forum, Vol. 35, pp. 1-10.
[27] Deegan, C. and Soltys, S. (2007), "Social accounting research: an Australasian perspective", Accounting Forum, Vol. 31, 73-89.
[28] Thomson, I. (2007), "Mapping the terrain of sustainability accounting", in Unerman, J., Bebbington, J. and O'Dwyer, B (Eds.), Sustainability accounting and accountability, Routledge, Ney York, NY, pp. 19-36.
[29] Burritt, R., Schaltegger, S. and Zvezdov, D. (2011), "Carbon Management Accounting. Explaining Practice in Leading German Companies", Australian Accounting Review, Vol. 21, No. 56, pp. 80-98.
[30] Friedlander, M.W. (1995), At the fringes of science, Boulder (Colorado), Westview Press.

Controlling management stimuli for greater sustainability based on the example of *Bosch*

Dr. Stefan Asenkerschbaumer and Dr. Richard Watterott

Strategic controlling can provide stimuli for more sustainable corporate development by firmly establishing sustainability in a company's vision and values, while environmental controlling is more operational in nature and focuses on the sustainability of the company's value-added processes. This article examines both controlling functions in greater detail based on a number of examples.

1. The *Bosch* Group and its understanding of corporate sustainability

For the *Bosch* Group, which celebrated its 125th anniversary in 2011, sustainability and a long-term strategic focus are part and parcel of the corporate culture. It was of vital importance to the founder *Robert Bosch* to ensure his company's independence and long-term survival in a manner reflective of his "spirit and will." In his will, he also set his successors and descendants the task of continuing this approach. As Bosch saw it, this meant achieving a balance between business and social concerns, even though he was aware this was no easy feat. In an article from 1936, he wrote: "It was not always easy to find a happy medium, to steer a middle course between the entrepreneur who needs to assert himself, and the socially minded businessman – in other words, the employer – with the desire to give his helpers their credit."

His grandson *Christof Bosch*, who is spokesperson for the *Bosch* family and a member of the shareholders' meeting and supervisory council, conveyed this "spirit" in his speech to mark the anniversary: "For me, there is one word that captures it best: Sustainability." He was convinced that *Robert Bosch* would have used this term had it not been exclusively applied to forestry practices at the time.

Continuing this tradition into the present day, the *Bosch* Group interprets corporate social responsibility as "balancing the triple bottom line of business, society, and the environment," as the chairman of the board of management *Franz Fehrenbach* put it in a presentation (see *Fehrenbach*, 2009, p. 5).

The company's comprehensive long-term orientation and its perception of corporate social responsibility are therefore already apparent in its vision and strategy. The vision, guiding principle, and values establish a clear basic strategic direction. Everyone at every level of the company is required to apply the key aspects in business operations. Due to the great sense of identification and integration they engender, they also offer great potential for synergies and are therefore a vitally important part of the *Bosch* portfolio alongside all the cost-efficiency criteria. Take the example of "Responsibility" – one of the seven values of the *Bosch* Group: "Above all else, we place our products and services in the interests of the safety of people, the economic use of resources, and environmental sustainability." This applies to all three business sectors of the diversified *Bosch* Group – automotive technology, industrial technology, and consumer goods and building technology.

As long ago as 1921, *Robert Bosch* said that "Improvements in the world of technology and business should always also be beneficial for mankind." This is reflected today in the *Bosch* Group's slogan "Invented for life." Sales of technical products and services by the *Bosch* Group are forecast to exceed 50 billion euros in 2011. The group comprises *Robert Bosch* GmbH and more than 350 subsidiaries and regional companies in over 60 countries.

In terms of company law, one special feature distinguishes *Bosch* from the majority of other companies of a comparable size. The *Robert Bosch Stiftung* holds 92 percent of the capital stock of *Robert Bosch* GmbH. The dividends it receives from this holding are used exclusively for charitable purposes. This constitution secures the entrepreneurial freedom of the *Bosch* Group. The bulk of the profit generated is not distributed and can be invested in the future. This facilitates the company's long-term orientation and thus its focus on sustainably stable economic, social, and environmental interests.

As part of its commitment to corporate social responsibility (CSR), the company's sustainability management activities comprise four aspects – the environmental, social, and economic dimensions, and the integration of these three challenges (see *Schaltegger* et al., 2007, p. 14). Accordingly, CSR involves a voluntary commitment on the part of management to go beyond existing legal requirements to include environmental and social considerations in business decisions (see *Günther*, 2008, p. 53). The greatest challenge lies in integrating the three dimensions. The objective here is to adopt an all-encompassing approach and, as far as possible, be equally effective in meeting the requirements of all three dimensions while also incorporating environmental and social management into the company's conventional economic management.

In line with this article's objective, the following observations focus on the environmental aspects of sustainability management.

2. Sustainability and controlling

As demonstrated using a simplified corporate process model to reflect the processes involved in providing goods and services, the contents and tasks of sustainability and the associated controlling activities are not simply an integral part of all value-added processes, but also and above all part and parcel of corporate development, management, and support processes (see Fig. 1). Environmental management is a multidisciplinary task to which every operational function and everyone involved contribute (see *Horv´ath* et al., 2011). Consequently, it concerns all hierarchy levels.

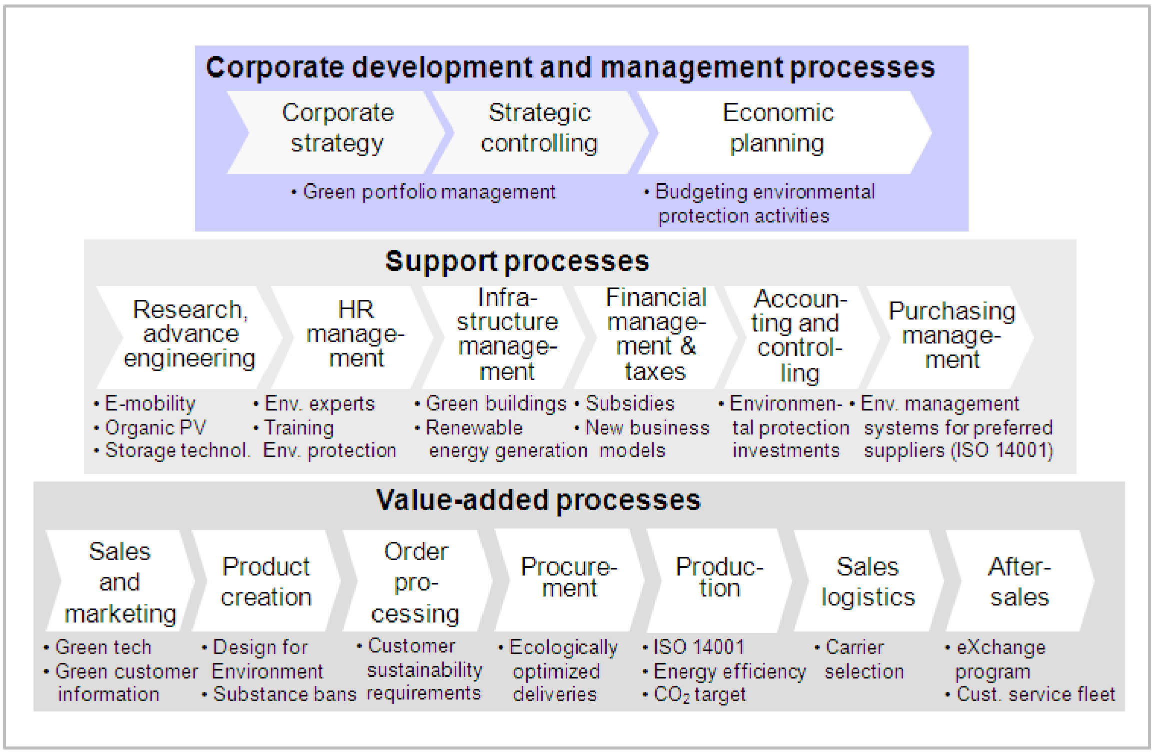


Fig. 1: Sustainability management affects all business processes

In the way that it is interpreted here, environmental controlling always relates to business goals. Its basic purpose is therefore to achieve a balance between ecology and economy, at least in the long term. An example from the field of automotive technology illustrates what thinking in the long term can achieve.

For a long time, there appeared to be no solution to the problem of wheels locking during braking that could be used in series production vehicles. Once electronics opened up the prospect of sufficiently fast and reliable brake control in the mid-1960s, *Bosch* started developing an antilock braking system that was suitable for series vehicles. It took 15 years to reach the series launch stage in 1978 and a further five years before the ABS became cost-effective for *Bosch*. By law, all new cars in the European Union must now be equipped with an

ABS. This example highlights that, in some respects, long-term thinking needs to extend far beyond the scope of normal medium- and long-term planning.

The strategic guiding principle "Invented for life" is a challenge to find technical solutions to improve and protect the environment. It is therefore geared toward making renewable energies more cost-effective and mobility even safer, cleaner, and more economical. More generally, the aim is to create products that protect the environment and conserve resources. Accordingly, ecology is seen as an innovation driver and an economic opportunity for the *Bosch* Group.

The task of controlling is to help management staff evaluate the economic opportunities and risks of innovations and the implementation of corporate strategies. At the initial stage, strategic controlling essentially relates to potential successes and capabilities, and thus to material targets. The focus is on three key elements – controlling the premises, controlling the consistency of the strategy, and controlling implementation (see Fig. 2). Strategic controlling is linked to the environment and the company. Unlike operational controlling, there is therefore less emphasis on formal targets such as improving sales, results, and profitability. At the second stage, however, strategic and operational planning, and planning geared toward material and formal targets, need to be networked (see *Horv´ath*, 2009, p. 221).

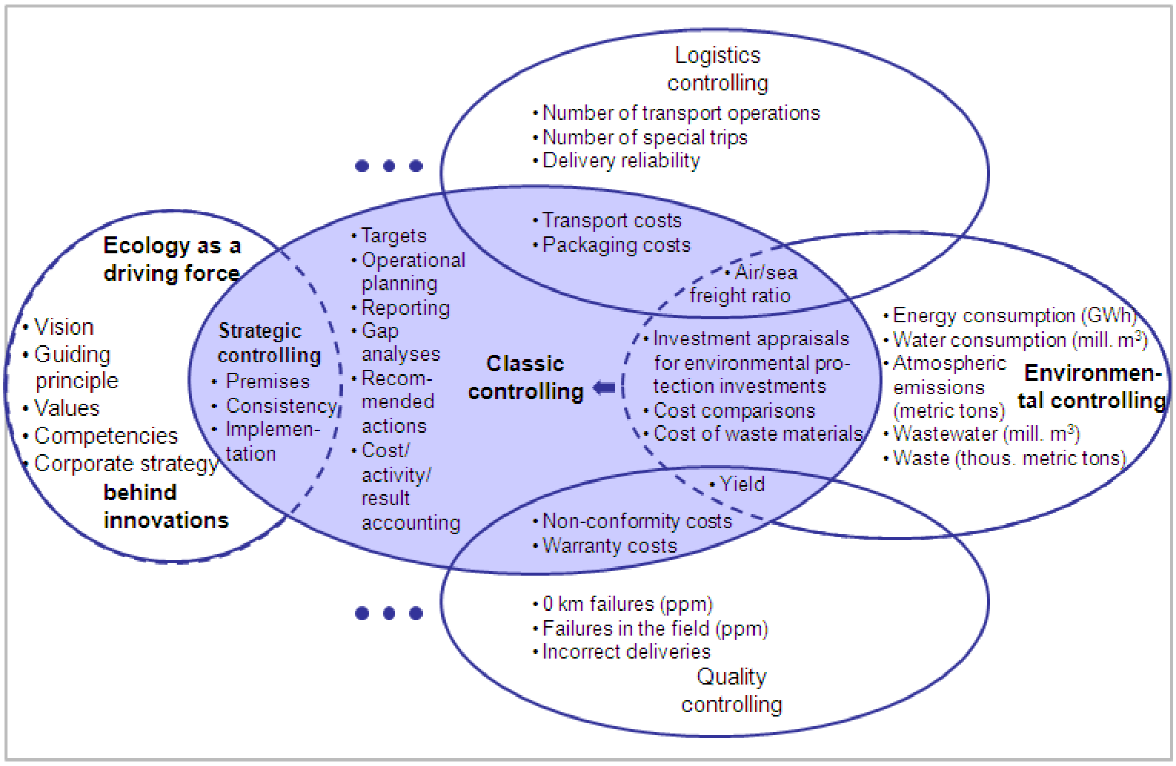


Fig. 2: Content and tasks in sustainability control

Given the *Bosch* Group's environmentally oriented strategic focus, the responsibility is on strategic controlling to help management staff boost sustainability, especially when it comes to finding and evaluating new areas of business. The relevant tasks are assumed by corporate controlling and the controlling staff of the divisions concerned. This is done in collaboration with the corporate strategy and corporate M&A teams.

Environmental controlling is more operational in nature. Relating to specific functional areas, it is roughly equivalent to logistics or quality controlling (see *Schäffer/Weber*, 2005, p. 389 ff.). From an organizational perspective, and as is the case with conventional controlling in the sense of financial corporate management, environmental controlling at *Bosch* primarily takes place in the management units, which are split between the three above-mentioned business sectors, each with several divisions (for greater detail see *Kümmel/Watterott*, 2008, p. 248 ff.). As part of the planning process, the board of management gives the divisions targets for their global business, which they pass on to their business units and other units or locations and agree with the relevant managers. The same applies to the environmental objective of cutting CO_2 emissions.

A differentiated analysis of the controlling tasks resulting from sustainability management shows that many environmental controlling tasks are performed at the company without this being directly visible in a "consolidated" form. The vast majority of tasks are performed on a decentralized basis at the locations. The environmental protection KPIs communicated as part of sustainability reporting are mainly of a technical nature and are not assigned to a specific controlling function. However, target values do exist for these and progress is checked on a regular basis. Consequently, they lay the foundation for environmental protection management (see the *Bosch Group's Corporate Social Responsibility Report*, 2008).

The corporate department for Health, Safety, Environmental and Fire Protection coordinates environmental protection and environmental controlling tasks within the *Bosch* Group. Experts in the relevant departments – especially operational environmental management, facility management, and production planning – coordinate the tasks at locations around the globe. The local controlling team provides assistance with investment appraisals and budgeting environmental protection activities.

The following sections use examples from corporate strategy and strategic controlling, infrastructure management, and production processes to address various aspects of sustainability and the associated controlling tasks.

3. Implementing a sustainable corporate strategy and strategic controlling

The commitment to corporate social responsibility must be reflected equally in the product portfolio and the pursuit of sustainable targets in the company's value-added processes.

The guiding principle "Invented for life" is rather like a strategic search filter for the further expansion of business with sustainable products. This applies both to the further development of existing areas of business and to the initial development of new ones. It is an approach with a long tradition at the company. The 3S program was first postulated back in 1973. It aims to make driving safer, cleaner, and more economical by using *Bosch* products. In addition, product and business ideas must fit in with the company's core competencies if they are to have a good chance of being successful. Fig. 3 shows key examples of sustainable future areas of business in which *Bosch* is currently active as a result of the strategic portfolio process (see the product examples in the *Bosch Group's Corporate Social Responsibility Report*, 2008, p. 22–43).

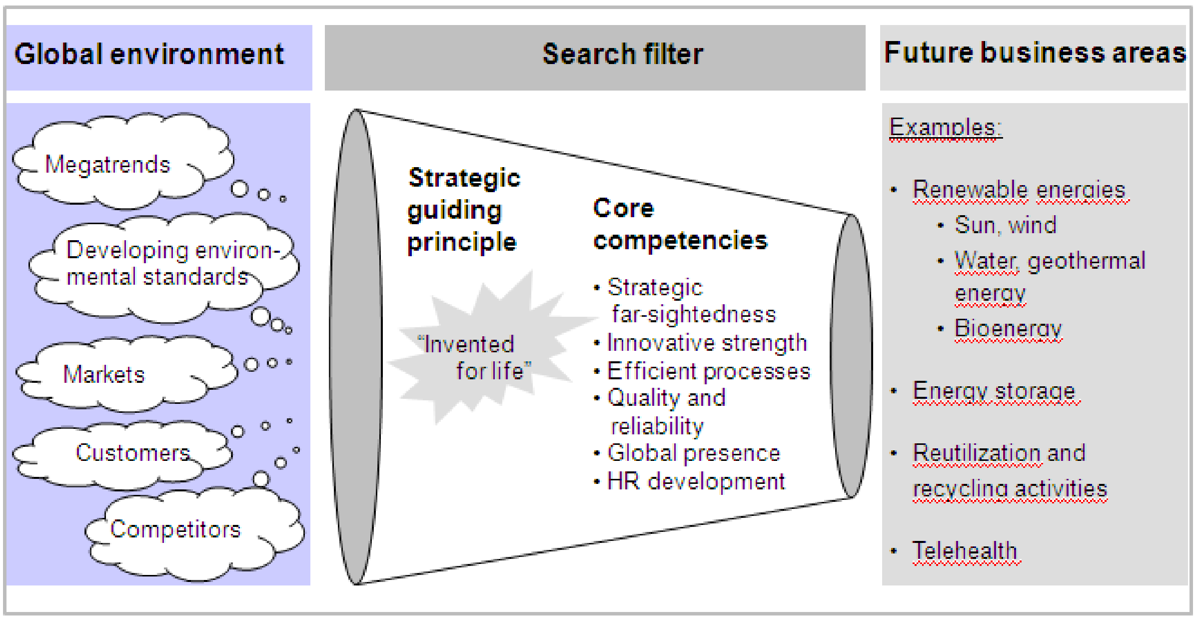


Fig. 3: Focusing on sustainable future fields

Over the past ten years, the *Bosch* Group has invested more than 30 billion euros in research and development focusing on innovations to make life safer, more comfortable, and greener. Some 34,000 associates out of a total of 283,500 worldwide work in research and development. The *Bosch* Group's innovative strength is based on their achievements.

Early incorporation in the product life cycle and the system boundaries that are taken into account are key criteria for the success of innovations. *Pfeiffer/Weiss* (1994) refer to this as a "fundamental principle for the effective and efficient structuring of value-added networks" (see Fig. 4). They argue that extending the system boundaries and early incorporation in the product life cycle have a disproportionately positive impact on the possibilities for improving economic criteria such as costs, time or quality (see *Asenkerschbaumer*, 1998, p. 264).

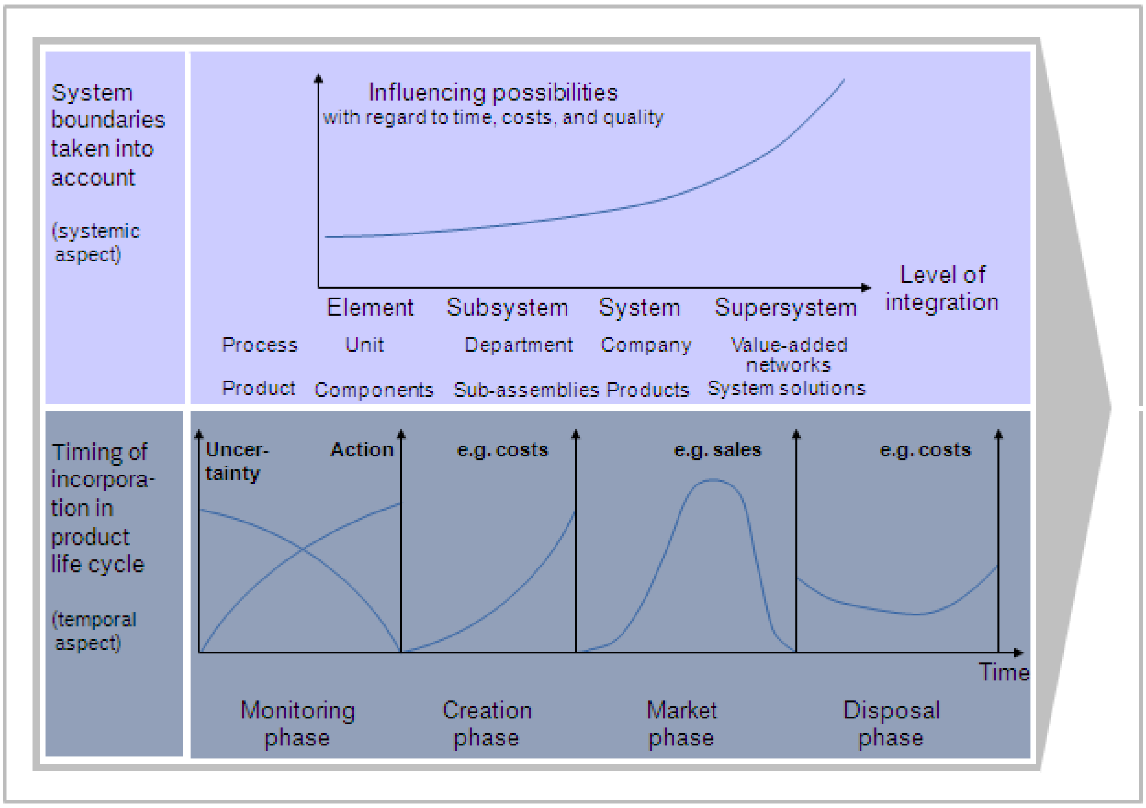


Fig. 4: Fundamental principle for effective and efficient design of value networks (adapted from Pfeiffer / White, 1994, pp. 180 ff)

The following example of crystalline photovoltaic modules demonstrates how systematic extension of system boundaries can make the use of solar energy more cost-effective with the same basic technology. However, a sustainable strategic orientation also involves monitoring and adopting fundamentally new technologies in addition to established ones at a very early stage. For some time now, *Bosch* has therefore also been working on organic photovoltaics as a possible addition to – or even a fundamental further development of – photovoltaic technologies that are already in widespread use.

Example of photovoltaics

Technologies to convert solar energy into electric or thermal energy are a future area of business that has been part of the *Bosch* Group's **monitoring cycle** for some years now. The main aim of this monitoring is to identify new technologies that could be important for use in an existing or emerging product or for creating a new product (see Fig. 5). In the search for less expensive technologies for harnessing solar energy, technologies have been identified that make it possible to produce "organic" photovoltaic cells from organic materials. The use of conductive polymers and dyes paves the way for a low processing temperature, which means that plastic films or even textiles can be used as substrates. In addition to delivering additional cost benefits, this also results in greater flexibility in terms of applications. *Bosch* is working with *BASF SE* and *Heliatek* GmbH on organic photovoltaics, which is currently at the **creation phase**.

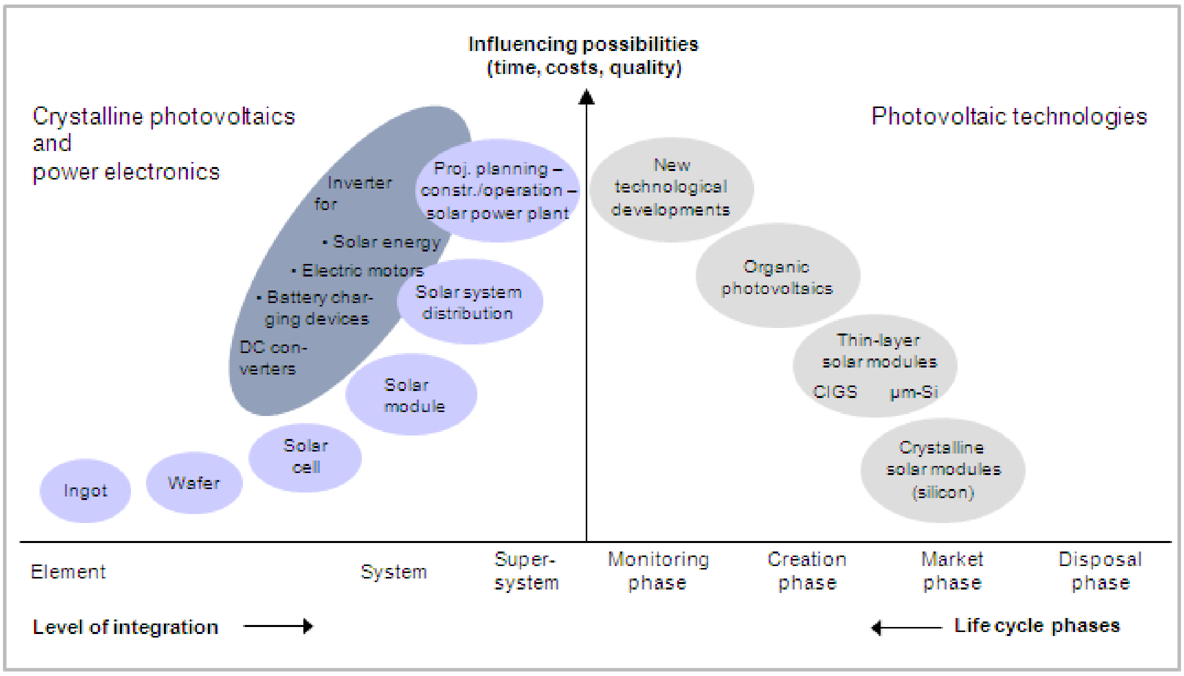


Fig. 5: Application of the fundamental principles of system design for photovoltaic

Thin-film modules made from mixed alloys are a relatively new development. Thanks to the small amount of material required, they are less expensive to make than crystalline solar modules. They are also less efficient, though, so the overall system costs in relation to output are currently comparable. Thin-film modules based on CIGS (copper/indium/gallium/selenide) or silicon are currently between the creation and market phases. *Bosch* has acquired both technologies through M&A projects.

Today's standard modules are at the **growth phase** and mainly consist of photovoltaic cells based on crystalline silicon. *Bosch* has also acquired this technology through its takeover of a solar cell manufacturer (*ersol Solar Energy* AG) and is currently involved in the rapid expansion and internationalization of production and sales markets.

Activities aimed at **extending the system boundaries** to increase the possibilities for influencing costs are subject to the same systematic approach as the strategic focus of the technology portfolio for photovoltaics as early as the monitoring phase. *ersol Solar Energy* AG covered the value-added stages from producing the ingots (blocks of pure crystalline silicon) and obtaining the silicon wafers to manufacturing the solar cells. By setting up a module production operation, acquiring the module manufacturer *aleo solar* AG, and developing photovoltaics project business, the *Solar Energy* division can now offer solar energy solutions from a single source – from photovoltaic modules and, as a service, the design and implementation of turnkey photovoltaic installations through to arranging the necessary financing.

In addition to the strategic focus on sustainable future areas of business, the company's **core competencies** need to cover the success factors in these areas to ensure the successful completion of key future tasks. Power electronics are needed to govern and control the large energy flows encountered in both photovoltaics and the electric vehicles of the future. Over 700 *Bosch* engineers are already working in this field alone.

The strategic focus on photovoltaics referred to here is supported by the strategic controlling activities of the company and the division, which illustrate the potential for success. This is expressed in terms of opportunities and risks but is normally not easy to quantify. One of the main tasks in this respect is to make the key premises plausible. Two important milestones in photovoltaics are achieving cost parity in respect of the grid (price to end consumers) and the generation costs of current average and peak load power plants. There are three decisive influencing variables here – progress on the manufacturing and installation costs of photovoltaics systems, their efficiency, and the level of insolation at the installation site. Progress on costs and efficiency improvements reduce the system price in euros/Wp.

Based on an insolation level of 900 to 1000 kWh/kWp, reducing the system price will first lead to cost parity with the price of domestic electricity in Germany after 2012/2013 (see Fig. 6). The curves in the graph show the electricity production costs for photovoltaic modules, in each case for a system price in euros/Wp depending on the level of insolation. As things stand at present, full cost parity with average and peak load electricity, for example from coal or gas, will not be achieved until after 2020. In sunny regions such as India with insolation levels of 1600 to 1700 kWh/kWp, cost parity with gas- and coal-fired power plants will be achieved far sooner than this.

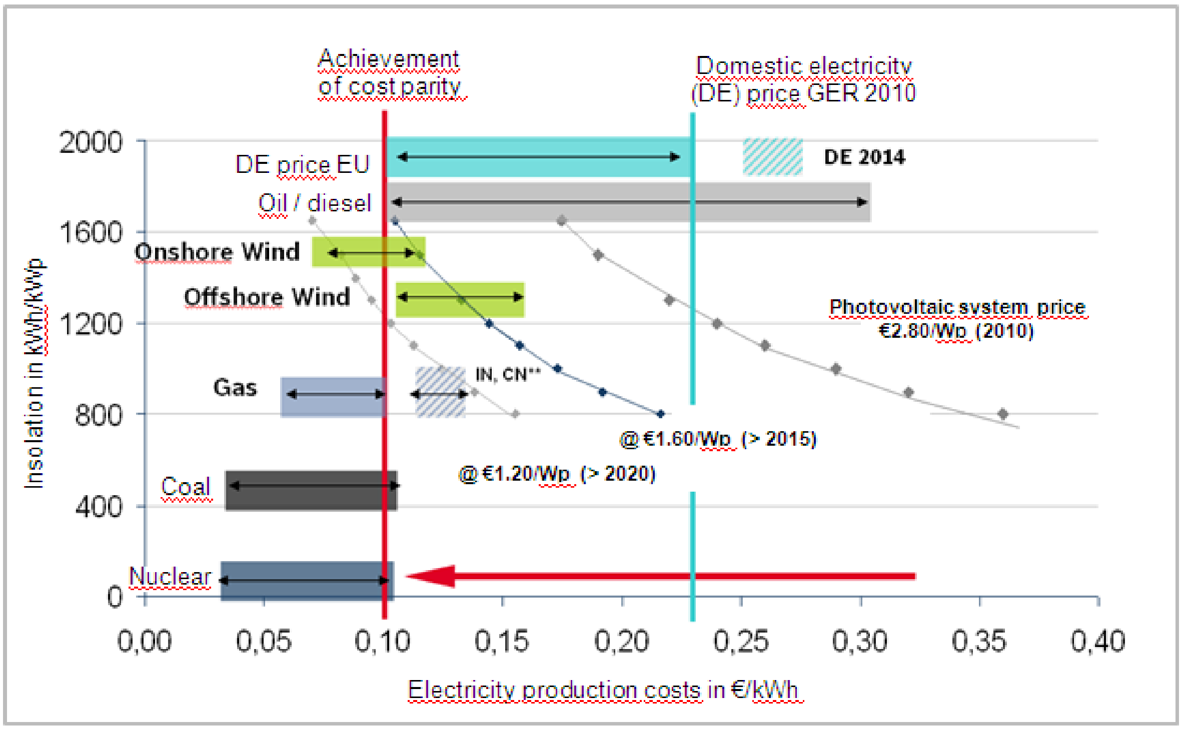


Fig. 6: Compare electricity costs of different energy sources (Source: IEA World Energy Outlook 2008, IEA projected costs of electricity in 2010, own calculations Bosch Solar Energy)

However, the objective of strategic controlling cannot be to forecast as precisely as possible where electricity production costs for the various generation types will be in five or ten years' time so as to adapt the strategy accordingly. Despite the environmental uncertainty, it is far more important to create conditions for achieving the desired goals in the future by incorporating the strategy into the company's strategic planning and implementing the short- and medium-term aspects in operational planning. Aspects such as building up capacity and expertise, investments, budget, M&A planning, market strategies, and organizational development need to be consistently dovetailed for this purpose. It is also necessary to set clear targets and pursue them systematically.

The immediate objective in the case of photovoltaics is to achieve cost parity in respect of the grid (price to end consumers). To do so, companies are endeavoring to reduce module costs by a third compared with 2010 levels. The intention is to more than halve these costs in subsequent steps, which will make them competitive with the production costs for conventional or alternative renewable energy sources in sunny regions (see Fig. 7).

Although strategic controlling primarily focuses on long-term objectives by controlling material targets, close dovetailing with operational controlling is still necessary. This is the only way to identify the key points for the necessary adjustments to strategic goals or resources. For example, operational controlling needs to respond to disruptions such as the economic crisis in 2008/2009 and sudden changes to the feed-in tariff in Germany in 2010. Together with stronger competition from Chinese suppliers, these factors have resulted in module prices falling by around 40 percent (see *Keil* et al., 2011, p. 238). This has changed little in terms of long-term objectives, but it has become necessary to speed up cost cutting and the expansion of activities on markets outside Germany. This in turn has led to a revision of short-term and financial planning. Maintaining the clear strategic focus on long-term objectives and expansion plans despite the disruption has ultimately strengthened the *Solar Energy* division (see *Keil* et al., 2011, p. 241).

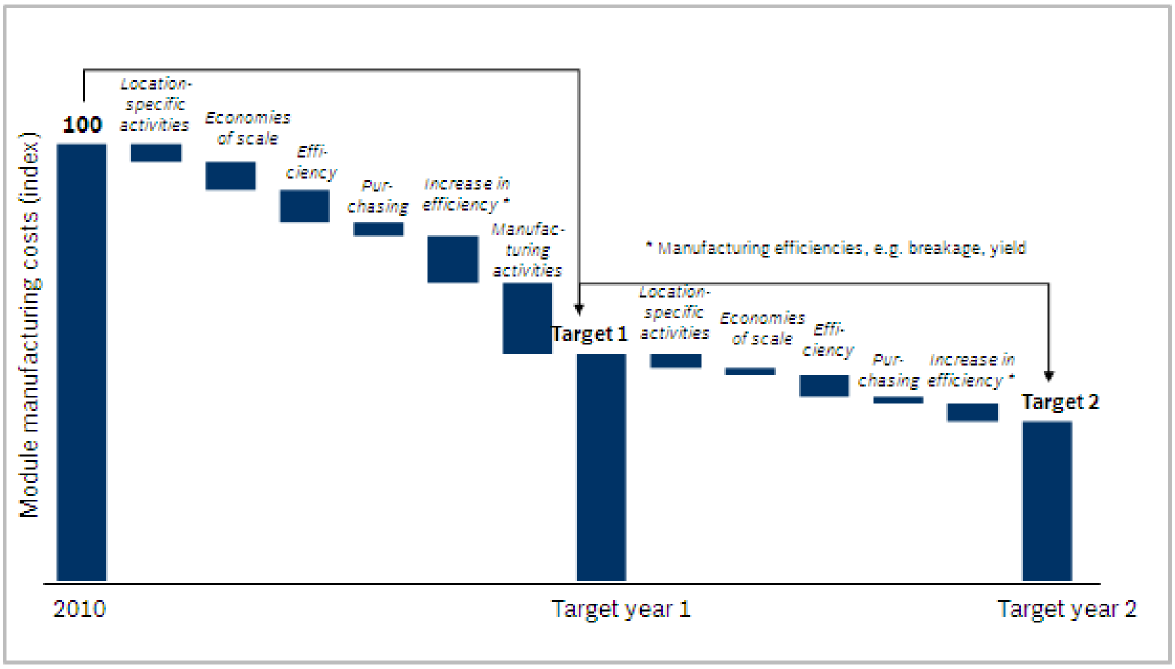


Fig. 7: Exemplary presentation of measures for reducing manufacturing costs of photovoltaic cells and modules

4. Sustainability in infrastructure management and production

Environmental protection at the company relates to many aspects and is set down in binding form in corporate regulations. The first environmental protection directive for the *Bosch* Group worldwide entered into force back in 1973. The following remarks on sustainability in the areas of infrastructure and production concentrate on energy efficiency as the current focal point in these areas. In 2008, the *Bosch* board of management approved the target of cutting relative carbon dioxide emissions by 20 percent between 2007 and 2020. These emissions are determined both directly and indirectly based on the relevant types of energy used. In this context, relative means that harmful emissions must be reduced in relation to the company's own manufacturing operations.

Energy-efficient infrastructure

The company is investing in technologies that go beyond the normal standard and lower energy consumption for lighting, heating, cooling, hot and cold water, and compressed air in office buildings, production facilities, and warehouses. This applies to both new buildings and buildings already in use.

A very effective strategy for lowering energy consumption is to use centralized control technology for building installations. This enables all energy consumers at a given location that are recorded using measuring points to be adapted to current requirements on an ongoing basis. For example, the lights and ventilation system can be switched off at a facility if there is no shift work. For years now, ventilation systems have been equipped with a heat recovery function. The higher investments involved pay for themselves through lower heating costs. Heat pumps are also used to recover process heat from test benches and production equipment, which can be more efficient than using other ambient heat or geothermal energy. At sunny locations, it is necessary to ensure sufficient shelter from the sun, and photovoltaics and solar thermal systems are installed where this is cost-effective.

When constructing new locations or buildings and renovating heating systems, a check is always performed to ascertain whether gas-operated co-generation plants are a cost-efficient option. Such plants achieve a generating efficiency of around 40 percent in relation to the fuel used. The waste heat generated can be used directly for heating/cooling and to produce hot water. This enables an overall efficiency of up to 90 percent to be achieved. In order for co-generation plants to make sense from both an environmental and an economic perspective, it must also be possible to use all the waste heat generated.

In addition to the technologies applicable as standard, specific local circumstances are also used. At the Austrian location of Hallein, for example, 100 percent of the heat required is obtained from a green district heating grid fed by industrial waste heat and biomass power plants. And in Blaichach, electricity is obtained from a hydroelectric power plant belonging to *Bosch*. At the newly built headquarters in Shanghai, up to 80 percent of heating requirements (or up to 60 percent of cooling requirements in the summer) are covered by 275 geothermal probes that extend down to a depth of 120 meters.

Investment appraisals are performed for all investment projects, with observation periods adapted to the relevant technology. Proof of cost-efficiency is required to implement the planned investments. In other words, ecology and economy are not opposites. It is more a case of striking a balance.

Energy-efficient production

Efficient building technology and building insulation alone are not sufficient to achieve the climate target *Bosch* has set itself. The greatest energy-saving potential lies in the area of production, as this is where 70 to 80 percent of a location's energy is used. This is reflected in the environmental data, split into input and output figures, that has been recorded worldwide for all relevant *Bosch* Group locations since 2003 using an IT-based environmental information system (see Fig. 8). The system comprises a central database into which the environmental managers at all manufacturing locations worldwide and all other locations with more than 100 associates enter the relevant data. The environmental indicators are included in environmental controlling, which uses an evaluation system to track the development of the various indicators down to the individual locations worldwide. This includes a breakdown of the carbon dioxide targets agreed with the divisions.

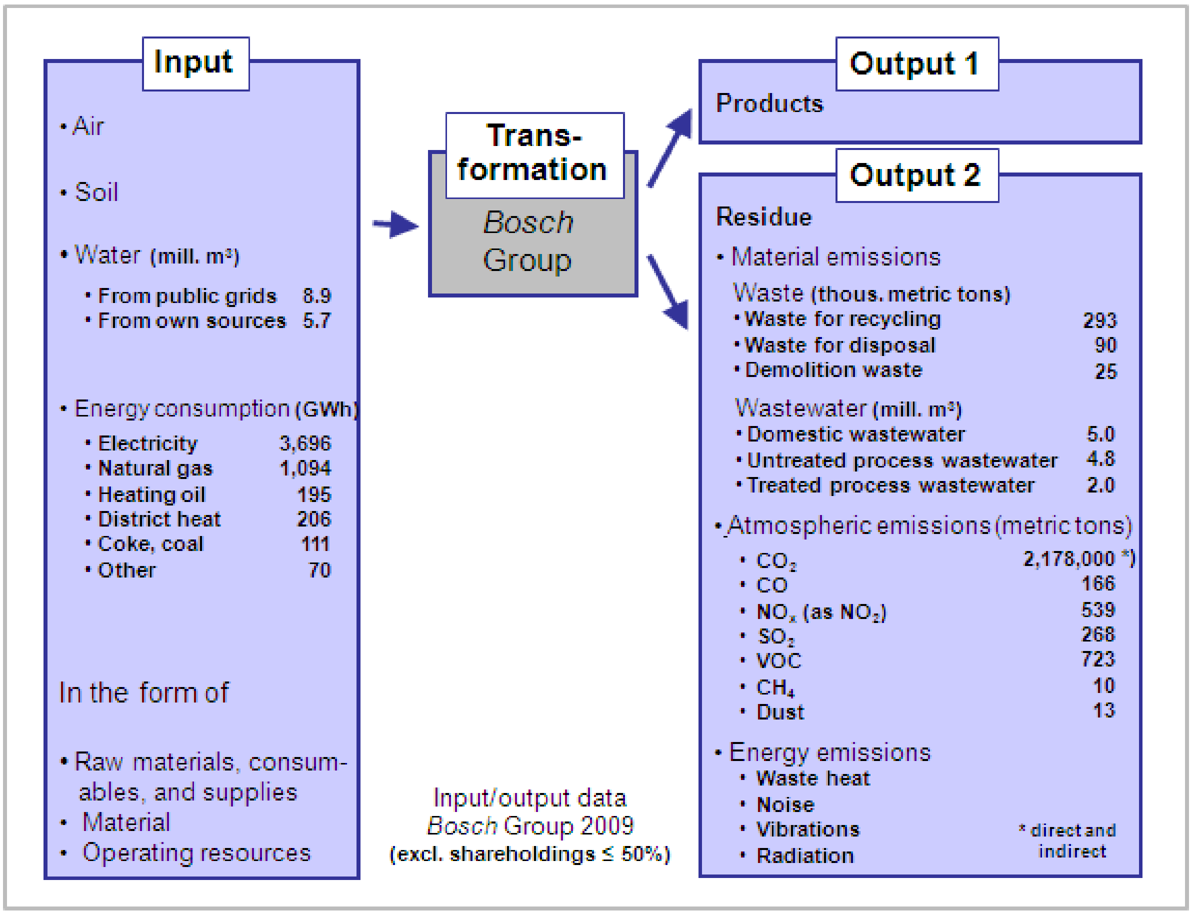


Fig. 8: Environmental input and output aspects of commercial production process (input / output structure based on de Boer, 1996, p 10)

The "Energy efficiency in production" project has been initiated to monitor and support the objectives. The project is coordinated centrally, and all divisions and larger locations have appointed energy efficiency consultants for this purpose. GoGreen, a global ideas competition for all associates involved in manufacturing, development, and production-related areas, is intended to improve energy efficiency in areas the company is able to influence while also raising environmental awareness. A central database supports the distribution of energy efficiency know-how to locations across the globe. This includes best-practice solutions, examples of projects implemented, standards, recommendations, and innovations.

The examples show that networked knowledge is the key to successful CO_2 reduction worldwide. The *Drive and Control Technology* division is using the experience gained for a new business model in which this know-how is made available to other companies. With the help of energy consultants and using the division's energy-saving components – such as variable-speed pump drives – customers can reduce their energy usage by up to 70 percent.

With know-how relating to business management methods, decentralized “conventional” controlling at the manufacturing locations helps production planning, manufacturing, and facility management associates responsible for energy efficiency to prove the cost-effectiveness of the intended environmental protection projects. This involves taking a critical look at the premises on which the evaluation is based but also making suggestions relating to the use of appropriate resources and ascertaining the amount of leeway in budgets.

At divisional level, controlling creates the necessary transparency for executive management in the consolidated divisional perspective. It helps management staff by summarizing the opportunities and risks associated with target achievement using the planned strategies. It also coordinates harmonization of environmental protection projects with the division's strategic and operational planning to ensure that environmental objectives are considered in strategic planning and the decentralized organizational units incorporate specific environmental protection investments with the relevant resources in operational medium-term planning.

5. Conclusion and outlook

Sustainability must be reflected in the vision and corporate strategy, and thus in the product portfolio and value-added processes. It must be embraced throughout the company. The *Bosch* Group's strategic guiding principle “Invented for life” throws down the gauntlet in this very respect. A number of examples have shown that, for the *Bosch* Group, protection of the environment and a sustainable economy complement and draw inspiration from each other. Environmental protection is the driving force behind numerous innovations, new products, and services. Consequently, *Bosch* spends around 45 percent, or more than 1.7 billion euros of its research and development budget on resource-conserving and energy-saving products. These products also generate nearly 40 percent of the company's sales.

A key task of strategic controlling is to support this long-term corporate strategy. Controlling is part and parcel of the company's vision and values. It must transparently evaluate long-term planning – especially the impact of the *Bosch* Group's sustainable future areas of business on management decisions – and support implementation. Controlling can boost sustainability with long-term entrepreneurial thinking.

Operational controlling can strengthen the focus on sustainability by adding indicators to reviews and reports that highlight environmental issues in a more “consolidated” form and, thanks to this enhanced transparency, reinforce the focus on ecology at all management levels. This is also important given that environmental requirements are likely to get tougher still in the future and may result in higher investments and costs for the company.

Bibliography

Asenkerschbaumer, S., Gestaltung und Optimierung des Lieferantenumfeldes – Darstellung exemplarischer Fälle am Beispiel eines Werkes der Automobilzuliefererindustrie, Robert Bosch Ltd., Cardiff, in: *Weiss, E.* (ed.), Innovative Unternehmensführung, Nuremberg 1998, p. 263–283.

Report on the Bosch Group's corporate social responsibility, report for 2007/2008 and data/targets for 2008, Stuttgart 2008. Current values at http://csr.bosch.com

Bosch, *C.*, speech at the gala event marking 125 years of Bosch in Stuttgart on May 19, 2011.

Bosch, R., speech on June 10, 1936, in: *Bosch* (ed.), "Sei Mensch und ehre Menschenwürde", Aufsätze, Reden und Gedanken von Robert Bosch, Stuttgart 1950, p. 58.

de Boer, E. (ed.), Ein computergestütztes Informationssystem für das betriebliche Umweltcontrolling: Entwicklung einer Gesamtkonzeption und prototypische Realisierung am Beispiel eines Informationssystems zur Beurteilung der Umweltverträglichkeit von Einsatzmaterial, Göttingen 1996.

Fehrenbach, F., Die regenerative Kraft der Krise: Unternehmerische Verantwortung gerade jetzt!, presentation at the Sustainability Congress in Stuttgart, March 25, 2009.

Fehrenbach, F., Nachhaltigkeit und Unternehmertum, presentation at "Börsenzeitung im Dialog", Stuttgart, October 27, 2009.

Günther, E., Ökologieorientiertes Management, Stuttgart 2008.

Horv´ath, P., Controlling, 11th edition, Munich 2009.

Horv´ath, P., Isensee, J., Michel, U., "Green Controlling" – Bedarf einer Integration von ökologischen Aspekten in das Controlling, in: *Tschandl, M., Posch, A.* (ed.), Integriertes Umweltcontrolling, 2nd edition, Wiesbaden 2011.

Keil, S., Pierburg, T., Habermann, N., Controlling bei Bosch Solar Energy im Wandel, in: Controlling, 23rd year (2011), vol. 4/5, p. 237– 244.

Kümmel, G.,Watterott, R., Konzerncontrolling am Beispiel Bosch – Globalisierung erfordert Standardisierung, in: Controlling, 20th year (2008), vol. 4/5, p. 247–257.

Pfeiffer, W., Weiss, E., Lean Management. Grundlagen der Führung und Organisation lernender Unternehmen, 2nd edition, Berlin 1994.

Schäffer, U., Weber, J. (ed.), Bereichscontrolling – Funktionsspezifische Anwendungsfelder, Methoden und Instrumente, Stuttgart 2005.

Schaltegger, S., Herzig, C., Kleiber, O., Klinke, T., Müller, J., Nachhaltigkeitsmanagement in Unternehmen, published by: BMU, Berlin 2007.

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Management control for sustainability: Exploring patterns in large European firms

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***Abstract*: A growing body of literature argues that management control is essential in promoting corporate sustainability. Furthermore, the conventional accounting and control literature has identified sustainability and control as an important emerging theme [1]. Nevertheless, except for a series of conceptual (and often prescriptive) papers, few papers have proposed to empirically explore management control practices for sustainability. This explains partly the scepticism that has been raised about the existence of these management controls in the context of sustainability and especially about their role in promoting sustainability within the organizations [2][3].**

Hence, this paper aims at exploring sustainability management control practices in large European firms. It investigates the extent to which large companies have developed a package of formal and informal management control mechanisms to pilot the implementation of corporate sustainability. Based on the empirical observations, it theorizes on sustainability control patterns of corporate practice.

The paper conducts a qualitative analysis on data collected in 17 European companies with a good sustainability reputation. Semi-structured interviews with the corporate sustainability managers were conducted and analysed in accordance with the framework proposed by Malmi and Brown [4]. Thus, it was analysed to what extent planning, cybernetic controls, rewards, administrative controls and cultural controls are used in management control for sustainability.

All of the researched companies deploy sustainability management control. There are, however, notable differences with regard to the complexity of the underlying systems and tools – from basic to advanced ones.

The paper also identifies two distinct approaches in management control for sustainability. Whereas some companies seem to focus on formal approaches of management control, others concentrate on informal management control. A mixture of both was not observed in the sample companies.

The insights and recommendations provided in this paper help organizations in translating their aspirations into their organization [5]. The results also highlight the need for research to better understand the situations in which formal and informal management control for sustainability yields the results anticipated.

I. INTRODUCTION

Despite the growing recognition that sustainability issues can play a major role in achieving corporate success [6]-[8], few empirical insights exist on intra-organizational aspects of management control for sustainability [9] and, in particular, on whether and to what extent formal and informal management controls promote sustainability behaviour.

Extant accounting and control literature commonly views management controls as a means to direct an organization towards strategic and operational goals [10]-[12]. In their literature review, Berry et al. [1] identify sustainability control as an important emerging theme. However, even if a growing body of literature argues that management control is essential in promoting corporate sustainability [2]-[3], apart from series of conceptual (and often prescriptive) papers, only few empirical studies have investigated firms' management control practices to promote sustainability behaviour [5]. This explains partly the scepticism that has been raised on the existence of these management controls in the context of sustainability and especially about their role in promoting sustainability within the organizations [2]-[3]. Norris and O'Dwyer [2] state that "recent evidence suggests that, among firms taking specific steps to instil (sustainability) into organisational decision making, most focus only on the first component—specifying and communicating objectives—and even here the efforts are incomplete with respect to the communication aspect. It is claimed they are doing very little with respect to the other two components, i.e. monitoring ethical behaviour and motivating ethical behaviour by linking rewards (negative incentives) to performance. Based on control theory, the absence of these latter two components can be expected to impair a firm's formal efforts at instilling ethical behaviour among employees.

Therefore, as sustainability management control has remained largely under-researched, investigating how sustainability control is designed in practice is likely to result in better understanding the obstacles and enablers of sustainability management as well as in developing approaches to dealing with the challenges uncovered herein.

Based on these observations, this paper explores sustainability management control practices in large European firms. It investigates the extent to which large companies have developed a package of formal and informal management control mechanisms in order to steer their organization towards corporate sustainability and, based on these empirical observations, it theorizes on a typology of sustainability control patterns.

More concretely, to shed light on the above issues, the paper adopts an inductive qualitative approach and it focuses on the existence of specific elements of the management control "package" (planning; cybernetic controls; reward and compensation system, administrative and cultural controls) to promote sustainability in 17 large Western European firms. With reference to the model proposed by Malmi and Brown [4], this empirical study contributes towards filling the gaps identified above by exploring and discussing individual sustainability control systems and, especially, by investigating the broad scope of sustainability management controls as a package. The analysis reveals two distinct patterns of sustainability control.

The remainder of this paper is structured as follows. The next section reviews the literature on management control in the context of sustainability by focusing on papers investigating practices. Section 3 briefly presents the methodology adopted for sampling and data collection, analysis and interpretation. The empirical findings are presented and discussed in Section 4. Section 5 proposes a pattern of management control tools. The concluding section relates the findings to the initially presented challenge.

II. Literature review

This section reviews the body of literature dedicated to management control in the context of sustainability.

Management controls include all the devices and systems managers develop and use to ensure formally and informally that the behaviours and decisions of their employees are consistent with the organisation's objectives and strategies, but exclude pure decision-support systems [4], [13]. Any system, such as budgeting or a strategy scorecard, can be categorised as a management control system [4]. The accounting and control literature traditionally distinguishes between the design (existence) of controls and their use (adoption, utilization and implementation) (Langfield-Smith, 1997; Tucker et al., 2009).

Management controls encompass formal as well as informal controls [10], [13]. Formal controls consist of purposefully designed, information based and explicit sets of structures, routines, procedures and processes that help managers ensure that their organizations' strategies and plans are carried out or, if conditions warrant, that they are modified [14]. Within the category of formal controls there are accounting controls, which have been studied in previous research.

Informal controls, in contrast to formal controls, do not control behaviour through explicit, verifiable measures. They consist of shared values, beliefs, and traditions that guide the behaviour of group members (employees) [2], [10], [14], [15]. Employees acquire the values, beliefs and traditions through a subtle reading of signals relayed by supervisors and co-workers. Such signals include symbols and informal structures. As. opposed to formal authority, informa1 authority refers to individual's ability to influence organizational decision and activities in ways that are not prescribed by the formal authority system. Behavioural theories of organizations have emphasized the importance of informal authority for decades [16].

Driven by the increased interest for corporate sustainability, including related concepts such as corporate social responsibility [17] in scientific research over the last decades, a growing body of literature on management control in the context of sustainability has emerged [2], [3], [5], [9], [18]-[22].

Based on the definition of management control proposed by Malmi and Brown [4], sustainability management control includes all devices and systems managers develop and use to ensure formally and informally that the behaviours and decisions of their employees are consistent with the organisation's sustainability objectives and strategies. Concretely, they deal with the interaction between business, society and environment. Although the term "sustainability management control" has been sporadically discussed [21] and although a series of publications argue that management control is essential to promote sustainability within an organization [2], [3], [9], [22], [23], few research on the topic has been identified. In addition, there is not yet a detailed elaboration of the concept [21]. As the literature on sustainability management control is still in an emerging state [24], papers dealing with the environmental and/or social pillar(s) of sustainable development are considered as belonging to the (broad) sustainability management control literature.

After an examination of this literature, apart from some conceptual (and often prescriptive) proposals [5],[18],[21],[25], it becomes evident that only few studies have investigated firms' management control practices with reference to sustainability. A limited number of survey-based and cased-based empirical studies investigate how management control has been deployed in practice to promote sustainability [2],[3],[9],[20],[26].

The following paragraphs summarize and synthesize the findings of case-based studies dedicated to sustainability management control in large firms. Indeed, the case study research methodology is considered to be the most suitable when the research question asks ''how'' and ''why'', as well as when the researcher cannot manipulate directly, precisely and systematically events and there is a contemporary focus in a real-life context [26, pp. 1-9]. Furthermore, previous research shows that large firms are more inclined than their smaller counterparts to develop sustainability strategies [28] as well as to design management control systems [29].

Almost all of the few papers on management control for sustainability identified are case-study based. For example Norris and O'Dwyer [2] explore the perceived influence of formal and informal control systems on socially responsive managerial decision-making through one in-depth case study in a large UK firm. Another example is the case study of Novo Nordisk A/S, based on which Morsing and Oswald [20] explore to what extent it is possible to influence sustainability at the operational level by contemporary management control systems in integrating the perspective of organizational culture. Riccaboni and Leone [30] rely upon the case of Procter & Gamble to explore how management control systems (MCS) work in order to translate sustainability strategies into action and how they should be modified when a strategic sustainability opportunity emerges.

None of these empirical case studies proposes an exploration of practices in large firms while multiple case studies are judicious because of their generation of cross data and causal relationships that enable replication [31]. Furthermore, the selection of controls under investigation in these studies is either not clearly developed or limited to one or two (formal and/or informal) control mechanisms.

This exploratory study fills the gaps identified above by exploring and discussing individual sustainability control systems but, especially, the broad scope of the sustainability management controls as a package [4].

III. Research approach

To enable an explorative qualitative analysis, the research sought to engage a group of companies, sufficiently large to achieve theoretical saturation. To start off, we used the Forbes list of the world's biggest public companies for 2009. Of these companies, 555 were based in Europe, which is the scope of this study. Large companies have resources that enable them to develop own approaches to various issues [28], [29]. Thus, company size was anticipated to play a role in finding companies with extensive management control practices that also address sustainability.

Subsequently, we excluded the companies residing in countries whose official language was not spoken by a member of the research team. This left 348 companies based in a country where English, German, French or Dutch is spoken.

The research aimed to capture good sustainability management control practice. As a preliminary indication of the availability of such a practice, we filtered out those companies which were not listed in Dow Jones Sustainability Index. This reduced the sample to 211 companies.

By random selection we contacted a third of these companies [32] and 17 companies expressed their willingness to take part in the research by dedicating resources in terms of employee time.

All of the 17 companies are large firms operating in Western Europe. All keep a high profile in terms of sustainability engagement (e.g. Dow Jones Sustainability Index members, winners of specific international/national awards, regular publication of sustainability reports, promotion of sustainability on their websites) and are thus sensitive to the importance of sustainability information management and management control.

Data was collected by means of semi-structured interviews conducted in 2010 and 2011 with the sustainability manager of each company. The face-to-face interviews had an average duration of about one hour. The interviews were documented by means of detailed notes. In addition to the interviews, internally and publicly available information such as annual reports, web information and policy statements were further analysed.

The interview agenda sought to shed light on the companies' sustainability strategy and the existence of a package control mechanisms to promote sustainability behaviour. Having framed the research within the framework of Malmi and Brown [4], we sought to identify to what extent the five components of management control (planning, cybernetic controls, incentive and reward system, administrative control and cultural controls) were deployed in the companies in managing sustainability performance.

These five components were investigated with regard to how they are deployed in management control for sustainability. We thus examined the extent to which each component i) exists and ii) is integrated alongside the conventional management control components.

Attention was also paid to the focus of management control – whether both social and environmental aspects are considered and paid equal attention. The research was thus led by the following questions:

Is the control observable in one or another form?

Does it control social and environmental performance?

Is it integrated in the core business, i.e. in the conventional management control?

Cultural controls presented a challenge due to their informal nature. We thus sought to observe a significant number of signals which signal sustainability engagement and can influence organisational culture (such as shared beliefs and values). These signals included (1) the availability of an intranet platform that served as a medium for discussing sustainability issues and distributing information on them and internal letters/emails dealing with sustainability, (2) internal events organised with social and environmental considerations, (3) opportunity to participate in community projects (volunteering), (4) shared values, (5) emphasis in the annual report and (6) other visual sustainability symbols such as architecture (e.g. green buildings), CEO examples (e.g. using public transportation) or symbols on letters (e.g. "consider the environment before printing this email").

IV. Findings and analysis

Based on the findings of the (case-based and survey-based) empirical studies reviewed in the literature [2], [9],[20] and as our sample comprises companies that are amongst the "best performers" in terms of sustainability in Europe, we expected to find few, but at least some, management controls in the sampled firms.

Of the five categories of management control mechanisms proposed by Malmi and Brown [4], long-range and short-term planning, cybernetic controls and formal organisational structure were observed (to a varying extent) throughout the sample. Less evidence could be identified for the existence of rewards and compensation (Table 1).

TABLE 1: Aggregated summary of the observations

Management control	No. of companies (out of 17)
Planning	14
Cybernetic controls	17
Rewards and compensation	4

Administrative controls	17
Cultural controls	14

Breaking down the individual components of management control reveals further details on their existence and integration in established management control systems.

The analysis reveals different extents to which the management controls were developed in these companies: from a very frequent observation of cybernetic controls to a very rare observation of rewards (Table 1). Another observation which is discussed in the following section is the difference in the complexity of tools applied within each of the five controls. For example a basic set of non-financial indicators may be limited to a list of non-monetary indicators such as CO_2 emissions, electricity consumption, etc. A more advanced system may on the other hand be based on a balanced scorecard or material flow cost accounting.

V. DISCUSSION

The above observations reveal a detailed insight into firms' practices. Yet, a key element of the model proposed by Malmi and Brown [4] lies in the broad scope of MCS as a package, rather than the depth of its discussion of individual systems.

When analysing the broad scope of formal and informal systems on which these large firms rely (vertical), we observe that all these companies do not rely on the same categories of control mechanisms (different combinations of control mechanisms are observed).

The following analysis reveals two approaches to formal management controls which is juxtaposed to informal management controls.

Having examined the formal controls, we looked into the role of informal management controls by comparing the availability of formal and informal management control mechanisms in the researched companies.

All of the sampled firms have developed a package featuring both formal and informal controls. However, none of the firms sampled have developed both strong formal and strong informal controls. The patterns of management control for sustainability furthermore show three distinctive groups.

The first pattern is associated with limited formal and informal control approaches. This paper builds upon the presumption that management control for sustainability is a prerequisite for achieving the sustainability objectives of a company. Therefore, there seems to be a mismatch between the public sustainability image of those companies and the actual measures taken in managing sustainability performance internally.

The second pattern identified can be characterised as predominantly informal. It is in line with the observation made by Norris and O'Dwyer [2]. The advantages of this approach are that it creates a high level of awareness about sustainability goals in the organization. However, this also created conflicts for managers in terms of pursuing social responsibility goals when these were not reflected in a formal control system (conflicts with the traditional formal management control). In addition, the importance of formal management control in motivating (sustainability) decision-making has been documented in in the traditional accounting and control literature.

The next pattern depicts a rather formalised approach to management control for sustainability. It is characterised by an emphasis on formal management control such as dedicated organisational structure, clear responsibilities, clear objectives and available resources reinforced by budgeting and planning. At the same time, the companies belonging to this pattern seem to neglect or avoid informal management controls.

Lastly, following the analysis pattern for the formal and informal corporate sustainability management control practices, a fourth pattern emerges – one that features both strong formal and strong informal management controls. In our sample, none of the 17 companies analysed falls in this category. Extant literature acknowledges that formal controls need to be supported by informal controls. Norris and O'Dwyer [2, p. 179] argue that "from an elementary view, the informal system operates to sustain or circumvent the formal system. For example, when the values and norms of the informal system fortify behaviours that support the formally identified organisation values and/or goals, the systems are deemed congruent". It could thus have been expected to observe companies in this category. The absence of such does nevertheless not surprise. Given the relative novelty of sustainability management, an extensive sustainability management control may need more time to be established. Extensive new management controls systems need resources (including time) and thus focus on either formal or informal controls at the same time.

VI. CONCLUSIONS AND OUTLOOK

This paper investigates sustainability management control in leading companies and finds distinctive control patterns in organisational practices. The analysis of formal and informal approaches of management control reveals that those companies with more pronounced formal controls have less developed cultural control systems and vice versa.

Arguments exist in favour of each pattern. It can however be anticipated that, in the long run, companies are likely to revert to both approaches, as formal and informal management controls are complimentary and may reinforce each other. Based on the accounting and control literature, a progressive development towards pattern D can be anticipated: complete formal control mechanisms should be supported by informal control mechanisms. In practice, companies do not currently seem to follow the most direct path towards pattern D. Instead, they seem to focus on pattern B (informal controls) or on pattern C (formal controls).

The findings also suggest the proposition that either culturally-dominated or formally established management controls are suitable for sustainability management.

Under this reasoned assumption, research is challenged to identify the factors influencing the adoption of one or the other system. Investigating the behaviour of companies will allow identifying issues that prevent companies from using management control to implement sustainability effectively.

REFERENCES

[1] Berry, C., Otley, D. and Stringer, H. (2009), “Emerging themes in management control: A review of recent literature”, The British Accounting Review,Vol. 41, pp. 2-20.

[2] Norris, G. and O’Dwyer, B. (2004), “Motivating socially responsive decision making: the operation of management controls in a socially responsive organisation”, The British Accounting Review, Vol. 36, pp. 173-96.

[3] Durden, C. (2008), “Towards a socially responsible management control system”, Accounting, Auditing & Accountability Journal, Vol. 21, pp. 671-694.

[4] Malmi, .and Brown, D. (2008), “Management control systems as a package—opportunities, challenges and research directions”, Management Accounting Research, Vol. 19, pp. 287-300.

[5] Epstein, M. and Wisner, P. (2001), “Using a Balanced Scorecard to Implement Sustainability”, Environmental Quality Managment, Vol. 11, pp. 1-10.

[6] Stanwick, P. and Stanwick, S. (1998), “The relationship between corporate social performance and organizational size, financial performance, and environmental performance: an empirical examination”, Journal of Business Ethics, Vol. 17, pp. 195-204.

[7] Bansal, P. and Roth, K. (2000), “Why companies go green: a model of ecological responsiveness”, The Academy of Management Journal, Vol. 43, pp. 717-736.

[8] Porter, M. and Kramer, M. (2006), “Creating Shared Value”, Harvard business review, Vol. 84, No. 12, pp. 76-92.

[9] Henri, J.-F. and Journault, M. (2010), “Eco-control: the influence of management control systems on environmental and economic performance”, Accounting, Organizations and Society, Vol. 35, pp. 63-80.

[10] Ouchi, W. (1977), “The relationship between organizational structure and organizational control”, Administrative Science Quarterly, Vol. 22, pp. 95-113.

[11] Simons, R. (1990), “The role of management control systems in creating competitive advantage: new perspectives”, Accounting, Organizations and Society, Vol. 15, pp. 127-143.

[12] Ferreira, A. and Otley, D. (2009), “The design and use of performance management systems: An extended framework for analysis”, Management Accounting Research, Vol. 20, pp. 263-282.

[13] Otley, D. (1980), “The contingency theory of management accounting: achievement and prognosis”, Accounting, Organizations and Society, Vol. 5, pp. 231-244.

[14] Simons, R. (1995), Levers of Control, Harvard Business School Press, Boston.

[15] Markus, L. and Pfeffer, J. (1983), “Power and the Design and Implementation of Accounting and Control Systems”, Accounting, Organizations and Society, Vol. 8, pp. 205-218.

[16] Fischer, F.M. (2010), The Application of the Controllability Principle and Managers’ Responses. A Role Theory Perspective. Springer, Wiesbaden.

[17] Schaltegger, S. and Burritt, R.L. (2005), “Corporate sustainability”, in Folmer, H. and Tietenberg, T. (Eds.) The International Yearbook of Environmental and Resource Economics, Edward Elgar, Cheltenham: pp. 185-232.

[18] Figge, F., Hahn, T., Schaltegger, S. and Wagner, M. (2002), “The Sustainability Balanced Scorecard – Linking sustainability management to business strategy”, Business Strategy and the Environment, Vol. 11, pp. 269-284.

[19] Chung, L. and Parker, L. (2008), “Integrating Hotel Environmental Strategies with Management Control: a Structuration Approach”, Business Strategy and the Environment, Vol. 17, pp. 272-286.

[20] Morsing, M. and Oswald, D. (2009), “Sustainable leadership: management control systems and organizational culture in Novo Nordisk A/S”. Corporate Governance, Vol. 9, No. 1, pp. 83-99.

[21] Schaltegger, S. (2011), “Sustainability as a driver for corporate economic success – consequences for the development of sustainability management control”, Society and Economy, Vol. 33, No. 1, pp. 15-28.

[22] Gond, J.-P., Grubnic, S., Herzig, C. and Moon, J. (2012), “Configuring management control system: Theorizing the integration of strategy and sustainability”, Management Accounting Research, Vol. 23, pp. 205-223.

[23] Schaltegger, S. (2012), “Sustainability Reporting beyond Rhetoric. Linking Strategy, Accounting and Communication”, in Jones, S. and Ratnatunga, J. (Eds.) Contemporary Issues in Sustainability Reporting and Assurance, Emerald Publishing, London, pp. 183-195.

[24] Schaltegger, S., Gibassier, D. and Zvezdov, D. (2013). „Is Environmental Management Accounting a Discipline? A Bibliometric Literature Review”, Meditari Accountancy Research, Vol. 21.

[25] León-Soriano, R., Muñoz-Torres, M. and Chalmeta-Rosaleñ, R. (2010), “Methodology for sustainability strategic planning and management”, Industrial Management & Data Systems, Vol. 110, pp. 249-268.

[26] Epstein, M. and Roy, M.-J. (2001), “Sustainability in Action: Identifying and Measuring the Key Performance Drivers”, Long Range Planning, Vol. 34, pp. 585-604.

[27] Yin, R. (2008), Case Study Research: Design and Methods, Sage Publications, London.

[28] Chrisman, J. and Archer, R. (1984), “Small Business Responsibility: Some Perceptions and Insights”, American Journal of Small Business, Vol. 9, No. 2, pp. 46-59.

[29] Widener, S. (2004), “An empirical investigation of the relation between the use of strategic human capital and the design of the management control system”, Accounting, Organizations and Society, Vol. 29, pp. 377-39.

[30] Riccaboni, A. and Leone, E. (2010), “Implementing strategies through management control systems: the case of sustainability”, International Journal of Productivity and Performance Management, Vol. 59, pp. 130-144.

[31] Masanet-Llodra, M. (2006), “Environmental management accounting: a case study research on innovative strategy”, Journal of Business Ethics, Vol. 68, pp. 393-408.

[32] Rao, J. (1997), “Developments in sample survey theory: An appraisal”, Canadian Journal of Statistics, Vol. 25, pp. 1-21.

Material Flow Cost Accounting in Management Control Systems – A Systematic Literature Review

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Abstract: **In order to support companies in better understanding both the environmental and financial consequences of their material and energy use and consequently in enhancing corporate performance, the International Organization for Standardization has developed a standard on Material Flow Cost Accounting (MFCA), that was released in September 2011. However, in order to continuously improve corporate performance, the alignment with the existing Management Control System (MCS) is indispensable, as it provides appropriate means for effective performance measurement and strategy implementation.**

This study therefore addresses the question how MFCA can be properly implemented into MCS. We systematically review 101 studies on MFCA and related flow-oriented methods. The objective of our review is to assess which levers of MCS (diagnostic control systems, interactive control systems, beliefs systems, and boundary systems) are already indirectly addressed in existing studies. Moreover, we summarize methodological issues relevant in this context.

I. INTRODUCTION

Shortages and increasing prices in the raw material markets have motivated material intense companies to improve their use of resources, both from a physical and monetary perspective. A promising approach to continuously improve the use of resources was standardized by the ISO 14051 on Material Flow Cost Accounting (MFCA), which aims to enhance corporate environmental and financial performance. First, MFCA provides the means to ameliorate the transparency of material flows with the related costs and environmental impacts and, thus, to visualize resource flows along the value chain. Therefore, it can better support operational decision-making and improve coordination and communication in various corporate departments. [1]

Second, in order to continuously improve corporate performance, the alignment with the corporate strategy is indispensable. Management control systems (MCS) such as the levers of control by Simons (1995) can provide the proper means for effective performance measurement and strategy implementation. [2]

Hence, we suggest implementing the environmental and financial drivers identified by MFCA analysis into MCS in order to promote opportunities to increase resource efficiency. Yet, a direct linkage from MFCA to MCS is still lacking in research and practice.

This study therefore addresses the research question: How can MFCA be properly implemented into MCS? For this reason, we systematically review the existing literature on MFCA. As still few publications exist regarding this recently standardized accounting instrument, we extend our literature search to antecedent flow oriented methods, a topic that has been researched for two decades. The objective of our review is to assess which levers of MCS (diagnostic control systems, interactive control systems, beliefs systems, and boundary systems) have already been indirectly addressed in existing studies. Moreover, we summarize methodological issues relevant in this context. Finally, we suggest an integration of MFCA into MCS.

II. THEORY

According to DIN EN ISO 14051, MFCA is a "tool for quantifying the flows and stocks of materials in processes or production lines in both physical and monetary units" [1]. Hence, this visual accounting instrument helps to improve the transparency of material flows with the related costs and environmental impacts. Thus, it can better support corporate decisions concerning business strategies. [1]

Regarding the widely discussed concept of MCS and its characteristics, we focus on the framework of Simons (1995) including his concept of Levers of Control, thereby providing a holistic and contemporary view of implementing management strategy, e.g. in terms of interactivity. The author describes MCS as "[...] the formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities" [2].

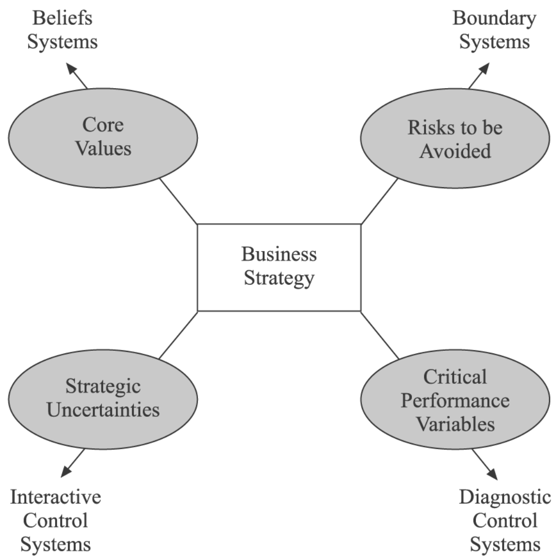

FIGURE 1: SIMONS, R. (1995)

The four levers (cf. Figure 1) control different key figures or values. Generally there are two main aspects of these levers; the first one combines positive things, which are the beliefs system and the interactive control system where people get the possibility to contribute to the main objectives of the company. The second one is a more constrained view; it is the boundary and the diagnostic control system. Hence, there are always two opposites in the levers of control to keep the balance between creativity and control, in order to implement business strategies effectively. [2]

Considering the objectives of MFCA and MCS with its corresponding levers of control, we expect fruitful research results when searching for approaches on how MFCA can support business strategy.

III. Material and Methods

In existing literature, no comprehensive article could be identified focusing on the relationship of MFCA or antecedent flow oriented methods with MCS. Hence, the purpose of this systematic literature review is to describe current knowledge and guide professional practice [3, 4].

We defined a review protocol to systematically guide the review process. The protocol covers three categories to answer the following research questions of this study: First, bibliographic data of the studies was compiled in order to get an idea of who the main contributing conversants are. Second, we assess in how far the different methods have already been implemented into the four levers of MCS. Third, we explore which conceptual and methodological issues are discussed in the study sample.

In a first screening, two coders searched nine databases with search terms for MFCA and antecedent flow oriented methods. These databases cover six broad databases (ScienceDirect, Emerald, Ebsco (Academic Search Complete, Business Source Complete), Wiley, WISO, SpringerLink), two databases which also cover conference proceedings and other unpublished literature (Web of Science, Google Scholar), and one technology database (TEMA). Our sample covers journal articles, books, dissertations, guidelines, reports, and conference proceedings in English and German language. Excluded from the sample were generic studies such as editorials, introductions, abstract summaries, columns, commentaries, or study notes. Moreover, duplicates within and between databases were eliminated. Studies were not excluded based on the publication date. In a second screening, two different coders searched the title, abstract, and keywords of the remaining studies to select those conceptual or empirical studies which addressed MFCA and antecedent flow oriented methods. During the development of the research question, databases and search terms as well as the screening and the review of the studies repeatedly scholars in interdisciplinary research seminars.

IV. Discussion of Results

1. Bibliographic Data

On the basis of the review protocol described above we identified 101 mainly academic studies from Europe (in particular Germany) and Asia (in particular Japan) which illustrates the initial efforts made in both regions. The studies cover many case studies from industries such as chemicals, metals, or waste management. Interestingly, also some market driven industries are included in the sample, e.g. food and beverage. In general, we identified studies which aim at process optimization, environmental management, or stock and flow analysis, but the sample also covers many conceptual studies. We differentiate the methodologies used in financial and solely physical analyses. The financial methodologies cover in particular MFCA, its antecedent Flow Cost Accounting (FCA), and Environmental Management Accounting (EMA). The physical methodologies include static as well as dynamic Material Flow Analysis (MFA).

2. Approaches for integrating MFCA to MCS

The analyzed 101 publications provide diverse approaches on how MFCA and antecedent flow oriented methods can merge into MCS and its levers of control.

Primarily, we find suggestions for the diagnostic control system and its critical performance variables. Since these variables measure and monitor organizational outcome, they are necessary for implementing corporate strategies. However, it is important that the critical performance variables represent the intended strategy [2]. Therefore, we determine some interesting indicators, yet they have to be adjusted to the firm´s individual strategy and specific targets.

One particular reason for the possible multiple indicators is the data volume provided by the analyzed flow oriented methods. To name just one example, the results of the MFCA directly indicate costs for material and energy uses and losses per production step. These variables may already represent critical performance variables for mainly material intense companies. Thurm (2002) underlines this aspect and refers to the possible combination of financial and technical orientated dimensions [5]. Moreover, the comparison to and evaluation of former periods may show significant changes of indicators [6] and, thus, provide a useful basis for decision-making.

Considering the aspect of improving the efficient use of resources, the indicators for resource productivity and resource intensity [e.g. 7] also provide useful approaches for the diagnostic control system. However, analyzed literature does not specify a possible implementation of social issues into the key indicators [8].

Regarding the interactive control system of a MCS, one might ask how managers involve it in the corporate decision making. Numerous authors describe how MFCA results can highlight hotspots with high material losses resulting from an inefficient production step [9, 10, 11]. Scholars suggest managers focus on these spots in order to analyze the losses in detail and generate new ideas and especially subsequent process and technology optimizations [12, 9]. However, although MFCA and related methods can provide diverse data and critical performance variables for deriving strategic uncertainties, there is still a lack of proper decision support [13].

Considering the fact that the analyzed flow-oriented methods do not focus on core values and risks to be avoided, both representing the key variables of the belief and boundary system, we are not surprised that the publications provide less approaches of how to use these methods for supporting this part of a business strategy. Schmidt (2009) supports this result and he even wonders about the possible mission statements for a flow-oriented optimized planning method [14]; whereas Däumler and Grabe (2000) describe how the intraorganizational data transparency may facilitate trans-border thinking and influence employee behavior [15]. The better internal communication due to the same database for every department, i.e. accounting, production, and environmental departments, may also improve the internal employee suggestion system as every single employee has more possibilities to integrate the organization as one entity into his ideas for improvement.

In one case study, the developed performance evaluation standards were not only used for evaluating management results, the established system also measured how management regulations and rules were improved [16]. This system serves as the basis for our proposition of integrating MFCA results into the belief and boundary system. Managers could derive critical threshold values for specific performance variables and transform these thresholds on the one hand into no-go criteria for the boundary system and, on the other hand, managers could formulate inspiring targets out of these thresholds for the beliefs system, e.g. for the waste rate.

3. *Conceptual and methodological issues*

Conceptual or methodological issues can be identified in the context of both feedback and measurement systems, i.e. diagnostic control system and interactive control system. For the diagnostic control system we identified studies which address visualization [e.g. 17, 14, 18], indicator development [e.g. 19, 7, 20], allocation of processes and outputs [e.g. 21, 12, 1], dynamic optimization models [e.g. 14, 18, 11], cost carryovers between processes as well as for internal material cycles [e.g. 1, 22] and inclusion of externalities [e.g. 23].

These studies show that there are already a number of diagnostic conceptual or methodological issues available. The visualization and indicator developments point to the advantages of MCFA and indicate that transparent approaches are a prerequisite in order to integrate MFCA with MCS. Transparent and comprehensible decisions on rules for allocation and cost carryovers are also important in this context. Dynamic modeling is still a challenge in MFCA as long as the necessary data for a regular performance of MFCA is not an integral part in the corporate accounting and MCS system. If the analyzed production process is characterized by significant external effects which are not represented by MFCA indicators, other indicators could be derived from environmental assessment methodologies such as Life Cycle Assessment (LCA). By extending the scope of the study to the whole life cycle, a broader view could be obtained and new optimization potentials could be identified, yet this is also the most challenging part as often such assessments involve good collaboration along the value chain as well as sensitive information (in particular, as costs are concerned).

For the interactive control system we identified studies which suggest a number of prioritization methodologies for multi criteria decision-support such as Analytical Hierarchical Process (AHP) [e.g. 24, 25, 26] and assess the robustness of the study results in terms of sensitivity analyses, variance analyses, uncertainty analyses etc. [e.g. 13, 17, 27]. Hence, we intend to raise the awareness that decision-makers need support in the interpretation and prioritization of the results as well as in how far results are affected by changes through varying or uncertain parameters in order to provide the impetus to inform business strategy.

The analyzed studies rarely address conceptual or methodological issues related to the belief and boundary systems. One study discusses how the implementation of organizational learning into environmental management can enhance corporate cooperation and communication [28]. However, further research is needed to improve the interplay of performance analysis strategy formulation and corporate communication. For instance, future studies could address how the MFCA results can be communicated in order to determine core values (beliefs systems) and codes of conduct (boundary systems).

V. Conclusion

We contribute to research by integrating material flows into the levers of MCS. Consequently, we can provide guidance for management to include more resource efficient thinking into business strategy.

The systematic review showed that MFCA already provides some measures to derive critical performance indicators for the diagnostic and interactive control systems. However, the other two levers of control are rarely considered yet.

The results of the review indicate that the main challenge to integrate the results of MFCA studies into the existing MCS and improved resource efficiency are MFCA studies over a whole life cycle. By extending the scope of a MFCA study, it is possible to combine MFCA with Life Cycle Costing [9]. Moreover, we want to motivate business and research to consider not solely cost impacts but also impacts on environment and society. As an example we mentioned the combination of MFCA with LCA [e.g. 9, 29]. In this way, indicators could cover physical, financial and environmental impact relationships. In order to support strategic decision-making, understandable prioritization methodologies could be applied.

An additional challenge for future studies is dynamic modeling as long as the necessary data for a regular performance of MFCA are not an integral part of the corporate accounting and management control system.

References

[1] Normenausschuss Grundlagen des Umweltschutzes (NAGUS) im DIN, 2011. Environmental management – Material flow cost accounting – General framework (ISO 14051:2011)

[2] Simons, R., 1995. Levers of control: how managers use innovative control systems to drive strategic renewal. Harvard Business Press, Boston, Mass.
[3] Fink, A., 2009. Conducting research literature reviews: from the Internet to paper, 3 ed. Sage Publications, Incorporated, Thousand Oaks
[4] Tranfield, D., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manage. 3, 207-222
[5] Thurm, R., 2002. 'Counting what Counts' – Raising Transparency through Environmental Management Accounting at Siemens, in: Bennett, M.e.a. (Ed.), Environmental Management Accounting: Informational and Institutional Developments. Springer Netherlands, pp. 123-135
[6] Bertram, M., Martchek, K.J., Rombach, G., 2009. Material Flow Analysis in the Aluminum Industry. J. Ind. Ecol. 5, 650-654
[7] Curry, R., Maguire, C., Simmons, C., Lewis, K., 2011. The use of material flow analysis and the ecological footprint in regional policy-making: application and insights from Northern Ireland. Local Environ. 2, 165-179
[8] Seuring, S., Müller, M., 2007. Integrated chain management in Germany – identifying schools of thought based on a literature review. J. Clean. Prod. 7, 699-710
[9] Viere, T., Möller, A., Prox, M., 2010. A Material Flow Cost Accounting Approach to Improvement Assessment in LCA. International Symposium on a Sustainable Future, 120-127
[10] Günther, E., Prox, M., 2012. ISO 14051 - die Norm zur Materialflusskostenrechnung, in: Gleich, R., Bartels, P., Breisig, V. (Eds.), Nachhaltigkeitscontrolling: Konzepte, Instrumente und Fallbeispiele für die Umsetzung. Haufe-Lexware GmbH, Freiburg, pp. 21-25
[11] Fröhling, M., Schwaderer, F., Bartusch, H., Schultmann, F., 2013. A Material Flow-based Approach to Enhance Resource Efficiency in Production and Recycling Networks. J. Ind. Ecol. 1, 5-19
[12] Bode, A., Bürkle, J., Hoffner, B., Wisniewski, T., 2012. Looking at the Cost: Using Flow Analysis to Assess and Improve Chemical Production Processes. Chemical Eng. Technol. 8, 1504-1514
[13] Pesonen, H.L., 1999. Material flow models as a tool for ecological-economic decision making. Eco-Management and Auditing. 1, 34-41
[14] Schmidt, M., Lambrecht, H., Möller, A., 2009. Stoffstrombasierte Optimierung, 1 ed. MV Verlag, Münster
[15] Däumler, K., Grabe, J., 2000. Prozesskostenrechnung (I). Betrieb und Wirtschaft. 4, 128-133
[16] Burritt, R.L., Saka, C., 2006. Environmental management accounting applications and eco-efficiency: case studies from Japan. J. Clean. Prod. 14, 1262-1275
[17] Nakajima, M., 2003. Introducing Material Flow Cost Accounting for Environmental Management Accounting System. International Symposium on Environmental Accounting, 47-51
[18] Lambrecht, H., 2011. Stoffstromnetzbasierte Optimalplanung des Ressourceneinsatzes industrieller Produktionssysteme
[19] Bergsdal, H., Brattebø, H., Bohne, R.A., Müller, D.B., 2007. Dynamic material flow analysis for Norway's dwelling stock. Build. Res. Inf. 5, 557-570
[20] Fischer-Kowalski, M., Krausmann, F., Giljum, S., Lutter, S., Mayer, A., Bringezu, S., Moriguchi, Y., Schütz, H., Schandl, H., Weisz, H., 2011. Methodology and Indicators of Economy-wide Material Flow Accounting. J. Ind. Ecol. 6, 855-876
[21] Rogler, S., 2000. Industrielle Umweltkostenrechnung. Controlling & Management. 3, 171-179
[22] Viere, T., Möller, A., Schmidt, M., 2010. Methodische Behandlung interner Materialkreisläufe in der Materialflusskostenrechnung. uwf-UmweltWirtschaftsForum. 3, 203-208.
[23] Loew, T., Fichter, K., Müller, U., Schulz, W., Strobel, M., 2003. Ansätze der Umweltkostenrechnung im Vergleich, 1 ed. Umweltbundesamt, Berlin
[24] Barankay, T., Jürgens, G., Rey, U., 2000. Kostentreiber aufgedeckt. FB/IE. 4, 175-177
[25] Günther, T., Günther, E., Hoppe, H., Mahlendorf, M., 2005. Entwicklung eines Entscheidungsmodells zur Anwendung von Umweltkostenrechnungssystemen: Aktuelle Entwicklungen und Anwendungsbereiche
[26] Bugallo, P.M.B., Stupak, A., Andrade, L.C., López, R.T., 2012. Material Flow Analysis in a cooked mussel processing industry. J. Food Eng. 113, 100-117
[27] Götze, U., Hache, B., Schmidt, A., Weber, T., 2011. Methodik zur kostenorientierten Bewertung von Prozessketten der Werkstoffverarbeitung; Methods for evaluating the cost effectiveness of materials processing chains. Materialwissenschaft und Werkstofftechnik. 7, 647-657
[28] Lang, C., Steinfeldt, M., Loew, T., Beucker, S., Heubach, D., Keil, M., 2004. Konzepte zur Einführung und Anwendung von Umweltcontrollinginstrumenten in Unternehmen: Endbericht des Forschungsprojekts INTUS
[29] Nakano, K., Hirao, M., 2011. Collaborative activity with business partners for improvement of product environmental performance using LCA. J. Clean. Prod. 11, 1189-1197

Sustainable Management Established by MFCA and SBSC

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Abstract: **Material Flow Cost Accounting (MFCA) has been used as a tool of Environmental Management Accounting in Japan since 2000. Many Japanese companies see MFCA as the new special cost studies in traditional cost accounting. But companies need to establish Sustainable Management with PDCA management cycle. MFCA can help to increase the transparency of material inefficiency in a process and show priority to the management that can reduce material loss, based on the information of material loss cost. But MFCA can't make many practical cases to reduce material loss with medium- and long-term investment. According to our researches, MFCA can show material losses ignored on traditional cost accounting, but it will not have any functions in reducing the material loss or measuring the performance to reduce material loss in corporate management. Recently companies are trying to integrate MFCA with the existing management tools, such as TOC (Theory of Constraints) and BSC (Balanced Scorecard). To reduce material losses systematically visualized by MFCA analysis, this research tries to integrate MFCA with BSC (Balanced Scorecard) / SBSC (Sustainability Balanced Scorecard).**

I. INTRODUCTION

This research tries to establish a framework of Sustainable Management based on the integration of Material Flow Cost Accounting (MFCA) with Sustainability Balanced Scorecard (SBSC).

MFCA is one of the most useful environmental management accounting. MFCA shows material loss in the process inside a company, and the company tries to reduce material loss by Kaizen and process innovation. In theory and practice, MFCA promotes material efficiency in a process for sustainability of business [11]. Usually many Japanese companies think that MFCA has made a temporary management to improve material efficiency in a target production process [10]. This practical usefulness of MFCA doesn't need a routine corporate management. And these MFCA projects haven't involved measuring the performance of corporate sustainable management.

MFCA can show material losses in a process, and there are two types of material losses, as shown in Figure 1 [13].

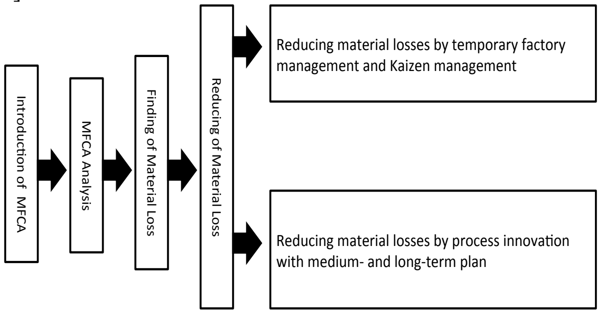

FIGURE 1: TWO TYPES OF MATERIAL LOSSES.

MFCA shows material losses of each input material in each quantity center, and the company examines how to reduce material losses. After the examination, material losses are usually divided into two types as follows [13];

(1) material losses reduced by simple improvement as Kaizen, and

(2) material losses reduced by relatively difficult improvement as process innovation.

Based on the division above, a company focuses mainly on (1) material losses that can be reduced by temporary factory management or Kaizen activity. The company doesn't understand MFCA as a continuous management tool but a visualization tool of new losses for Kaizen. In the first step of MFCA project, the company can get short-term benefits through new Kaizen activity from a MFCA viewpoint. Many companies are satisfied with the results from this temporary factory management or Kaizen. Factory leaders and workers can find new subjects on Kaizen activity from MFCA data. They are hungry for new Kaizen subjects because they could't find many Kaizen subjects from the existing factory management.

On the other hand [13], when a company tries to reduce (2) material losses by relatively difficult improvement, MFCA can't help the company to insert a target of these material losses reduction into corporate business plan. In Japan, Kaizen doesn't need any or higher investments to reduce loss in general. Although Kaizen doesn't have a function to create process improvements with any medium- and long-term investments, many companies evaluate that MFCA can make a new Kaizen, but not process innovation. They might unconsciously think Kaizen can connect with medium- and long-term improvements systematically and automatically as process innovation if the Kaizen tool has strong power or relevant skill for it. Therefore, when companies see MFCA as a new Kaizen tool, it will usually find the bigger amount of these material losses, but these material losses become overshadowed by the business of daily living in the company.

It is one of the most important subjects for companies to use MFCA to establish sustainable management by reducing all material losses. We need to make a general PDCA cycle management to improve material efficiency in the whole process inside the company on the basis of MFCA data.

At the starting step to establish the sustainable management, we have tried to find possibilities to integrate MFCA with the existing management.

MFCA focuses on material flow and stock, while BSC and SBSC (BSC/SBSC) focus on both the financial and non-financial issue. Both of MFCA and BSC/SBSC have a common aim to achieve and to increase corporate profit. The integration between MFCA and BSC/SBSC will produce a synergistic effect on corporate sustainable management. This research is to integrate MFCA with BSC/SBSC to establish a routine sustainable management.

II. From BSC to SBSC

Balanced Scorecard (BSC) was started as a medium- and long-term performance measurement system from comprehensive perspective vision incorporating financial indicators and non-financial indicators in the activities conducted by the companies [4]. To achieve the vision and strategy, BSC breaks down necessary strategic targets or critical success factors down into four levels to practice specific activity plans. Thus, the framework of BSC is constructed from financial perspective, customer perspective, internal business process perspective, learning and growth perspective at the upper level [5].

Not only among these four perspectives but also within themselves, it is required to make them like a causal chain. The BSC framework means that learning and growth perspective is connected with internal business process perspective, customer perspective, and finally financial perspective. As stated above, the achievement of indicators that locate in low-level becomes crucial condition for that of upper-level. In addition, BSC means the balancing performance table as its name implies and it integrates the balance of financial indicators and non-financial indicators, short-term indicators and mid-and-long term indictors.

Furthermore, as the tool to show the causal chains among four perspectives clearly, strategy map has been proposed [6]. The BSC concept has been combined with the concept of the more recently strategy map, which can function as a strategic management system [6] & [7]. The Strategy Map is a framework with a common language that visualizes and communicates a strategy, according to processes, systems necessary to its realizations. It is a direct extension of the BSC as it depicts critical objectives and relationships identified in the BSC process [17].

The BSC is able to integrate soft, intangible and qualitative aspects, nevertheless it has to be developed further to become an integrated system of corporate sustainability management [17]. To implement environmental management, companies need to decide on an environmental mission and then develop an environmental vision and strategy to accomplish this mission. To achieve this environmental vision and strategy, companies should establish a management system to implement the environmental strategy efficiently and effectively and then evaluate the performance of their environmental activities comprehensively. With the growing worldwide attention to global environmental issues, an environmental or sustainability-conscious BSC to be used to solve environmental and social problems has been developed, known as the Sustainability Balanced Scorecard (SBSC). In essence, the SBSC adds environmental and social concerns to the four traditional perspectives of the BSC (financial, customer, internal business process, and learning and growth) to evaluate more comprehensively the performance of medium- and long-term sustainability (environmental, social, and economic) activities [15], [19], [20] & [21].

By combining a strategy map, the SBSC can function as a management system that ensures the efficient and effective development, execution of corporate sustainability vision and strategy [21], [23], [24] & [16]. The SBSC helps to address different environmental and social aspects with regard to their relevance for strategy implementation and execution at the business unit or company level [17]. In this manner, the SBSC is not only concerned with economic aspects but also environmental and social aspects, and a win–win–win relation in accomplishing economic, environmental, and social objectives together.

MFCA can provide basic physical and cost data of environmental issues, especially natural resources, to SBSC. And the performance of MFCA improvement can contribute concretely to the final target of SBSC. We will show the possibilities of sustainable management that is based on MFCA experiences in Japan and theoretical research of SBSC.

III. Integration of MFCA with SBSC

At the first phase of MFCA development in Japan, we tested and analyzed the relevance of MFCA in Japanese manufacturing processes. We have already found usefulness in manufacturing process in Japan, as mentioned in the Section of the Introduction. MFCA has shown possibilities of itself to improve material inefficiency in the supply chain, too. But we faced with a bigger subject that we need a leader of MFCA companies in Figure 2. And to establish a company as a leader, the company should structure the MFCA PDCA management, as indicated in Figure 2. MFCA could give a management plan based on MFCA data and analysis. And we have many case examples of process improvement as Kaizen. But we don't have an evaluation tool for management performance from MFCA project.

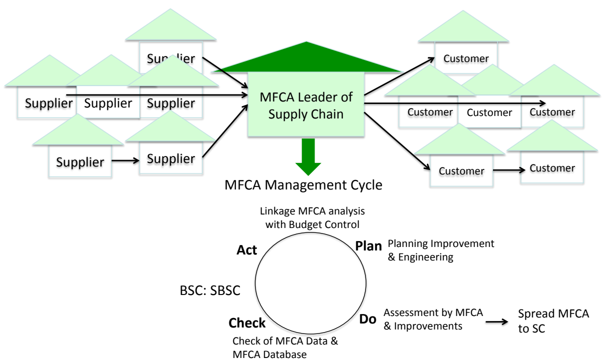

FIGURE 2: MFCA MANAGEMENT CYCLE OF THE LEADER COMPANY IN GREEN SUPPLY CHAIN.

Therefore, when a company would like to introduce MFCA as a general routine management in corporate management, MFCA should be integrated with BSC/SBSC which has the function of performance evaluation management and strategic management system. The data of material losses on physical and monetary unit by MFCA analysis could be useful as performance indicators in internal business process perspective of BSC/SBSC. For example, MFCA could give the amount of material loss and energy use as non-financial indicator of BSC/SBSC, and the cost of material loss and energy use as financial indicator of BSC/SBSC. BSC/SBSC could evaluate reductions of material loss and energy use as management performance.

When the company could make MFCA management with BSC/SBSC, the company tries to promote MFCA performance indicators in internal business process perspective of BSC/SBSC. To do so, the company needs to educate employees to operate MFCA activities, from learning and growth perspective of the bottom construction of the strategy map on BSC/SBSC.

The aim of BSC/SBSC in the company is to improve material efficiency, the company should establish a framework to achieve simultaneously both environmental protection and profit promotion. To build MFCA in internal business process perspective of BSC, the company should establish relationships among perspectives and indicators in BSC/SBC.

Figure 3 is clearer relationship between MFCA information, management information chain and responsibility of management. When a company introduces CO2 management based on SBSC, organizational structure and MFCA information as shown Figure 3, MFCA Database gathers material, energy and CO2 emission data on physical units from Production and Logistic areas. MFCA Database could make MFCA costs and assess the amount of CO2 emission. The CO2 Management Department can collect the management data from MFCA Database and make management reports, then give these management reports to Environmental Department, and Sustainability Department, they can report the sustainable performances to higher management. Moreover, the CO2 Management department reports to Legal Affairs Department, this department operates environmental management based on ISO14001 and ISO14051 [3].

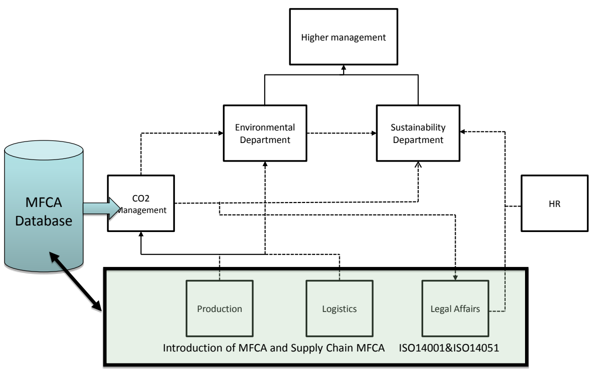

FIGURE 3: AN EXAMPLE OF AN INTERACTIVE CHAIN OF CARBON (INFORMATION) MANAGEMENT WITH MFCA (ORIGINAL SOURCE: [1], P.92, ADDED "MFCA DATABASE" AND SO ON BY AUTHORS).

According to Japanese MFCA case examples, there are two types of MFCA introduction ways, Top-down type MFCA introduction and Bottom-up type MFCA introduction [12]. The management system of BSC/SBSC can support both of them.

In modern companies, the top construction of SBSC is consists of financial perspective and environmental perspective. MFCA that integrate both of them will set up important management information on BSC/SBSC.

IV. CONCLUSION

The Introduction shows the present important subjects to make sustainable management with MFCA, based on many Japanese case examples and research works. Many companies have accepted MFCA as a new Kaizen tool, which has both good and bad aspects to establish MFCA management. In good aspects, MFCA becomes popular especially in Japanese companies, but in bad aspects MFCA user has generally limited to manufacturing section. In order to develop MFCA to MFCA management as Sustainable Management, we have to examine the integration of_MFCA with the existing management tool as BSC/SBSC, and show the usefulness of MFCA data to other management section.

And we show the potentials to integrate MFCA and BSC/SBSC to establish sustainable management with PDCA management cycle in the Section □. BSC basically focuses on financial and non-financial aspects to manage corporate management. At present, BSC has developed to SBSC, which includes environmental issues as one of the non-financial aspects. We suggest MFCA be integrated with SBSC on the basis of MFCA Database. MFCA is going to expand the whole company from the front line, and BSC has covered the whole company from top management. This integration is more useful for company to establish totally sustainable management system.

In BSC/SBSC, the targets to reduce the amount and cost of material loss could become KPIs (Key Performance Indicators). When MFCA is operated in isolation from a general management as BSC, targets by MFCA as reduction of material loss couldn't become KPIs linked with general management. When a company integrates MFCA with BSC/SBSC, MFCA data could be based on medium- and long-term management. MFCA could be linked with general PDCA management, MFCA activity could be built in corporate management naturally.

Finally we relate about the future subjects. One is to establish theoretical framework of MFCA-BSC/SBSC. The other is to find some case examples of MFCA-BSC/SBSC based on MFCA companies.

REFERENCES

[1] Burritt, R. L.,Schaltegger, S. and Zvezdov, D. (2011), "Carbon Management Accounting: Explaining Practice in Leading German Companies,"*Australian Accounting Review*, Vol. 56, No. 21, pp. 80-98.

[2] Figge, F., T. Hahn, Wagner, M. and Schaltegger, M. (2002), "The Sustainability Balanced Scorecard: Linking Sustainability Management to Business Strategy,"*Business Strategy and the Environment*, Vol. 11, No. 5, pp. 269-284.

[3] ISO (2011), *ISO 14051 Environmental Management – Material Flow Cost Accounting – General Framework*, ISO.

[4] Kaplan, R. S.and Norton, D. P. (1992), "The Balanced Scorecard: Measures that drive performance", *Harvard Business Review*, Vol. 70 No.1, pp. 71-79.

[5] Kaplan, R. S.and Norton, D. P. (1996), *The Balanced Scorecard: Translating Strategy into Action*, Harvard Business School Press, Boston, MA.

[6] Kaplan, R. S.and Norton, D. P. (2001), *The Strategy-Focused Organization: How Balanced Scorecard Companies Thrive in the New Business Environment*, Harvard Business School Press, Boston, MA.

[7] Kaplan, R. S.and Norton, D. P. (2004), *Strategy Maps: Converting Intangible Assets into Tangible Outcomes*,

[8] Kaplan, R. S. (2009),"Conceptual Foundations of the Balanced Scorecard," in *Handbook of Management Accounting Research: Volume 3*, C. S. Chapman et al., Eds. Oxford: Elsevier, pp. 1253-1269.

[9] Kaplan, S. E. and Wisner, P. S. (2009), "The judgmental effects of management communications and a fifth balanced scorecard category on performance evaluation", *Behavioral Research in Accounting*, Vol. 21, No. 2, pp. 37-56.

[10] METI, *Case Examples of Material Flow Cost Accounting (MFCA)*, 2008, Ministry of Economy, Trade and Industry, Japan (METI).

[11] Nakajima, M. and Kokubu, K. (2008),*Material Flow Cost Accounting*, 2nd. Tokyo: Nikkei Publishing Inc (available only in Japanese).

[12] Nakajima, M. 2011, "The Chapter 2: Environmental Management Accounting to support Cleaner Production, Management Systematization of Material Flow Cost Accounting ", in Ueda, K. and Kokubu, K. Eds, *Environmental Management Innovation 5: Accounting System to support Environmental Management Decision-making*, *Chuokeizai-sha*, pp. 27-50. (available only in Japanese)

[13] Nakajima, M. and Kimura, A. (2012), "Promotion of Innovative Improvement integrated MFCA with Budgeting," *The Journal of Cost Accounting Research*, Vol. 36, No. 2, pp.15-24. (available only in Japanese)

[14] Onishi, Y., Kokubu, K. and Nakajima, M.(2008),"Implementing Material Flow Cost Accounting in a Pharmaceutical Company," in *Environmental Management Accounting for Cleaner Production*, S. Schaltegger et al., Eds. Dordrecht: Springer, pp. 395-409.

[15] Schaltegger, S.and Wagner, M. (2005), "Current trends in environmental cost accounting – and its interaction with eco-efficiency performance measurement and indicators", in Rikhardsson, P. M., et al. (Eds.),*Implementing Environmental Management Accounting: Status and Challenges*, Springer, Dordrecht, pp.45-62.

[16] Schaltegger, S. (2011), "Sustainability Management Control," in *Environmental Management Accounting and Supply Chain Management*, R. L. Burritt et al., Eds. Dordrecht: Springer, pp. 337-352.

[17] Schaltegger S. and Lüdeke-Freund, F. (2011), "The Sustainability Balanced Scorecard: Concept and the Case of Hamburg Airport", working paper, Centre for Sustainability Management, Leuphana University, Lüneburg.

[18] Schaltegger, S. and Csutora, M. (2012), "Carbon accounting for sustainability and management: Status quo and challenges,"*Journal of Cleaner Production*, Vol. 36, pp. 1-16.

[19] Wagner, M.and Schaltegger, S. (2006), "Mapping the links of corporate sustainability: Sustainability balanced scorecards as a tool for sustainability performance measurement and management",in Schaltegger, S. and Wagner, M. (Eds.), *Managing the Business Case for Sustainability: The Integration of Social, Environmental and Economics Performance*, Greenleaf Publishing, Sheffield, pp.108-126.

[20] Dias-Sardinha, I.,Reijnders L., and Antunes, P. (2007), "Developing sustainability balanced scorecards for environmental services: A study of three large Portuguese companies", *Environmental Quality Management*,Vol. 16, No.4, pp. 13-34.

[21] Hsu, Y. L. and Liu, C. C. (2010), "Environmental performance evaluation and strategy management using balanced scorecard", *Environmental Monitoring and Assessment*, Vol. 170, No. 1-4, pp.599-607.

[22] Möller, A.and Schaltegger, S. (2005), "The sustainability balanced scorecard as a framework for eco-efficiency analysis", *Journal of Industrial Ecology*,Vol. 9, No. 4,pp.73-83.

[23] Hubbard, G. (2009), "Measuring organizational performance: Beyond the triple bottom line", *Business Strategy and the Environment*, Vo. 18, No.3, pp.177-191.

[24] Hansen, E. G.,Sextl, M. and Reichwald, R. (2010), "Managing strategic alliances through a community-enabled balanced scorecard: The case of Merck Ltd, Thailand", *Business Strategy and the Environment*, Vol. 19, No. 6, pp. 387-399.

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Identification of Improvement for Multistage Serial Processes with respect to Material Flow Cost Accounting via Dynamic Programming

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Abstract: **This paper presents an application of deterministic dynamic programming technique to locate and design the process improvement that yields the optimal solution of a maximum positive cost for a given production lot based on Material Flow Cost Accounting concept. The methodology results in an identification of improvement location(s) which yield(s) the reduction of negative product percentages throughout the manufacturing processes. The justification of investing the process improvement is made by comparing the gain from increased positive cost with the investment. The methodology can be applied to both discrete and continuous production. This method is applied to a woven wire mesh processes to define the quality improvement needed.**

I. INTRODUCTION

Consider a material flow model of a multistage serial discrete production process in which each quantity centre represents a manufacturing unit as shown in FIGURE 1. Suppose the process consists of N stages which stage 1 represents the final production stage. Sequence of the production stages and the production lot size is assumed to be predetermined and known. According to the material flow model, the manufacturer can retrieve the bill of materials &manufacturing information such as main/sub/auxiliary materials need for each production stage as well as cycle or processing time and energy. This information is practically available and assumed to be known and deterministic. The Material Flow Cost Accounting (MFCA) technique is applied to analyze the process. Therefore the material flow cost matrix can be calculated and used to determine a product cost as well as identify an improvement location or kaizen activity.

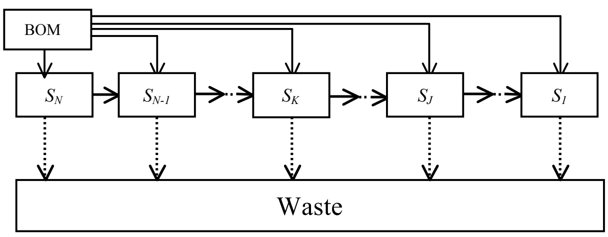

FIGURE 1: MATERIAL FLOW MODEL OF A MULTISTAGE SERIAL PROCESS.

The location(s) of the process needed to be improved can be determined in various ways. One can adopt a design of experiment to conduct an analysis by alternating the process performances at each quantity centre and identifying the most economical investment strategy. However the numbers of experiments, i.e., based on factorial design, can grows very large such that the comparison may be tiresome or difficult. Alternatively this research present a methodology to investigate, identify an improvement location, and find the economical investments of the process with less computation based on a dynamic programming.

This paper applied the dynamic programming technique that has been often used to locate the inspection/screening gate to the multistage serial process with respect to the MFCA concept such that the cost of a positive product is maximized. Meanwhile the cost of the negative product will be minimized. This will lead to more profits and less environmental impacts. This paper addresses another contribution of the MFCA technique in planning and designing the multistage serial process as well as the supply chain model. Section II gives an overview of the literature reviews of the MFCA, the dynamic programming technique and its application on locating the inspection gate. Section III provides the mathematical representation of the problem including numerical results. The conclusion and discussion is given in Section IV.

II. LITERATURE REVIEW

The MFCA is one of an important environmental management accounting tool which becomes increasingly adapted by industries [1]-[5]. The MFCA technique has often been applied to identify the loss and improve the operation [6]. The differences between the MFCA and conventional accounting can be found in [7]-[8]. Applications of MFCA is designing the improvement and cost has been increasingly presented. [9] adopted the MFCA to find and calculate the hiding environmental waste in the processes and used simulation model to analyze the ratio of negative product costs with respect to the work-in-process inventory level and presented an approach of controlling the work-in-process which can both improve the production capacity and reduce the green environmental cost. The application of the MFCA in identifying the wastes can found recently in [10]. This research presented an explicit decision model that can be used to locate the improvement of the quantity centre for multistage-serial processes in order to reduce the negative product. The improvement means reducing the negative product by investing capital and/or installing technology at each quantity centre. Dynamic programming has been used to one of a tool especially for designing screening stations in the design of multistage system has been studied, investigated and proposed by [11]-[12]. Others modern methods based on simulation and heuristics can be found in [13]-[15]. Most models aim to determine whether inspection operations should be performed to minimize the expected traditional total cost per unit manufactured and do not account for the improvement strategy. Therefore this paper (i) applied the environmental accounting concepts to quantify the positive cost, (ii) defined alternative improvements at each quantity and (iii) presented an application of dynamic programming to locate the improvement plans. This research applied the MFCA-based costing to justify the most economical investment. This method has never been presented in the literature before.

III. Methodology

1. Production Process Modelling

Consider the production process of N stages in which stage 1 represents the final production stage. Assume the fraction of defective $f_i : i = N, N-1, ..., 1$ defines the amount of the negative products which become the non-recyclable. Let Q, MC_i, SC_i, EC_i, WC_i represent the production quantity/lot size, material cost, system cost, energy cost and waste treatment cost at stage i^{th} for a given production lot of size Q. According to the defective/waste generated, the positive product will be decreased along the transition from the upstream. The amounts of negative products occurs at each quantity centre can be determined and approximated based on the past records of yield monitoring or production record. Hence the manufacturer can normally determine the refill amount of materials/subcomponents at each quantity centre in order to fulfil the demand of Q units at the final stage. The amount of refill(s) can be expressed explicitly and can be converted in to newly input costs at each stage. Without loss of generality, this paper simply represent these basic information in terms of the newly input MC_i, SC_i, EC_i, WC_i for the given lot size, at each stage. This paper also assumes the fraction defective is used to allocate positive and the negative product when computing the MFCA cost matrix. This assumption is actually not necessary. Any appropriate allocation methods can be used. The only information used for the dynamic programming part is solely the newly input costs and the positive cost of the finished product which can be determined according to [1].

2. Dynamic Programming Model with MFCA Cost

For a given serial process, the positive cost of the final production lot can be calculated and is defined as the base line positive cost. Let $f(J,K) : J < K$ denotes the increased positive cost of a lot of finished product of size Q when considering either "improve" or "not to improve" the production stage J where the last process improvement occurs at stage K. This increased positive cost is measured against the positive cost of the final production lot where stage K is improved. Note that when the process is not improved anywhere, the increased positive cost of a lot is equal to zero. The positive gain/increase of the positive cost implies that the improvement decision should be taken.

Let $f(0,K) : K = N...1$ denotes the increased positive cost of the lot where the process improvement occurs solely at stage K. At each step, the decision is either to improve or not to improve the process. The manufacturer has to consider (i) the improved positive cost of the lot of finished product with respect to the positive cost of the current decision step and (ii) the investment cost $W(J,K) : J < K$; the cost of investing the improvement activity at stage J where the last improvement is at stage K. If the increased positive cost is less than the investment, the decision "not to improve" shall be taken.

One can assumed that the increased positive cost of the lot of finished product with improvement at stage K first and then J will lead to the same increased positive cost of the same lot where the last improvement is only at stage J. Normally, once the stage J is improved, the proportion of positive to negative product and cost will be greater leading to the increased positive cost of the finished product. When stage K is previously improved, the amount of newly, i.e., material costs could be greater than that when there is no improvement of the stage K. Hence this assumption is valid if the $W(J,K)$ is deemed to absorb the increased newly input costs after stage J as well as the handed-over positive cost adjusted with the extra material, system and energy costs at stage K. In this research we assumed that the total input cost is the same whether the improvement(s) is taken place. So expression for $f(J,K) : J < K$ is defined as

$$f(J,K) = \max\{f(J-1,K),\ f(J-1,J,K) - W(J,K)\} \quad (1)$$

where $f(J-1,J,K)$ denotes the increased positive cost when considering the production stage J-1 and the last improvements occur at stage J, K. Without loss of generality, this paper assumed $f(J-1,J,K) = f(J-1,J)$. This is not required as a necessary condition. Without this assumption the recursive computation based on eqn. (1) can still be used and valid. Therefore, the simplified case will result in

$$f(J,K) = \max\{f(J-1,K),\ f(J-1,J) - W(J,K)\} \quad (2).$$

For example, consider the decision whether to invest an improvement at stage 2 given the last improvement is at stage 4. Without improvement of the stage 2, the next decision step is to consider whether the next stage, stage1, should be improved. To justify the improvement of the stage 2, the gain from increased positive cost adjusted with the investment $W(2,4)$ will be compared with "not to improve" alternative and its related gain. Therefore, $f(2,4) = \max\{f(1,4),\ f(1,2) - W(2,4)\}$.

3. Numerical results

Consider a production of woven wire mesh product shown in FIGURE 2. The wire mesh is used to manufacture filters of various shapes. The production process of wire mesh is simplified to consist of 3 stages where stage 1 is the last stage. The newly input costs are shown in Table1. Table 2 indicates the proportion of negative products at each stage. Table 3 shows the MFCA cost matrix.

FIGURE 2: WOVEN WIRE MESH.

TABLE 1: NEWLY INPUT COST FOR EACH STAGE

Cost	Stage3	Stage2	Stage1
Total	14,717	22,691	278
Newly input MC	12,825	9,175	-
Newly input SC	1,079	8,479	150
Newly input EC	812	5,037	128

TABLE 2: PROPORTIONS OF NEGATIVE PRODUCT AT EACH STAGE

	Negative Product (kg)
Stage3	*0.58%*
Stage2	*5.44%*
Stage1	*0.43%*

TABLE 3: MFCA COST MATRIX

	Material Cost	System Cost	Energy Cost	Total Cost
Total	22,000.51 *58.38%*	9,708.06 *25.76%*	5,977.03 *15.86%*	37,685.61 100.00%
Positive	20,646.14 *54.79%*	9,142.83 *24.26%*	5,630.17 *14.94%*	35,419.14 93.99%
Negative	1,354.37 *3.59%*	565.23 *1.50%*	346.87 *0.92%*	2,266.47 6.01%

To determine the improvement location, $W(J,K)$: the investment cost of improvement , was defined and shown in TABLE4. The results of the dynamic programming computation were shown in Table 5. The improvement at each stage was defined as the reduction of the negative product proportion to be 0.15%, 4.35%, 0.11% for stage 3, 2, 1 respectively. The solution is of the form *f(2,3)*→ *f(1,2,3)* which has the highest *increase positive cost.* Given an improvement at the beginning stage 3, the investment at stage 2 is economical as well as stage. stage 1 given the last improvement at stage 3 and 2. The final conclusion is to improve all the stages. The gain from increased positive is greater than the total investments. In other words, the increased positive cost is the same as reductions of negative cost. This example reveals that the total investment is less than the reduced negative cost.

TABLE 4: $W(J,K)$ MATRIX

$W(J,K)$	K=0	K=1	K=2	K=3
J=0		50	100	100
J=1			100	100
J=2				120

TABLE 5: DYNAMIC PROGRAMMING RESULTS

$f(0,0)$	0
$f(0,1)$	66.56-50=10
$f(0,2)$	237.23-100=137.23
$f(0,3)$	290.72-100=190.72
$f(1,2)$	*Max { f(0,2), f(0,1,2)-w(1,2)}* *= Max {* 137.23, (304.55-100)*}= 204.55* *"Improve at stage 1 given stage 3 improved"*
$f(1,3)$	*Max { f(0,3), f(0,1,3)-w(1,3)}* *= Max {* 190.72, (119.68-100)*}= f(0,3)* *"Not Improve at stage 1 given stage 3 improved"*
$f(2,3)$	*Max { f(1,3), f(1,2,3)-w(2,3)}* *= Max {* 190.72, (358.19-120)*}= 238.19* *"Improve at stage 2 given stage 3 improved"*

If the assumption of $f(J-1,J,K) = f(J-1,J)$ is used, the solution is of the form *f(2,3)*→ *f(1,3)*→ *f(0,3)* as shown in TABLE 6. Given an improvement at the beginning stage 3, the investment at stage 2 is not economical. Next consider investment in the stage 1 given the last improvement at stage 3. The results also indicate that improvement of stage 1 is not economical. Therefore the assumption can make difference in the solution obtained. However this paper shows the computation for both cases.

TABLE 6: DYNAMIC PROGRAMMING RESULTS

$f(0,0)$	0
$f(0,1)$	66.56-50=10
$f(0,2)$	237.23-100=137.23
$f(0,3)$	290.72-100=190.72
$f(1,2)$	*Max { f(0,2), f(0,1)-w(1,2)}* *= Max {* 137.23, (10-100)*}= f(0,2)*
$f(1,3)$	*Max { f(0,3), f(0,1)-w(1,3)}* *= Max {* 190.72, (10-100)*}= f(0,3)*
$f(2,3)$	*Max { f(1,3), f(1,2)-w(2,3)}* *= Max {* 190.72, (137.23-120)*}= f(1,3)*

IV. CONCLUSION

This research of applying the dynamic programming with MFCA-based cost results in an identification of quality improvement. The recursive formulae used can be adopted with and without assumption on history of process improvement. If the most recent history of investing the improvement is solely used, the recursive formula becomes simpler and eases of use. However the positive cost can depend not only on the most recent history. In this case the computations will become more complex but still applicable and enumerable. The comparison between the investment and the increased positive cost and is the same as that and the decreased negative cost. If the total investment is less than the gains from loss or negative production reduction, the investment is justified. This proposed method showed that the environmental accounting technique such as MFCA can be used not only for environmental management purpose but also for making decision such as process design and quality improvement. This research contribution is in both domain of MFCA as well the quality improvement paradigm.

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REFERENCES

[1] ISO 14051, *Environmental management-Material flow cost accounting-General framework*, 2011.
[2] B. Wagner and R. Enzler, *Material flow management: Improving cost efficiency and environmental*, Physica-Verlag, 2006.
[3] S. Schaltegger and R. Burritt, *Contempory Environmental Accounting*, Greenleaf publication.
[4] M. Nakajima, "Evolution of Material flow cost accounting (MFCA): Characteristics on development of MFCA companies and significance of relevance of MFCA," *Kansai University Review of Business and Commerce*, vol. 11, pp. 27-46, 2009.
[5] M. Nakajima, "Environmental management accounting for sustainable manufacturing: Establishing management system of material flow cost accounting," *Kansai University Review of Business and Commerce*, no. 12, pp. 41-58, 2010.
[6] "Material Flow Cost Accounting: MFCA Case Examples 2011," Ministry of Economy, Trade, and Industry, Japan, 2011.
[7] K. Kokubu and H. Kitada, "Conflicts and Solutions between Material Flow Cost Accounting and conventional management thinking," *Proceeding of the 6th Asia-Pacific Interdisciplinary Perspectives on Accounting Research (APIRA) Conference* , pp.1 – 26, 2010.
[8] M. Nakajima, "On the differences between Material Flow Cost Accounting and Traditional Cost Accounting-In reply to the questions and misunderstandings on Material Flow Cost Accounting", *Kansai University Review of Business and Commerce*, no.6, pp.1 – 20, 2004.
[9] R. Zhao, "Simulation-based environmental cost analysis for Work-In-Process," *International Journal of Simulation Modelling*, vol. 11, issue 4, pp. 211-224,2012.
[10] M. B. Fakoya, H. M.Poll, "Integrating ERP and MFCA systems for improved waste-reduction decisions in a brewery in South Africa," Journal of Cleaner Production, vol. 40, pp. 136-140, 2013.
[11] G. F. Lindsay and A. B. Bishop, "Allocation of screening inspection effort—A dynamic programming approach," *Management Science*, vol. 10, no. 2, pp. 342-352, 1964.
[12] P. M. Pruzan and J. T. R. Jackson, "A Dynamic Programming Application in Production Line Inspection," *Technometrics*, vol. 9, no. 1, pp. 73-81, 1967
[13] S. V. Volsem, W. Dullaert, H. V. Landeghem, "An Evolutionary Algorithm and discrete event simulation for optimizing inspection strategies for multi-stage processes," *European Journal of Operational Research*, vol. 179, pp.621–633, 2007.
[14] M. Barad, "Break-even quality level approach to location of inspection stations in a multi-stage production process," *International Journal of Production Research*, vol. 28, pp. 29–45, 1990.
[15] K. Kang, K. Ebeling and S. La, "Optimal location of inspection stations using a rule-based methodology," *Computers and Industrial Engineering*, vol. 19, pp. 272–275, 1990.

Application of Material Flow Cost Accounting (MFCA) in Dried Longan Manufacturer: A Case Study of Small-to-Medium Enterprise Company in Thailand

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Abstract: **Longan is one of the major economic crops in the northern region of Thailand, its various kinds of products are consumed locally and internationally. Dried longan products have a large portion of the entire longan products' market. The scale of the longan manufacturers are from a small household factory (less than 100 kilograms per day) to a large factory of the capacity over 300 tons per day. In this case study, the MFCA technique was applied to a medium size factory located in Chiang Mai, Thailand. This factory shipped out 90% of its product to customers oversea; therefore, the long shelf-live is critical. The author started the MFCA analysis when the fresh longan from the contracted farms were sent to the factory, and the analysis was carried out for each process until the dried longan was packed and the truck took them out from the factory. The long shelf-life requirement of the product required a significant amount of energy for the drying process. The factory used the gas as the heating sources, which is more expensive than the energy cost of smaller companies where their heating source is the wood. The results showed that the majority of the cost is the material cost of about 95% of the total cost and the energy cost is about 4% and since the majority of the production line is automatic, the labor cost is very few. The systematic layout planning technique, SLP, was used, and the proposed new factory layout design could reduce tasking steps as well as distances of moving longan cart.**

I. INTRODUCTION

Longan is one of the major economic crops in the northern region of Thailand. The majority form of longan products is a dried longan. Fresh longan contains the moisture content of about 70%, when it passes through the drying process, the moisture content reduces to about 18%; the level of moisture contents that can provide a long shelf-life of the product. The drying temperature is about 70-80ºC and hold it for 40-48 hours depending on the size of the longan. The LPG gas is used for a typical medium size company, becomes a major contribution to the overall cost of the drying company. Besides, wastes in the production processes such as broken peel of the longan, spoilage, also contribute to the overall cost.

Customers of the dried longan are from local people to international customers in many countries. The demand from international customers has been increased recently; thus, an improvement in productivity would provide a great benefit to the company. The objective of this research is to provide a case study of an application of the Material Flow Cost Accounting, (MFCA) in evaluation of the major sources of wastes in term of the cost and suggest some solutions for reducing wastes as well as enhancing the productivity.

II. MATERIAL FLOW COST ACCOUNTING (MFCA)

Material Flow Cost Accounting (MFCA) was proposed to the ISO/TC207 (ISO 14000 families) in 2007 by the Japanese government [1]. It becomes an ISO standard in 2011. According to ISO 14051: 2011 (MFCA), the technique provides management and environmental accountings for internal organization decision-making [2]. The MFCA involves cost accounting, cost allocation, energy cost, material balance, material flow, system cost, waste management cost, and so on. According to Watanabe A. [3], the major elements in MFCA are Quantity Centre, Material Balance, Cost Calculation, and Material flow model. The implementation steps of MFCA are the following [2]:

- Involvement of management
- Determination of necessary expertise
- Specification of a boundary and a time period
- Determination of quantity centres
- Identification of inputs and outputs for each quantity centre
- Quantification of the material flows in physical units
- Quantification of the material flows in monetary units
- MFCA data summary and interpretation
- Communication of MFCA results
- Identification and assessment of improvement opportunities

In this research, a medium-size dried longan manufacturer, located in Chiang Mai, Thailand is used for demonstrating the application of the technique. The MFCA analysis was started when the fresh longans from the contracted farms were sent to the factory, and the analysis was carried out for each process until the dried longan was packed and the truck took them out from the factory. The main materials are fresh longans and groundwater with auxiliary materials of some accessories in the packing process. The batch size of the drying process is the fresh longan of 185 tons. The dried longan manufacturer obtained fresh E-dor longans from contracted farms in the northern region of Thailand. The manufacturer bought 3 sizes of longan; B, A, AA, B is the smallest and AA is the largest. The manufacturer selectively bought only longans in good conditions from farmers. The water used in the factory was groundwater, which was free, and currently no water-waste management was performed. The process flow is showed in Figure 1.

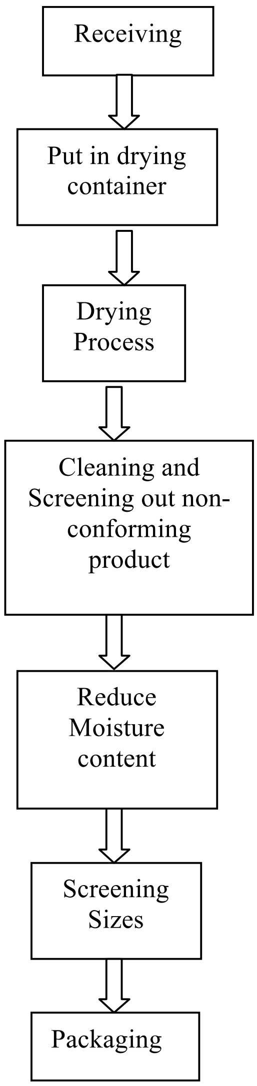

FIGURE 1: DRIED LONGAN PROCESS FLOW

Each process in Figure 1 was defined as Quantity centre, and the mass balance of input and output was performed on each quantities centre. The mass balance of each quantity centre was converted to costs; material cost, energy cost, system cost, and waste management cost. Wastes were considered as negative products, and conforming parts were called positive products. Only positive products were carried out to the next process/quantity centre. The negative as from all the quantity centres were added to provide the overall negative products; likewise for positive products. Wastes in dried longan process were broken peel of the dried longan, and spoilage.

III. MFCA CALCULATION

The MFCA technique uses mass balance in allocating negative and positive products based on constructing the flow of material through quantity centres shown in Figure 2. The ratio of good/non-conforming product at each quantity centre will be used in allocating positive and negative costs for all material cost, energy cost, and system cost. The waste management cost in this study was not included. The mass balancing for each quantity centre is shown in Table 1-7. (Noted that 1€ ≈40 THB)

TABLE 1: MASS BALANCE TABLE (RECEIVING PROCESS)

Material Balance Table (Receiving Process)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	185,000	Longan		Longan	185,000
Quantity percentage	100%	Quantity percentage		Quantity percentage	100%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,145,000	Total (THB)	-	Total	3,145,000

TABLE 2: MASS BALANCE TABLE (PUT IN CONTAINER)

Material Balance Table (Put in Drying Container Process)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	185,000	Longan		Longan	185,000
Total	185,000	Total		Total	185,000
Quantity percentage	100%	Quantity percentage		Quantity percentage	100%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,145,000	Total (THB)	-	Total	3,145,000

TABLE 3: MASS BALANCE TABLE (DRYING PROCESS)

Material Balance Table (Drying Process)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	185,000	Longan		Longan	185,000
Quantity percentage	100%	Quantity percentage		Quantity percentage	100%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,145,000	Total (THB)	-	Total	3,145,000

TABLE 4: MASS BALANCE TABLE (CLEANING AND SCREEN)

Material Balance Table (Cleaning and Screening out non-conforming product)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	185,000	Longan	2,775	Longan	182,225
Quantity percentage	100%	Quantity percentage	1.50%	Quantity percentage	98.50%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,145,000	Total (THB)	47,175	Total	3,097,825

TABLE 5: MASS BALANCE TABLE (REDUCING MOISTURE CONTENT)

Material Balance Table (Reducing moisture content)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	182,225	Longan		Longan	182,225
Quantity percentage	100%	Quantity percentage		Quantity percentage	100%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,097,825	Total (THB)	-	Total	3,097,825

TABLE 6: MASS BALANCE TABLE (SCREENING SIZES)

Material Balance Table (Screening size process)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	182,225	Longan	929.3475	Longan	181,296
Quantity percentage	100%	Quantity percentage	0.51%	Quantity percentage	99.49%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,097,825	Total (THB)	15,799	Total	3,082,026

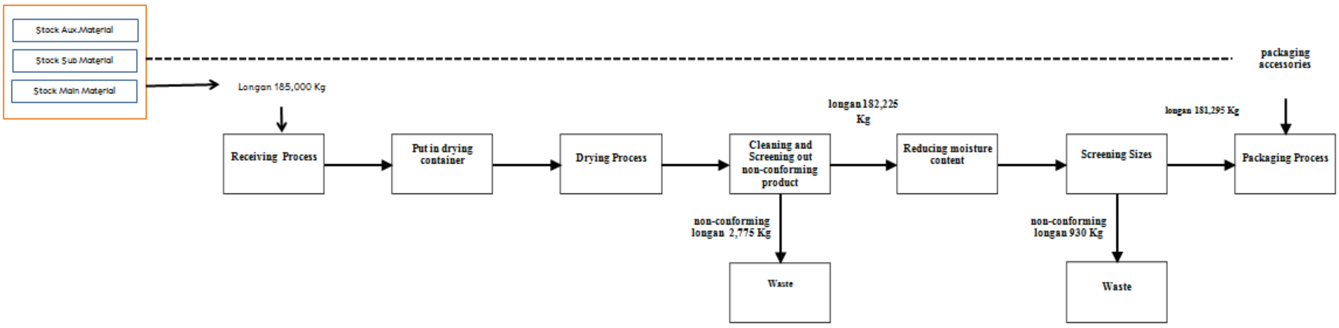

FIGURE 2: QUANTITY CENTERS

TABLE 7: MASS BALANCE TABLE (PACKAGING PROCESS)

Material Balance Table (Packaging Process)					
Input: material		Output: waste		Output: products	
Major materials	Quantity	Waste (negative product)	Quantity	Company products	Quantity
Longan	181,296	Longan		Longan	181,296
Quantity percentage	100%	Quantity percentage		Quantity percentage	100%
Cost of input materials		Cost of wasted materials (nagative product)		Cost of materials used for positive product	
Total (THB)	3,082,026	Total (THB)	-	Total	3,082,026

From the Mass Balance Table 1-7, the positive and negative costs of 3 major cost categories will be calculated: Material cost; Energy cost, and System cost.

1. *Material cost(MC):* the price of fresh longan was 17 THB/ Kg. The positive material cost for each quantity centre was calculated based on the percentage of good product/non-conforming product (waste).

2. *Energy cost (EC):* the energy cost based on machined used in each quantity centre shown in Table 8.

TABLE 8: POWER OF MACHINE USED

Processes	Machines
Receiving	motor 20 HP
Putin drying container	
Drying process	motor 704 HP; forklift LPG 48 kg; LPG 2,300 kg
Cleaning and Screening	motor 11.5 HP; forklift LPG 12 kg
Reducing moisture content	motor 21 HP; LPG 300 kg
Screening sizes	motor 6 HP
Packaging	motor 7.5 HP

Positive or negative energy cost was based on the mass balance ratio. The power shown in Table 8 was converted to cost by multiplying the power with operating time and the THB/kWh (assuming the efficiency of the machine is 90%).

3. *System cost (SC):* the system cost was calculated based on the labour cost/hour x amount of operating hours .

TABLE 9: MFCA OVERALL COST MATRIX

Cost (THB)	MC	SC	EC	TC
Total	3,391,144.00	35,067.00	157,113.44	3,583,324.44
	94.64%	0.98%	4.38%	100.00%
Positive	3,328,170.09	34,568.23	155,170.41	3,517,908.72
	92.88%	0.96%	4.33%	98.17%
Negative	62,973.91	498.77	1,943.03	65,415.72
	1.76%	0.01%	0.05%	1.83%

IV. RESULT AND DISCUSSION

The overall MFCA cost matrix was shown in Table 9 and the Figure 3 showed the proportion for each cost elements.

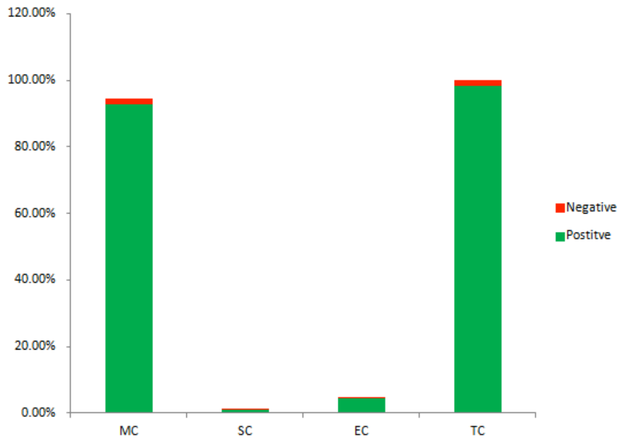

FIGURE 3: POSITIVE VS. NEGATIVE COSTS

The majority of the cost was the material cost (about 94%) with the energy cost and system cost of 4.38% and 0.95%, respectively. From the mass balance tables, the wastes were found in the cleaning/screening out non-conforming product and the screening size process (1.5% and 0.51%, respectively). The author used one of the 7-QC tools: the fish-bone diagram (cause-and-effect diagram) to find the possible causes of the problems and the fish-bone-diagrams for cleaning/screen process shown in Figure 4.

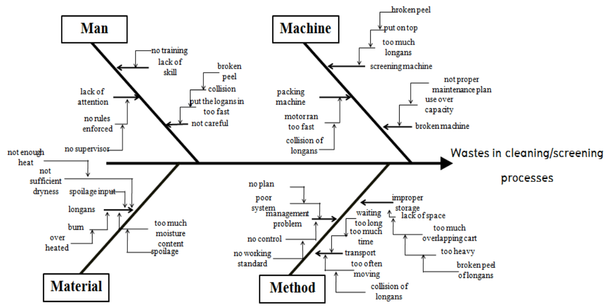

FIGURE 4: FISH-BONE DIAGRAM OF CLEANING/SCREENING PROCESSES

From the fish-bone diagram, the causes of the problem of wastes (broken peel of longans and spoilage) could be dued to the collision of longans and overlapping of one cart on top of the other. One of possible solutions could be providing more storage spaces.

In order to provide more storage spaces, the layout of the factory must be investigated. The Systematic Layout Planning (SLP) was conducted [4]. The SLP is a layout design technique that firstly identifies relationships among machines/workstations with some weighting. The SLP relationship diagram was shown in Figure 5.

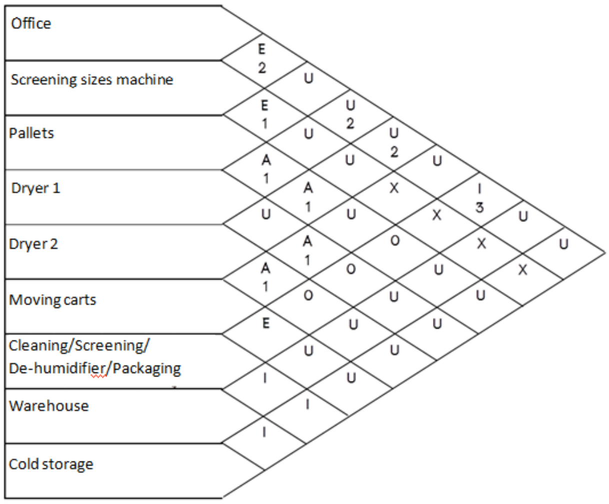

FIGURE 5: SLP RELATIONSHIP DIAGRAM FOR DRIED LOGAN FACTORY

Where the definitions of each letter was shown in Table 10.

TABLE 10: DEFINITION OF SLP DIAGRAM

Level	Definition	# of items
A	Absolutely Necessary	4
E	Especially Important	3
I	Important	4
O	Ordinary Closeness OK	3
U	Unimportant	18
X	Not desirable	4
	total	36

The SLP diagram was constructed by asking group of supervisors in the factory to identify the relationships of all of the machines and equipments insides the factory. From the SLP diagram, the machines and equipments were rearranged and the new factory layout was proposed to the owner. From a simulation, conducted by measuring the time and distances between machines/ equipments, the new layout could eliminate one of the manufacturing steps, reduced transporting distance of carrying carts from 708 m. to 501 m.

V. CONCLUSION

The MFCA technique was used for analyzing the cost in longan dried manufacturer in Thailand. It was found that the material cost is the most contribution to the overall cost (about 95%), followed with energy cost (4%), and system cost (1%) accordingly. The wastes found in the factory were the broken peel of longans and spoilage. To find causes of the wastes, the fish-bone diagram (cause-and-effect diagram) was used, and it was found that the collision of longans due to the overlapping of carts on top of one another was one of the important reasons. The overlapping problem was from the lack of storage spaces. The SLP technique was used for analyzing relationships among machines and equipments. The SLP relationship diagram was conducted and a new factory layout was proposed. The simulation results showed that the total carrying distances of moving carts was reduced from 708 m. to 501 m.

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REFERENCES

[1] A. Yasuo, "Material Flow Cost Accounting as an effective Tool for Environment Activities at GENBA of Canon", *Environment Management*, vol. 42, no. 2, pp. 46-50.
[2] ISO 14051:2011 (E)
[3] A. Watanabe, "Overview of ISO 14051 Module 2, Propharm Japan Co., Ltd.
[4] S.S. Heragu, Facilities Design, PWS, 1997.

Material Flow Cost Accounting for Carbon Management: Utilizing PAF Approach

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***Abstract*: Since the methods of current material flow cost accounting (MFCA) are mainly concentrated on the flows and stocks of raw materials, it is necessary to extend MFCA to assist organizations make decisions that are more carbon-minimizing. This paper considers the possibility of applying MFCA to organizational carbon management, and proposes an enhanced MFCA model by preparing carbon accounting matrices. These matrices clarify the relationship between *ex ante* activities and resulting *ex post* material flow costs and losses.**

I. INTRODUCTION

Several methods of environmental management accounting (EMA) have been developed and proposed by accounting researchers, practitioners and international organizations (*e.g*., Shaltegger and Burritt, 2000; Burritt *et al.*, 2002; IFAC, 2005; UNDSD, 2001; METI, 2002). One of the most promising tools of EMA is Material Flow Cost Accounting (MFCA). MFCA was originally proposed by a German-based environmentally related institution —Institut für Management und Umwelt (IMU) — in the late 1990s (Strobel and Redmann, 2000); however, Japanese EMA academics and the Japanese Ministry of Economy, Trade and Industry (METI) have promoted and improved the method of MFCA. One of the outcomes of their efforts has been the publication of the ISO 14051- , which is the international standard of MFCA- (ISO, 2011).

While MFCA has been disseminated among Japanese companies in recent years, the problems of global warming have seriously worsened as insisted by the "Stern Review" (Stern, 2007). Hence, management for minimizing greenhouse gas (GHG) emissions, which can be called carbon managements, has been requested within organizations and even within supply chains and regions. Since MFCA is based on rigid accounting structures and its information is expected to be used in corporate environment-related decision-making, the purpose of this presentation is to consider the possibilities of MFCA for organizational carbon management, and to propose an enhanced MFCA model by establishing the carbon accounting matrices (CAM). To establish the CAM, a prevention-appraisal-failure (PAF) cost classification approach that was originally used in the area of quality costing will be applied to MFCA.

II. MATERIAL AND METHODS

According to ISO 14051, MFCA is a management "tool for quantifying the flows and stocks of materials in processes or production lines in both physical and monetary units." (ISO, 2011, par.3.15) MFCA is also expected to "assist organizations to better understand the potential environmental and financial consequences of their material and energy use practices, and seek opportunities to achieve both environmental and financial improvements via changes in those practices." (ISO, 2011, p.v) Therefore, MFCA can play a crucial role in improving the transparency of organizational production processes from the perspectives of environmental preservation and cost savings.

There are three dimensions to prior studies on MFCA (Nakajima, 2010).

The first dimension is government-supported MFCA studies. For example, the Japanese METI has supported MFCA practices and published several the guidebooks and case examples (METI, 2007 and 2011).

The second dimension of former MFCA studies is theoretical studies carried out by academics. MFCA was pioneered by IMU, and its basic concepts and methods were described by Strobel and Redmann (2000). MFCA methods proposed in that study have been introduced to Japanese academics and debated internationally (*e.g.*, Nakajima and Kokubu, 2002; IFAC, 2005; Jasch, 2009).

The final dimension of MFCA is case studies.

Although MFCA is expected to improve decision-making by companies' such that the decisions are economically and environmentally sound, limitations to MFCA have been pointed out in former studies (*e.g.,* Nakajima, 2007). One of the limitations is that MFCA does not provide any motivation for managers to engage in voluntary preventive activities such as activities of environmental conservation. These activities cannot directly generate short-term profit or reduce conventional costs. This study attempts to overcome this shortcoming of MFCA.

III. LITERATURE REVIEW OF EMA FOR CARBON MANAGEMENT

It has been pointed out that accounting discipline should be applied to efforts to reduce carbon emission, because the relationship between business activities and carbon emissions has deepened through the establishment of CO_2 emission trading scheme in the European Union and other countries, and the subsequent foundation of an emission trading market (*e.g.*, Hopwood, 2009). To prevent or solve environmental problems, especially global warming, researchers have attempted to apply EMA and/or MFCA to corporate carbon management.

Stechemesser and Guenther (2012) surveyed 111 carbon-related accounting studies and classified them according to accounting object, such as the organization, product, project or nation. Furthermore, they classified the literature in line with the EMA framework, which was mainly proposed by Burritt *et al.* (2002). Stechemesser and Guenther (2012) surveyed almost all the carbon-related accounting literatures; however, our study concentrates on EMA for organizational carbon management.

Especially from the perspectives of management accounting and cost accounting, Ratnatunga (2007) and Ratnatunga and Balachandran (2009) proposed two types of carbon accounting methods. The first is called Carbon Strategic Cost Accounting, which links product costs, such as material, labor, overheads and waste treatment, with carbon emissions. The other is Carbon Strategic Management Accounting, which adapts carbon-cost related information to strategic decision-making by managements. These are remarkable early studies, because they insist on the necessity of the measurement of the volume of carbon emissions and costs. However, the studies have not precisely shown a concrete method for making the required measurements.

Burritt *et al.* (2011) carried out an early study on CMA. They applied the framework of environmental accounting proposed by Schaltegger and Burritt (2000), and replaced CMA in a matrix that expresses information from three different perspectives: past-oriented information and future-oriented information, routinely generated information and *ad hoc* information, and monetary accounting and physical accounting. They then examined carbon-related information for leading German companies, and proposed the integration of the three different perspectives (Burritt *et al.*, 2011).

Shaltegger and Csutora (2012) examined several CMA methods more concretely using the CMA framework proposed in Burritt *et al.* (2011). They defined CMA as "a means for identifying, collecting, processing, disclosing and communicating carbon information" and stated that it "encompasses a set of information management tools which are commonly used as part of carbon management and carbon policy in private and public organizations"(Shaltegger and Csutora, 2012, p. 7). They proposed that the volume of GHG emissions is needed to link with CMA. They also pointed out that the method for the measurement of GHG should include Scopes 1 through 3 of the Greenhouse Gas Protocol. Concretely speaking, Scope 1 GHG emissions are directly emitted by internal production processes and are accounted for by CMA based on traditional management accounting; Scope 2 GHG emissions are indirect GHG emissions, such as energy consumption, and are accounted for by CMA based on energy-supply-chains; and Scope 3 emissions are indirect GHG emissions for the whole life cycle, and accounted for by life-cycle-based CMA (Greenhouse Gas Protocol, 2004).

We will examine recent studies that have modified or extended MFCA methods in the area of carbon management. Furukawa (2009), Ito (2010) and Kokubu *et al.* (2012) attempted to integrate MFCA with carbon emissions in representative studies. These studies gave high priority to *ex post* measures; therefore, these extended MFCA methods cannot directly motivate managers to take measures that are more preventive.

Consequently, we need to consider companies' preventive activities, such as environmental conservation and voluntary activities. To consider both *ex post* and *ex ante* activities, we propose applying PAF cost classification to MFCA.

IV. PAF APPROACH

1. *PAF approach*

PAF cost classification was originally used in quality costing. Quality costing is a "win-win" approach that aims at not only cost reduction but also quality improvement. The PAF approach was first proposed by Feigenbaum (1956), who subsequently redefined it (1961). In the area of quality costing, prevention costs are the costs incurred in preventing defects from occurring in the early stage. Appraisal costs are the costs for maintaining a company's and/or products quality levels, and failure costs refer to the costs of defective materials and products that do not meet a company's quality requirements. This classification can be divided into two different cost categories: internal failure costs and external failure costs.

The objective of quality management and environmental management is to obtain a specific level of quality for produced goods and services. Therefore, the two management types are closely related. In particular, since environmental costs and quality costs share common characteristics, the use of quality costing framework is seen as a useful approach that could be extended to environmental problems. This field of accounting is referred to as quality costing for the environment (QCfE).

2. *Quality costing for the environment*

Remarkable former studies in QCfE are those of Diependaal and de Walle (1994) and Hughes and Willis (1995). Both studies considered quality management and environmental management in the same dimension. The costing structure consists of three steps. The first step is to classify environmental costs using the PAF approach. The second step is to analyze economic and ecological efficiencies of corporate environmental conservation activities. The final step is to create information on environmental measures that can be used for decision-making by management.

Ito *et al.* (2006) rearranged the PAF approach to fit environmental management. The reclassified PAF approach is summarized in Table 1.

Environmental conservation and appraisal costs correspond to prevention costs and appraisal costs respectively. Additionally, internal and external environmental losses are renamed failure costs, and are regarded to come under the quality cost classification. QCfE assumes a whole company or production processes as a whole, whereas this paper clarifies each production process and each life cycle stages.

TABLE 1: ENVIRONMENTALLY REARRANGED PAF APPROACH

Classification	Definition
Environmental conservation costs	The *ex ante* expenses which are designed to prevent environmental problems from arising and to reduce future outlays: for example, operational expenses for environmental management systems, expenses for pollution treatment, the balance of the expenses of green procurement and design for the environment (DfE), expenses for recycling, expenses for environmental insurance, etc.
Environmental appraisal costs	The expenses of monitoring the environmental effects for which a company is responsible, and the expenses of checks and inspections to prevent the design, development and shipping of environmentally harmful products. For example, expenses related to life cycle costing (LCC) and environmental impact assessment (EIA), expenses for toxicity testing, and other checking and inspection expenses.
Internal environmental losses	The losses caused by imperfect environmental conservation measures, inspection, etc.: for example, the costs of waste materials (including costs of non-product outputs and materials flows), waste treatment expenses, pollution treatment expenses, waste products collection and recycling expenses, compensation costs, and budget forecasts of energy and packaging expenses which are inaccurate despite being based on rational and reasonable assumptions.
External environmental losses	The losses borne by the community or local residents. These are caused by inadequacies in a company's environmental conservation measures, inspection procedures, etc. This type of loss includes environmental burden where the liability could not be currently identified such as air pollution, land contamination, and water pollution caused by the emission of CO_2, NOx, CFC, etc.

(Source: Ito *et al.*, 2006, p. 361, Table 16-1.)

V. ENHANCED MFCA FOR CARBON MANAGEMENT

In this section, we propose the enhanced MFCA model, which is expected to contribute to organizational carbon management. Ito *et al.* (2006), as previously mentioned, proposed an EMA method, which employs the Green Budget Matrix (GBM). The GBM acts as a priority setting tool in the environmental budgeting processes. Concretely, the GBM is a matrix that clarifies the relationship between environmental conservation activities, which are considered *ex ante* activities, and the reduction of environmental losses, which are understood as internal and external environmental losses. Ito (2010) newly proposed a modified GBM to clarify the relationship between the measures taken to reduce material losses and the material losses themselves. In this section, we will approach the GBM from a perspective other than that taken by Ito (2010), and propose a framework of carbon cost management. This framework comprises a matrix called the Carbon Accounting Matrix (CAM), which consists of am MFCA matrix and a Cost-Benefit matrix. Table 2 gives an idea of the CAM.

TABLE 2: HYPOTHETICAL MODEL OF CARBON ACCOUNTING MATRIX

MFCA Matrix (Unit; CU, t-CO2)

Activities / Product and Loss Items		VC1				VC2				…	Total costs/ emission
		QC1	QC2	…	Sub total	QC4	QC5	…	Sub total	…	
Products	Material costs			…				…		…	
	System costs			…				…		…	
	Energy costs			…				…		…	
Material losses (Internal environmental losses)	Material costs			…				…		…	
	System costs			…				…		…	
	Energy costs			…				…		…	
	WMC			…				…		…	
Total costs				…				…		…	
External environmental losses	Scope 1 emission (t-CO2)										
	Scope 2 emission (t-CO2)										

* QC: Quantity Center
VC: Value Chain
WMC: Waste Management Costs
CU: Currency unit

Cost-Benefit Matrix (Unit; CU)

		Environmental conservation costs					Total
		Measure 1	Measure 2	Measure 3	Measure 4	Measure n	
Amount of environmental conservation costs (*ex ante* costs)							
ΔMaterial loss	Material cost reduction						
	System cost reduction						
	Energy cost reduction						
	WMC reduction						
ΔExternal environmental loss	Scope 1 emission reduction (t-CO2)						
	Scope 2 emission reduction (t-CO2)						

As with the MFCA matrix, product costs and material losses are calculated using MFCA methods for each value chain (VC). Each VC can be subdivided into several quantity centres (QCs). A QC refers to a "selected part or parts of a process for which inputs and outputs are quantified in physical and monetary units."(ISO, 2011, par. 3.20)

Both product costs and material losses are composed of material, system and energy costs. Material losses can be understood as internal environmental losses in line with PAF classification. Furthermore, GHG emission volumes are calculated for each QC and VC, and considered as external environmental losses.

The MFCA matrix helps managers determine which QCs and VCs are environmentally and financially problematic. For example, managers can find which QCs contribute to the generation of internal and/or external environmental losses. Therefore, managers could rationally select vital points of production to address. The managers could then plan and execute selected environmental conservation activities, which can be regarded as preventive activities.

Next, we explain the Cost-Benefit matrix. This matrix records each environmental conservation activity that is executed during the previous accounting period. The matrix also records reductions in internal environmental losses or material losses and external environmental losses or GHG emissions that result from each environmental conservation activity. Incurred costs in relation to environmental conservation activities are called environmental conservation costs, and corresponded to prevention and appraisal costs in the PAF classification. For example, the introduction of highly efficient bulbs contributes to the reduction of energy costs and GHG emissions. Such information is recorded in each cell of the matrix.

The results of the Cost-Benefit Matrix are reflected in the MFCA matrix. To be more precise, environmental conservation activities carried out in period *t* are planned using the MFCA matrix for period *t-1*. The results of the executed environmental conservation activities are recorded in the Cost-Benefit matrix for period *t*, and the results of an organization's operations are also recorded in the MFCA matrix for period *t*. Furthermore, managers set an environmental conservation plan for period *t+1* using the MFCA matrix for period *t*, and so on.

Consequently, MFCA can be used not only as a one-off management tool such as in a special cost study but also as a current management tool that can contribute to the continuous reduction of GHG emissions and link the planning and execution of preventive *ex ante* activities and *ex post* costs such as material costs. It is thus expected that the CAM helps managers reduce both GHG emissions and material flow costs.

The hypothetical CAM presented in Table 2 only considers a single company's production processes; however, the headings of the MFCA matrix that represent each VC can be enlarged to the whole life cycle of goods and services. In general, the life cycle of goods and services begins with resource extraction, continues with processing by several suppliers, manufacturing by a manufacturing or assembly company, transportation by transporters, and use by users, and ends with waste disposal or recycling. Therefore, it can be said that the life cycle of goods and services consists of three stages: upstream, production and downstream stages. If CAMs are prepared by each of the entities that constitute the whole life cycle, then we can understand the relationship between the increase in *ex ante* activities and the decrease in *ex post* costs, and that between cost reduction and carbon emission reduction, through the preparation of a life-cycle-based CAM.

VI. CONCLUSION

We examined many former studies of EMA from the perspective of carbon management. This paper proposed an enhanced MFCA framework that employs the PAF approach and GBM model. However, the proposed model is only one possibility of utilizing MFCA, and the model is only understood as a framework of EMA for carbon management. We have not attempted to apply the CAM to actual organizations, and it is likely that many challenges will have to be solved in the preparation of the CAM.

Even if the preparation of the CAM poses many challenges, it may be useful to clarify the relationship between *ex ante* activities and resulting material flow costs and losses in the context of the MFCA procedures, because the two matrices of the CAM can clarify the relationship between the *ex post* costs connected to the generation of environmental burdens and the *ex ante* costs connected to the reduction of such burdens. Managers can then move towards reducing carbon emissions, which are representative of external environmental losses. Furthermore, managers can determine whether their carbon management practices are improving.

As previously mentioned, we considered Scopes 1 and 2 of the Greenhouse Gas Protocol rather than Scope 3. The CAMs of the different entities in the product life cycle could be summed, thereby clarifying the relationship between carbon emissions and carbon reduction activities. With this consideration, the accounting entity of a CAM could be extended to a region or nation.

Before considering the future use of CAM, the CAM has to be applied to a company to determine its usefulness in management decision-making related to reducing carbon emission.

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REFERENCES

[1] R. L. Burritt, T. Hahn and S. Schaltegger, "Towards a comprehensive framework for environmental management accounting: links between business actors and environmental management accounting tools," *Australian Accounting Review*, Vol. 12 No. 27, 2002, pp. 39-50.

[2] R. L. Burritt, S. Schaltegger and D. Zvezdov, "Carbon management accounting: explaining practice in leading german companies," *Australian Accounting Review*, Vol. 56 No. 21, Issue 1, 2011, pp. 80-98.

[3] M. J. Diependaal and F. B. de Walle, "A model for environmental costs for corporations (MEC)," *Waste Management & Research*, Vol. 12 No. 5, 1994, pp. 429-439.

[4] A. V. Feigenbaum, "Control (design + material + product + process) ÷costs (inspection + rejects) ×customer satisfaction = total quality control," *Harvard Business Review*, Vol. 34, No. 6, 1956, pp. 93-101.

[5] A. V. Feigenbaum, *Total Quality Control: Engineering and Management*, New York: McGraw-Hill, 1961.

[6] Y. Furukawa, "Material flow cost accounting: its methodological characteristics and application to corporate carbon management," in *Theory and Practice of Carbon Liability: Measurement, Evaluation, Disclosure and Management*, Y. Fujii, , Ed. Tokyo: Chuokeizaisha, 2009, pp. 121-147, Available only in Japanese.

[7] The Greenhouse Gas Protocol, *A Corporate Accounting and Reporting Standard*, Rev. ed., Geneva: World Business Council for Sustainable Development, and Washington, DC: World Resources Institute, 2004, pp. 24-33.

[8] A. G. Hopwood, "Accounting and the environment," *Accounting, Organizations and Society*, Vol. 34, No. 3/4, 2009, pp. 433-439.

[9] S. B. Hughes and D. M. Willis, "How quality control concepts can reduce environmental expenditures," *Journal of Cost Management*, Vol. 9, No. 2, 1995, pp. 15-19.

[10] IFAC (International Federation of Accountants), *International Guidance Document; Environmental Management Accounting*, New York: IFAC, 2005, pp. 10-71.
[11] ISO (International Organization for Standardization), *ISO14051:2011(E), Environmental Management- Material Flow Cost Accounting- General Framework*, First ed., Geneva: ISO, 2011, pp. 1-36.
[12] Y. Ito, "EMA for the environmental conscious operation improvements: directions of deepening and enhancing MFCA," in Special Committee of Japanese Accounting Association (JAA), *Special Committee Report: Study of Decision-Making for Environmental Management and Accounting System*, Chair: K. Kokubu, Tokyo: JAA Conference at Toyo University, 2010, pp. 46-57, available only in Japanese.
[13] Y. Ito, H. Yagi and A. Omori, "The green-budget matrix model: theory and cases in Japanese companies," in *Sustainability Accounting and Reporting*, S. Schaltegger, M. Bennett and R. Burritt, Eds. Dordrecht: Springer, 2006, pp. 355-372.
[14] C. Jasch, *Environmental and Material Flow Cost Accounting: Principles and Procedures*, Springer.com, 2009, pp. 75-159.
[15] K. Kokkubu, T. Fuchigami and A. Yamada, "Development of MFCA and CFP integrated model," *Kankyo Kanri (Environmental Management)*, Vol. 48, No. 2, 2012, pp. 46-76, Available only in Japanese.
[16] METI (Japanese Ministry of Economy, Trade and Industry), *Environmental Management Accounting (EMA) Workbook*, Tokyo: METI, 2002, pp. 1-265
[17] METI, *Guide for Material Flow Cost Accounting*, Ver. 1, Tokyo: METI, 2007, pp. 1-45.
[18] METI, *Material Flow Cost Accounting: MFCA Case Examples 2011*, Tokyo: METI, 2011, pp. 1-93.
[19] M. Nakajima, "Environmental management accounting for sustainable manufacturing: establishing management system of material flow cost accounting (MFCA)," *Kansai University Review of Business and Commerce*, No. 12, 2010, pp. 41-58.
[20] M. Nakajjima and K. Kokubu, *Material Flow Cost Accounting: An Innovative Method of Environmental Management Accounting*, Tokyo: Nihonkeizaishinbunshupansha, 2002, pp. 1-196, Available only in Japanese.
[21] J. Ratnatunga, "Carbon cost accounting: the impact of global warming on the cost accounting profession," JAMAR, Vol. 5, No. 2, 2007, pp. 1-8.
[22] J. T. Ratnatunga and K. R. Balachandran, "Carbon business accounting: the impact of global warming on the cost and management accounting profession," *Journal of Accounting, Auditing and Finance*, Vol. 24, No. 2, 2009, pp. 333-355.
[23] S. Schaltegger and R. Burritt, *Contemporary Environmental Accounting: Issues, Concepts and Practices*, Sheffield: Greenleaf Publishing, 2000, pp. 89-160, 260-314.
[24] S. Schaltegger and M. Csutora, "Carbon accounting for sustainability and management: status quo and challenges," *Journal of Cleaner Production*, Vol. 36, 2012, pp. 1-16.
[25] K. Stechemesser and E. Guenther, "Carbon accounting: a systematic literature review," *Journal of Cleaner Production*, Vol. 36, 2012, pp. 17-38.
[26] N. Stern, *The Economics of Climate Change: The Stern Review*, Cambridge: Cambridge University Press, 2007, pp. 3-45.
[27] M. Strobel and C. Redmann, *Flow Cost Accounting: Cutting Costs and Relieving Stress on the Environment by Means of an Accounting Approach Based on the Actual Flow of Materials*, Augsburg: Institut für Management und Umwelt, 2000, pp. 1-33.
[28] UNDSD (United Nations Division for Sustainable Development), *Environmental Management Accounting; Procedures and Principles*, New York: United Nation Publications, 2001, pp. 67-87.

Material Flow Cost Accounting and Conventional Management Thinking: Introducing a New Environmental Management Accounting Tool into Companies

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***Abstract*: Material flow cost accounting (MFCA) has been developed worldwide as a major tool in environmental management accounting. The International Standard on MFCA was published as ISO 14051 in 2012. In Japan, the Ministry of Economy, Trade and Industry (METI) has been strongly supporting the promotion of MFCA, and the number of companies introducing this tool has been steadily increasing. However, in order to apply MFCA in companies continuously, it is necessary to overcome conflicts between MFCA and conventional management thinking. This paper argues that such conflicts are likely to be caused by the essential features of MFCA, and indicates some theoretical solutions. Then, by looking at three example cases of companies that have succeeded in the continuous use of MFCA, specific countermeasures for dealing with conflicts are investigated.**

***Keywords*: MFCA, controllability, Japan, case study**

I. INTRODUCTION

Environmental management accounting (EMA) has been rapidly expanding over the last decade. Of the various environmental management accounting tools available, material flow cost accounting (MFCA) is one of the most promising. In Japan, the Ministry of Economy, Trade and Industry (METI) launched its EMA project in 2000, and since then has been strongly supporting the promotion of MFCA [1] , and the number of companies introducing this method in Japan has been steadily increasing. In 2011, the International Organization for Standardization (ISO) published the International Standard on MFCA as ISO 14051.

ISO (2011) defines MFCA as a "tool for quantifying the flows and stocks of materials in processes or production lines in both physical and monetary units." As noted in this international standard, information gained from MFCA can act as a motivator for organisations and managers seeking opportunities to simultaneously generate financial benefits by reducing material costs and reducing adverse environmental impacts by improving material efficiency. Although the majority of environmental management tools, including environmental management systems such as ISO 14001, are effective in reducing adverse environmental impacts, their contributions to corporate profits are obscure and tend to generate additional costs for companies, at least in the short term. However, given that MFCA addresses these problems by reconciling the environment and the economy, the number of companies introducing MFCA is increasing throughout the world.

However, upon analysing a wide range of examples of the introduction of MFCA, one finds that the skillful application of MFCA has enabled some companies to reduce their adverse environmental impact and increase their productivity at the same time, while others have not managed to achieve such results—despite their initial expectations. In order to successfully introduce MFCA into a company, it is necessary to adjust MFCA in the existing management system. Because MFCA provides new ideas to management, conflicts may occur between MFCA and conventional management thinking. These conflicts may be impediments for the practice of MFCA in companies. The purpose of this paper is to examine the conflicts and possible solutions between MFCA and conventional management thinking. In this paper, the authors examine the problem from the theoretical perspectives by referring to management theories such as controllability; then we investigate three companies that have successfully and continuously applied MFCA in practice as case studies in order to ascertain what, if any, countermeasures they have implemented.

II. MATERIAL AND METHODS

First, the authors examine conflicts between MFCA and conventional management thinking. In this paper, we pick up controllability as one of the most influential conventional management thinking. This analysis is conducted based on the theoretical review of MFCA and previous studies on controllability, and find some conflicts between MFCA and controllability.

Second, the authors picked up tree cases of the companies, which have continuously applied MFCA as a company-wide level, and analysed to explore how they have dealt with the conflicts between MFCA and conventional management thinking. This study is conducted based on multi-case studies, using interviewing, disclosed documents and observation of corporate activities.

III. THEORY / CALCULATION

Regarding conventional management thinking, this paper analyse many previous literature on controllability and compare the concept with MFCA [2], [3], [4]. It has been discussed that in many cases managers have accountability over their controllable range. Some empirical studies suggest that it is not reasonable for managers to be accountable for matters beyond their controllable range, and that this can lead to dysfunctional decision-making, making managers feel they are being unfairly treated [2]. However, much empirical research suggests that it would be reasonable for managers to be accountable for some aspects of uncontrollable factors [4], [5]. Frow *et al*., (2005) pointed out that "managers are more rather than less likely to have accountability without controllability" [5], and Simons (2010) introduced the concept of the "entrepreneurial gap" to explain that the span of accountability is wider than the span of control [4].

Based on these recent arguments about the controllability principle, the idea of enlarging a manager's accountability over the controllable range can be applied to the case of the introduction of MFCA. The essential point of MFCA is to calculate the cost of material loss and to report it to the manager. If the manager tries to introduce this new visibility into their factory as additional accountability, the previous controllability range should be enlarged. However, this trial is likely to generate some resistance from workers because they generally do not want to enlarge any additional accountability.

Therefore, valuable research could be carried out by examining what sorts of countermeasures could be incorporated in order to deal with this issue in the MFCA practice. This is the point of our case studies.

IV. RESULTS

The advantages of MFCA and the conflicts surrounding it are like the two sides of a coin. As these problems are related to conventional management thinking, effective countermeasures are needed to succeed in the continuing company-wide use of the MFCA technique. The cases of three companies (Tanabe Seiyaku, Canon, Sekisui Chemical), which have continuously applied MFCA at a company-wide level, are analysed to explore how they have dealt with these problems in practice.

1. Tanabe Seiyaku Co. Ltd.: Company-wide MFCA performance report meetings

Tanabe Seiyaku, a pharmaceutical company, participated in METI's EMA project from 2001 to 2002. It introduced MFCA into one production line as a trial in 2001, and applied the method throughout the company in 2003. Tanabe Seiyaku applied MFCA to all its products (422 products, 12,310 processes) and as a result an annual cost reduction of JPY 230 million was achieved in 2006 (Tanabe Seiyaku, *CSR Report*, 2007, p.33). Tanabe Seiyaku was merged with Mitsubishi Welpharma, and became Tanabe Mitsubishi Seiyaku in 2008. However, the descriptions are based on documents prior to the merger.

The most important feature of MFCA at Tanabe Seiyaku is the development of an MFCA system combined with ERP on a company-wide scale. In Japan, where most companies carry out MFCA calculations using Microsoft Excel, Tanabe Seiyaku deserves special mention for being the first to succeed in its systemisation. By combining MFCA with its ERP system, Tanabe has integrated MFCA data into the corporate financial information system and promoted improvement activities [6]. Tanabe Seiyaku not only continuously collected MFCA data and used the information in activities at individual sites, but also conducted regular meetings to share information about improvement results based on MFCA data at the sites. These meetings, called "MFCA performance report meetings," in which top management participates, were held every year from 2004 to 2007 prior to the merger.

These MFCA performance report meetings, which are held with the participation of representatives from all of Tanabe Seiyaku's principal sites, present cost reductions resulting from MFCA and the details of their environmental improvement activities. Therefore, in the case of Tanabe Seiyaku, information about improvement activities brought about by MFCA is shared throughout the company and material losses measured by MFCA are perceived as an object of accountability by persons in charge. From the point of view of the controllability principle, Tanabe Seiyaku is an example that has adopted on a company-wide scale the extension of accountability as a method for dealing with the problems involved in MFCA.

Onishi et al., (2008) evaluated the effects of these meetings based on their investigation through observations and interviewing as follows [6]:

> These meetings enable information-sharing on the achievements of factories and departments throughout the entire company. Since several executives take part in these sessions, all personnel within the company can recognise that the amount of cost reduction calculated using MFCA is more important than that calculated using conventional standard costing. Therefore, results reported at the performance evaluation meeting affect the performance evaluation of departments and employees. Moreover, since many participating department heads can understand what is going on in other departments, the sessions function as a forum in which issues can be shared with other department to encourage cross-functional improvement activities. (p.406)

In MFCA performance evaluations at Tanabe Seiyaku, managers at factories are not only evaluated for having reduced manufacturing costs, but also are evaluated on their environmental performance by the amount of reduced waste costs. The MFCA performance report meetings have been strongly supporting this evaluation activity. the incorporation of environmental performance evaluation.

2. Canon Inc.: Applying MFCA information into a workplace PDCA cycle

Canon is one of the leading manufacturers of precision machines in Japan, and its consolidated sales in fiscal 2010 were JPY 3,707 billion. This company, like Tanabe Seiyaku, participated from 2001 to 2002 in METI's EMA project, and has attempted a company-wide introduction of MFCA. Unlike Tanabe Seiyaku, however, Canon is not oriented towards constructing company-wide MFCA information systems as a combined ERP system. Instead, Canon introduced MFCA at individual manufacturing plants on the basis of cooperation between the MFCA section in the Head Office environmental department and the plants. As of December 2007, Canon had introduced MFCA at 17 sites in Japan and 9 overseas. The economic benefits resulting from improvements based on MFCA analyses at major manufacturing sites worldwide were JPY 1.3 billion in 2007 (Canon, *Sustainability Report*, 2008, p. 47).

In order to implement MFCA throughout the company, Canon has linked MFCA to its "workplace-centred environmental assurance system." This is the basic mechanism of Canon's workplace-centred environmental assurance system. The purpose of this mechanism is to enhance material efficiency by incorporating the use of MFCA information into the PDCA (plan-do-check-act) cycle of environmental conservation activities practiced at the workplace.

The effects of this system were described under the heading "Devising workplace-centred environmental assurance system through MFCA" in Canon's Sustainability Report (Canon, *Sustainability Report*, 2008, p. 47) as follows:

> At workplaces that have introduced MFCA, managers have led efforts to help employees recognise the amount and cost of negative products (material loss) that are generated in the manufacturing process of each workplace, and to analyse exactly how these losses occur. Improving the implementation of MFCA has enabled the individual workplace to devise an autonomous environmental assurance system that meets its specific needs.

Following the above explanation, the report described two cases in Canon's manufacturing subsidiaries.

> After introducing MFCA in 2005, Nagahama Canon Inc. designated a person in charge of MFCA for the site. Workplaces producing key parts took the initiative for the company's activities. By emphasising MFCA's effectiveness at regular meetings and in internal reports, the company enhanced awareness and firmly established this approach.
>
> Since the company introduced MFCA in 2003, individual workplaces at Canon Chemicals Inc. have worked to reduce waste and costs. The company has thoroughly adopted MFCA practices by sharing the results of analyses of workplaces. Employees' awareness and actions have changed positively, shifting from QCD to EQCD activities. The company's processing, development, and technological divisions are promoting MFCA in a concerted manner.

Incorporating MFCA into Canon's workplace-centred environmental assurance system is one possible way of overcoming the limitations of ISO14001, which tended to be restricted to mechanisms for general reductions of adverse environmental impact, such as paper, waste and electricity. However, it is also expected to be a means of organically integrating factors such as environment, quality, costs and delivery on manufacturing sites. In this way, incorporating MFCA as regular information into on-site improvement activities means that the range of losses calculated by MFCA for a site is regarded as accountable. Therefore, it can be said that Canon's workplace-centred environmental assurance system deals with possible conflicts between the conventional controllability principle and MFCA.

3. Sekisui Chemical Co. Ltd.: Establishing company-wide targets via MFCA

Sekisui Chemical is one of the leading chemical and housing companies in Japan, its consolidated sales in fiscal 2010 were JPY 915 billion. Unlike the preceding two companies, Sekisui Chemical did not participate in METI's EMA project. However, it started introducing MFCA in 2004, and in 2006 it set up a "manufacturing innovation centre" to support the company-wide introduction of MFCA. Sekisui Chemical positioned introducing MFCA as part of its activities to strengthen environmental management, with the objective of becoming an "environmentally creative company," a goal that was elaborated in the company's midterm corporate plan. Sekisui Chemical has launched a plan to put it at the forefront of environmentally-aware companies by 2030, and has established strict environmental targets in the midterm environmental plan. The introduction of MFCA, which forms part of these efforts, is being pursued as an activity that combines environmental improvements and production innovations.

As each company within the Sekisui Chemical Group incorporates reduction targets for loss costs discovered by MFCA in their midterm action plans, and because each unit conducts its own PDCA management cycle, a possible conflict between MFCA and the controllability principle may have been avoided. On the other hand, it would seem that by achieving loss-cost reduction targets through MFCA on a company-by-company basis, a problem of conflict with the corporate profit-seeking objectives mentioned earlier can indeed arise. Although it is difficult for an outsider to examine how Sekisui Chemical actively deals with this problem, it could be important that it has set reduction targets through the use of MFCA. By introducing MFCA into all companies in the group, Sekisui Chemical set a target of achieving a reduction of waste-related costs of a total of JPY 5 billion from 2006 to 2008. This target was also publicly announced through its CSR report. As a result of promoting the theme of making improvements at 35 sites and across 106 products and processes, Sekisui Chemical has been able to reduce the total amount of material loss costs by JPY 7.2 billion on a cumulative basis, which was greatly exceeding its target (Sekisui Chemical, *CSR Report*, 2009, p. 28).

Sekisui Chemical evaluates the effects of MFCA in its CSR report (Sekisui Chemical, *CSR Report*, 2009, p. 28) as follows:

> While the second half of fiscal 2008 in particular was plagued by a large number of negative factors such as rising raw-material costs and decreasing production volumes due to the economic slowdown, and the steady cost reductions that had continued since fiscal 2006 through the activities of Manufacturing Development Innovation utilising MFCA proved to be highly beneficial from a business standpoint.

This company decided to continue MFCA activities in fiscal 2009 and beyond. The new midterm plan starting from 2009 of Sekisui Chemical includes the target of a cumulative reduction of JPY 5 billion in material loss costs over the five-year period from fiscal 2009 through fiscal 2013. Sekisui Chemical's CSR report in 2011 (Sekisui Chemical, CSR Report, 2011, p.31) indicated this target as follows:

> Since fiscal 2006, Sekisui Chemical Group has employed Material Flow Cost Accounting (MFCA) in pursuit of both ecological and economic goals to reduce waste and costs. The midterm environmental plan includes the target of achieving a total reduction of 5 billion yen vs. fiscal 2008 on a cumulative basis over the five-year period from 2009 through fiscal 2013. In fiscal 2010, we reduced costs by 1.3 billion yen through efforts including increasing the thickness precision of housing exterior wall panels and decreasing the volume of materials disposed of as defective. Total waste generated by production sites also decreased by 9% from the fiscal 2007 level.

The announcement and determination of targets for loss reduction by MFCA are likely to be important within the company as a guideline when it comes to evaluating alternative management plans, and will no doubt help motivate managers to favour the adoption of improvements suggested by MFCA. Public announcements, as one of the environmental targets, are a particularly important strategy, which may relieve tensions between short-term profit objectives and MFCA. MFCA-based activities could be promoted even more energetically in the presence of a virtuous circle wherein society and the market appreciate the attitude of companies such as Sekisui Chemical.

V. Discussion

With respect to three corporations that have been successful in the continuous implementation of MFCA, we made an analysis as to whether they adopted measures to overcome the conflict between MFCA and conventional management thinking, and discovered that all three companies had done so. In the case of Tanabe Seiyaku, it held company-wide MFCA performance report meetings, which are deemed to have mitigated the conflict between MFCA and traditional controllability principle. In Canon's case, by incorporating MFCA information into its workplace PDCA (plan-do-check-action) cycle, it has been deemed to have added a new managerial responsibility by the adoption of MFCA, that is, to have expanded the existing managerial responsibility.

However, both Tanabe Seiyaku's company-wide MFCA performance report meetings and Canon's incorporation of MFCA information into the workplace PDCA cycle are only partial commitments, when viewed from the overall perspective of their existing management systems. In this sense, these measures are to be highly evaluated not as ones for expanding the existing managerial responsibility as a whole by incorporating MFCA, but rather for enabling a partial expansion of managerial responsibility by means of MFCA. This shows that in both corporations, that implementation of MFCA is limited to only a small part of the overall managerial practice. Nonetheless, these two cases demonstrate that for continuous implementation of MFCA in corporations, it is necessary to devise measure to eliminate conflict between MFCA and conventional management thinking, which serves to support the argument of this paper.

In the case of Sekisui Chemical, it has made public in its environmental reports its targets and achieved performances in the reduction of waste costs by the adoption of MFCA, which is regarded by the corporation as its responsibility to society. If a cost-reduction idea and a sales-growth idea are presented as alternatives to each other, management has the tendency to choose the latter, but if the target of waste cost reduction is publicized, it will become a measure to motivate the implementation of MFCA. In Sekisui Chemical's case, the target amount of waste cost reduction is not so large compared with the actual sales amount, but it is large as an amount to be achieved by the improvement of resource efficiency, and the setting of such a target itself is important from the perspective of environmental management. In fact, corporations that set cost-reduction targets from the environmental viewpoint are rarely to be found, which indicates the difficulty of conducting such activities.

More importantly, Sekisui Chemical can be interpreted to have expanded the management executives' span of accountability by publicizing the targets for cost reduction by MFCA. The management executives, who are always charged with the gravest responsibility for the pursuit of profit, are required to achieve environmental conservation as well. The most important issue here is how to conduct environmental management when environmental conservation targets are in opposition to profit targets. Sekisui Chemical's case can be said to have shown one method for their coexistence. It also shows that there is a possibility of top management eliminating conflicts between MFCA and the controllability principle and between MFCA and profit-pursuit targets, which are discussed in this paper.

MFCA is a method that is aimed simultaneously at cost reduction and environmental-burden reduction by improving resource efficiency, in which minimization of resource losses is to be targeted. Conventional management thinking targets maximization of profit and minimization of opportunity loss for the achievement of the former, and therefore, MFCA and conventional management thinking are likely to come into conflict with each other—even in the phase of the pursuit of profit. The three companies introduced countermeasures in order to overcome these conflicts. In conclusion, the hypothesis of this paper that in order to actually introduce MFCA into corporations and to have it continuously utilized by them there must be a method in place to overcome the conflict, has been supported by the cases of the three corporations that introduced MFCA into their systems.

However, the measures that the three corporations each adopted are different, and as such, there are additional questions, such as which measure is more effective, whether there are other methods than these three, and whether the combined use of one of them with another measure is more effective. However, MFCA is a new method and corporations that have introduced it into their systems are still at the stage of practicing it by trial and error, and therefore, it can be interpreted that a variety of measures are being experimentally conducted at this current stage. With the wider spread of MFCA, the actual effects of such measures will need to be validated, which will be a future research issue.

VI. CONCLUSION

It has been indicated in this paper that MFCA possibly conflicts with conventional management thinking because it provides a new concept of loss for a company. Even though these conflicts are not exclusive, they can often occur when MFCA is introduced. If the continuing use of MFCA is to succeed, the resolution of these problems is essential. In terms of the conflict with the principle of controllability, this paper has argued that it is essential to change the manager's level of accountability, and to ensure that top management are committed to bringing this about.

From this analytical viewpoint, this paper examined three case examples—Tanabe Seiyaku, Canon and Sekisui Chemical—which have continuously applied MFCA at a company-wide level. It was found that various means of resolving these problems have been devised and introduced in practice. Specifically, Tanabe Seiyaku's performance report meetings on MFCA and Canon's workplace-centred environmental assurance system by introducing MFCA are considered to function as a means of mitigating or dealing with conflicts between MFCA and the conventional controllability principle. In both companies, the accountability of managers can be extended to include the loss provided by MFCA. These findings are supportive of the previous literature suggesting that managers should be accountable for some aspects of uncontrollable factors, and can provide new evidence in this area. Sekisui Chemical's elaboration of targets for reducing loss costs by the use of MFCA and its publication is also considered to have the effect of motivating top management to make the reduction of material losses a higher priority. This is considered to help mitigate conflicts between top management's accountability to shareholders and environmental conservation.

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REFERENCES

[1] METI (2011), *Material Flow Cost Accounting: MFCA case example 2011,* Japanese Ministry of Economy, Trade and Industry.
[2] Merchant, K.A. (1987), "How and why firms disregard the controllability principle", Bruns, W.J. and Kaplan, R.S. (Eds.), *Accounting and Management: Field Study Perspectives*, Harvard Business School Press, Boston, pp. 316-338.
[3] Rowe, C., Birnberg, J.G., and Shields, M.D. (2008), "Effects of organizational progress change on responsibility accounting and managers' revelations of private knowledge", *Accounting, Organizations and Society*, pp. 164-198.
[4] Simons, R. (2010), "Accountability and control as catalysts for strategic exploration and exploitation: field study results", *Harvard Business School Working Paper*, 10-051.
[5] Frow, N., Marginson, D. and Ogden, S. (2005), "Encouraging strategic behaviour while maintaining management control: multi-functional project teams, budgets, and the negotiation of shared accountabilities in contemporary enterprises", *Management Accounting Research*, Vol. 16, No. 3, pp. 269-292.
[6] Onishi, Y., Kokubu, K. and Nakajima, M. (2008), "Implementing material flow cost accounting in a pharmaceutical company", in Schaltegger, S., Bennett, M., Burritt, R.L. and Jasch, C. (Eds.), *Environmental Management Accounting for Cleaner Production*, Springer, pp. 395-409.

Extending the scope of material flow accounting: risks and opportunities in hybrid accounting

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Input-output assisted or hybrid accounting has been gaining more and more relevance in the field of material flow cost accounting. (Crawford 2008) The methodology is based on the combining company data with macro-level monetary matrices in the data NAMEA system (Jasch 2009) in order to supplement missing physical flow information.

The presentation gives an overview of input-output assisted, also called hybrid, environmental accounting methods. The following potential areas of application will be covered and assessed:

- SCOPE 3 accounting in the Greenhouse Gas Protocol. (Stechemesser,K. Guenther 2012)
- input-output assisted life cycle costing of products, including carbon footprint calculations and carbon neutrality claims.
- internal EMA assisted by hybrid accounting, when collecting primary physical data are difficult and costly.
- environmental impacts of the extended supply chain, including Tier 3, 4 etc. suppliers and consumers. (Schaltegger – Csutora (2012)
- application in SMEs

	Internal	Supply Chain oriented
Enterprise focus	• application in SME as an economical way of tailoring environmental information	• Scope 3 carbon accounting • ecological footprint of the organisation (Lenzen et al. 2003)
Product focus	• supplementary data for material flow costing when the financial burden of data collection is overwhelming (Kral et al. 2009)	• LCA analysis of products

It will discuss the potential gains, obstacles and risks of combining physical and monetary (NAMEA based) environmental accounting. It will provide good and bad examples for the application, including the carbon neutral products of DOLE, Scope3 accounting within Danone, carbon footprint calculations for the Norwegian University and applications in the automotive industry. (Lee 2012, Strømman et al.2009,Suh et. al. 2004)
The presentation also raises the question whether „soft" hybrid accounting methods can be combined with „hard" cost information in order to arrive at hybrid material flow cost accounting.

REFERENCES

- R.H. Crawford. Validation of a hybrid life-cycle inventory analysis method. Journal of Environmental Management, 88 (3) (2008), pp. 496–506
- Jasch, C. Environmental and Material Flow Cost Accounting: Principles and Procedures. Springer. 2009.
- C. Kral, M. Huisenga, D. Lockwood. Product carbon footprinting. Improving environmental performance and manufacturing efficiency. Environmental Quality Management, 19 (2) (2009), pp. 13–20
- K.H. Lee. Carbon accounting for supply chain management in the automobile industry. · Journal of Cleaner Production, 36 (2012), pp. 83–93

0

- M. Lenzen, S. Murray, B. Korte, C. Dey. Environmental impact assessment including indirect effect. A case study using input–output analysis. Environmental Impact Assessment Review, 23 (3) (2003), pp. 263–328
- Schaltegger, S. Csutora, M.: Carbon accounting for sustainability and management. Status quo and challenges. Journal of Cleaner Production. Volume 36, November 2012, Pages 1–16

- Stechemesser,K. Guenther, E.: Carbon accounting: a systematic literature review. Journal of Cleaner Production, Volume 36, November 2012, Pages 17–38
- Strømman, G. Peters, G. Hertwich. Approaches to correct for double counting in tiered hybrid life cycle inventories. Journal of Cleaner Production, 17 (2) (2009), pp. 248–254
- Suh, M. Lenzen, G.J. Treloar, H. Hondo, A. Horvath, G. Huppes, O. Jolliet. System boundary selection in life-cycle inventories using hybrid approaches. Environmental Science & Technology, 38 (3) (2004), pp. 657–664

Environmental Performance Measurement - The Case of Small and Medium-sized Enterprises

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***Abstract*: The objective of this paper is to analyze how characteristics of SMEs influence the design and the implementation of EPM systems. A literature review shows that available EPM approaches does not go into the requirements of SMEs in detail. Therefore we develop the EE-CSI. The design is based on general requirements regarding PM systems for SMEs and further identified design requirements. By using an action-based research approach we analyze, in the context of three case studies, whether the developed approach fulfills the identified implementation requirements und which positive and negative outputs the EE-CSI produces.**

I. INTRODUCTION

Performance measurement has always been dealing with operationalising the financial and the operational objectives of an enterprise. The main focus is on the measurement of strategic outcomes of the enterprises, towards which the operations should orientate. Environmental PM (EPM) is, focusing strongly on the environmental objectives and the environmental performance of the enterprise. While traditional PM focuses mainly on other performance dimensions like quality, time, flexibility, finance, customer satisfaction and human resources [1].

PM approaches and implementation frameworks from SMEs differ from those of large companies caused by particular characteristics which distinguish SMEs from large companies. Differences lie in the area of strategy alignment and development, focus on stakeholders, balance of performance measures, dynamic adaptability, process orientation, depth and breadth of PM systems as well as causal relationships of results and their determinants in PM and clarity and simplicity [2].

Approaches for EPM have so far, to a high extent, been developed and implemented for large companies. Only a few concepts address the characteristics of SMEs. Questions remain unanswered, how these particularities influence the design and implementation of EPM. Thus the purpose of our study is to answer the following key question:

How do the characteristics of SMEs influence the design and implementation of EPM systems?

We first analyse whether the characteristics of SMEs in the context of traditional PM are valid in the context of EPM as well and which additional requirements have to be added.

Based on our results we develop and test a process, in order to implement, a strategy aligned EPM in collaboration with the SME.

Finally we assess the results of the implementation and formulate implications for further research.

II. METHODS

The research design is based on the Constructive Research Approach (CRA) [3] [4]. The CRA, a variation of action research-based research (or "interventionist research" [5]), was developed by Kasanen, Lukka and Siitonen [6] [7]. The CRA design consists of 3 phases: preparatory phase, fieldwork phase, and theorizing phase. Lukka and Jönsson 2007 [8] suggests seven steps within the framework (Table 1).

TABLE 1: PHASES AND STEPS OF CRA

Phases of CRA	Steps within the phases
Preparatory phase	Finding a theoretically and practically interesting problem
	Examining the potential for research cooperation with target organizations
Fieldwork phase	Obtaining a profound understanding of the prior theory and practical knowledge of the topic
	Developing a theoretically grounded solution construction
	Implementing and testing the construct
Theorizing phase	Examining the scope of applicability of the construct
	Analyzing the theoretical contributions

The CRA is applied in action research case studies. These draw on standard case study techniques, but include the active participation of the researcher as part of the CRA. Compared to alternative research approaches, there is not only a claim for theoretical contribution but also the necessity for evaluation of practical consequences of the same [9]. Hence, with CRA, changes and change processes can be made empirically observable and actively controllable. The CRA follows experimental and quasi-experimental research approaches.

In the case of action research, researchers can demonstrate rigour in research-design and methods in four areas: Construct Validity, External Validity, "Internal Credibility" and "External Credibility" [10] [11] [12]. Each of these areas is addressed for this study.

Construct validity aims to ensure that research effectively investigates the research question. To ensure construct validity in this study, multiple data sources were utilized. Sources of data included notes from semi-structured interviews and workshops, site visits, emails and screenshots of the current performance measurement IT-system.

The raw data were analyzed and grouped into three groups following the chronological order of CRA:

1. Data about current PM processes (preparatory phase)
2. Data about the design of EPM (fieldwork phase)
3. Data about outputs of the designed EPM process (theorizing phase)

Case summaries were produced to facilitate peer review in the theorizing phase. The case summaries were first peer reviewed and then reviewed by a case study participant.

External validity addresses concerns regarding the generalization of the results. Therefore typical cases were identified and literal replication logic was applied for all three cases [13]. Beside sector and size the logic regards SME characteristics.

All cases are logistics service providers with a comparable size of less than 100 million Euros in revenues. Implementing EPM in logistics service providers is highly relevant as they leverage a significant part of total supply chain environmental performance. Following Hudson Smith and Smith 2007 [14] the cases were compared by different SME characteristics namely organizational and competitive environment as well as management practices. The following companies were identified as case study participants (characterization regarding environmental initiatives):

Company A is a logistics service provider with 700 employees and one site. The organizational environment is characterized by a high flexibility, adaptability and innovativeness, by a visible, involved management and a shortage of environmental management skills. The competitive environment has high degrees of market adaptability as well as of strategic planning capabilities. In terms of management practices the company can be characterized by a high degree of a complete planning processes and a rational management. The company's participation is based on the request to be recognized by customers and employees as a "green company" in terms of high quality, accountability and innovativeness. Therefore current environmental actions should be more focused as well as controllable and the outputs should be measurable and reportable.

Company B is a logistics service provider with 200 employees and three sites. The organizational environment is characterized by flat structures, a lack of bureaucracy and (blue collar) resources and less environmental management skills. The competitive environment has high degrees of market adaptability and limited strategic planning capabilities. In terms of management practices the company can be characterized as a reactive planner with little planning processes. The main management decisions are made by the owner, who is also CEO of the company with bounded rationality. The company's participation is motivated by the possibility to anticipate "green initiatives" of their key customer to be recognized as an accountable and innovative partner. The outputs of environmental actions should therefore be more measurable and reportable.

Company C is a logistics service provider with 200 employees and one site. The organizational environment is characterized by a less involved management and high environmental management skills. The competitive environment has high degrees of market adaptability and limited strategic planning capabilities. In terms of management practices the company can be characterized as an opportunistic planner. The top management consists of members of the owner family with bounded rationality. The company's participation is based on the wish to extend and refocus the environmental management in the context of a new environmental manager. Company C is the only company where no top management member participated in the case study.

"Internal Credibility" and "External Credibility" are specific quality measures for action-based research [15] [16]. Internal credibility aims on the credibility of the research results in face of the case study participants. This is achieved through disclosure and discussion of all decisions within the research process as well as through review and approval of all documentations by the case study participants.

External credibility aims on the credibility of the research results in face of third parties. Therefore a replicable and reasonable data organisation was applied. As noted above all raw data were organized within three groups that are duplicated logically in folders of the used IT-system. Furthermore the final evaluation of the research process happens solely through the researchers without any influence of the case study participants [17].

III. Theory

1. EPM design and implementation requirements in SMEs

Requirements of EPM design extend requirements for traditional PM systems [18]. Requirements that must be considered [19] [20] [21] [22] are

- derive environmental performance measures from environmental strategy (D-1);
- support finding environmental target values for top level performance measures (D-2);
- create transparency regarding actual values of physical inputs and outputs such as energy and waste for all corporate processes (D-3);
- create transparency regarding the direct and indirect monetary inputs and outputs such as environmental action costs and monetary effects of stakeholder reactions (D-4);
- regard performance measure definition of external stakeholders like the Global Reporting Initiative (D-5).

Existing implementation requirements of EPM systems also extend the requirements of EPM systems in SMEs [23]. Subsequently these requirements are [24] [25]

- a "pro-active" environmental strategy, that motivates to act strategically and environmentally oriented (I-1);
- integration into existing PM systems to avoid a parallel and independent environmental performance dimension (I-2);
- involvement of key users like the environmental manager and the management accounting department (I-3).

An EPM system for SMEs ought to regard all requirements D-1 to D-5 and I-1 to I-3.

2. EPM systems for SMEs

There are several approaches that are designed as EPM systems. Only a scarce number is explicitly designed for SMEs. None of these approaches addresses all the requirements mentioned above (Table 2). Therefore we designed a new EPM system approach for SMEs.

TABLE 2: EPM APPROACHES FOR SMES

	Requirements							
EPM-Name	**D-1**	**D-2**	**D-3**	**D-4**	**D-5**	**I-1**	**I-2**	**I-3**
EPM-Kompas	X		X			X		
EPI			X		X			
BP	X	X	X	X			X	X
SEM	X		X	X			X	X
HMM	X	X			X	X	X	

An "x" marks a fulfilled requirement. EPM-Kompas = Environmental Performance Measurement-Kompas [26]; EPI = Environment Performance Indicators [27]; BP = Benchmarking Program [28]; SEM = Structural Equation Model [29]; HMM = Hart-Milstein-Matrix [30]

3. An EPM system for SMEs

The designed EPM is based on the Continous Strategic Improvement (CSI) Process developed by Hudson et al. 2001 [31] as a PM system for SMEs. The Environmentally Enhanced CSI (EE-CSI) extends the four steps of CSI ("Name", "Act", "Use", "Learn") by two additional steps ("Initial Plan", "Initial Action") (Figure 1, Table 3). Furthermore adjustments were necessary to make from an application-oriented viewpoint of the case study participants.

The adjustments are inspired by Epstein's Sustainability Management Framework [32] and are guided by real-time feedback of the case study participants [33]. Epstein's framework is based on different inputs that trigger and influence an environmentally oriented strategy. The implementation of environmental actions is based on four process elements namely leadership, strategy, structure and programs [34]. The framework differentiates between outputs and outcomes of the process elements. Outputs regard the sustainability performance and the stakeholder reactions while outcomes focus on the long-term financial perspective. For all parts of the framework performance measures are applied. Epstein's framework is a comprehensive management control system that extends the requirements of an EPM for SMEs substantially. For that reason it is applied as a recommendation not as a blueprint.

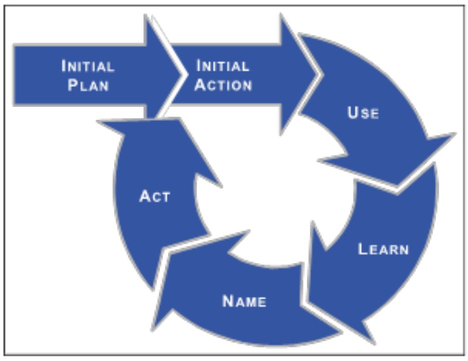

FIGURE 1: EE-CSI

The first two phases of the EE-CSI are characterized by the derivation of the measures and their target values as well as by the implementation of environmental concerns in the organization. To achieve this, the process elements of the Epstein's framework will be applied.

The step "initial plan" addresses particularly the design requirements D-1 ("derive environmental performance measures from environmental strategy") and D-5 ("regard performance measure definition of external stakeholders"). The strategic aims are taken from the input parameters, especially from the external, internal and business context as well as from the human and financial resources. The requirements of the different stakeholder groups and aspects of an ecological competitive strategy are particularly important. A data sheet has been developed for the definition of the performance measures. It contains several data fields, which have to be indicated for each key performance indicator. In order to fulfill design requirement D-5 a data field "corresponding GRI-indicator" has been introduced as an obligatory field.

In the step "initial action" especially the design requirements D-2 ("support finding environmental target values for top level performance measures"), D-3 ("create transparency regarding actual values of physical inputs and outputs") and D-4 ("create transparency regarding the direct and indirect monetary inputs and outputs") have been addressed.

In order to define target values for the performance measures a method has been used, which had already been applied in the context of the eco-design approaches in product development [35]. In this context targets are derived from the overlap of the dimensions "company objectives" Is it technologically possible?), "competitive objectives" (What is industry standards and how is the situation of the direct competitors?) and "anticipation of standards" (What is industry standard and does the development of the legal situation?).

In order to fulfill D-3 the key performance indicator data sheets have to be filled for all measures within the

framework of an implementation plan. Fields contain for example statements about the sources of the data and about dysfunctional effects which could make the key performance indicator collection more difficult. D-4 was covered by the development of a marking scheme for the improvement measures that had been developed by the employees. The evaluation thereby expands, according to Lankoski [36] and Schaltegger [37], a classical investment calculation by non-monetary aspects.
The further steps (use, learn, name and act) correspond to a high extent to the traditional CSI with little alterations.

TABLE 3: STEPS OF EE-CSI

Step	Explanation
Initial Plan	• Analyze input parameters (external/internal/business context, resources) • Identify long-term environmental targets • Develop top-level measures for each target • Identify short-term actions for process elements (leadership, strategy, structure and programs)
Initial Action	• Identify current and target values of top-level measures • Develop appropriate business unit measures (e.g. drill down top-level measures) • Develop implementation plan for all measures • Consult staff to collect long-term improvement suggestions for all targets and process elements • Evaluate (monetary and non-monetary) and select appropriate improvements
Use	• Collate data centrally • Report measurement and progress towards targets to management and staff • Action feedback from reviews
Learn	• Periodically review progress towards targets on performance measures • Review continued appropriateness of existing performance measures • Feedback any actions to relevant staff for action
Name	• Identify and analyze modification in input parameters • Adjust long-term environmental targets (if necessary) • Adjust top-level measures for each target (if necessary)
Act	• Identify current values of top-level measures • Check appropriateness of target values of top-level measures • Check implementation status for all measures • Consult staff to collect long-term improvement suggestions for all targets and process elements • Evaluate (monetary and non-monetary) and select appropriate improvements

IV. RESULTS

The following result section are divided into two parts. In each case study initially the implementation is described. In this context the question in the foreground is to what extent EE-CSI fulfills the implementation conditions (I-1, I-2 and I-3). In the second part of the description of the case study the positive and negative results of the case studies are considered. The classification of the results thereby concerns the question whether the application of EE-CSI supports (positive results) or constrains (negative results) the implementation of the environmental objectives.

1. Implementation results

The implementation in company A was accompanied by the wish of the management to position the organization to a greater extent towards the environmental targets. Before the implementation of EE-CSI, environmental targets were already formulated as a part of the corporate vision but not manifested in the form of strategic aims. EE-CSI has not been the initial reason for environmental engagement but has improved the engagement by the inclusion of all stakeholders ("inputs" from the Epstein model) as well as by the inclusion of all managers (step "initial action").

In Company B the top management was convinced that there were already a sufficient number of environmental initiatives implemented in the enterprise. The analysis of the input parameters thereby resulted in a re-thinking. It became visible that the management had no consistent and global answer to the strategic requirements. The EE-CSI thereby had an "activating" function concerning a "pro-active" environmental strategy.

In Company C the implementation was accompanied by the environmental management with no participation of the top management. The effort to integrate the top management was not successful. Therefore, the leadership dimensions of the Epstein's framework were not part of the implementation. Although the identified strategic objectives referred to the entire enterprise, short- and long-term actions were limited to the environmental management sector. A "pro-active" orientation of the environmental strategy was not possible because of the "thinking in cost-dimensions" which was dominating in the enterprise. Therefore, the environmental objectives only contained efficiency objectives.

It became obvious in the case studies that the orientation towards the four process elements, suggested by Epstein, is a strong support for the implementation of EPM.

Because of the parallel treatment of all four dimensions in short- and long-term actions the strategic reorientation could penetrate the entire organization in company A and B.

The integration of the developed performance measures in the existing PM system (I-2) was respected in the context of the implementation plan. Starting point in Company A was an existing and very complex IT-solution for the company. In this IT-solution relevant key performance indicators were already implemented which partially only had to be reorganized and recombined. The integration of the new performance measures (e.g. energy efficiency in the transshipment technologies) was supported by the key performance indicators data sheets. These data sheets helped in the context of the identification of source and target systems concerning the key performance indicators.

In Company B the reporting is significantly lower formalized. The CEO obtains all reports which have been generated in the enterprise and evaluates them personally ("on Saturday afternoons"). A top management report does not exist. The reports contain all information on the lowest aggregation level. The formalized integration of the new measures could be supported by the key performance indicators data sheets but could not be ensured definitively. It was not clear in which of the numerous reports the key performance indicators had to be integrated. For this reason an own report was generated additionally.

In Company C top-level measures were defined, but no integration in the reporting systems was realized. The engagement had to be stopped prior to the integration.

Based on our observation, we claim, that the integration into reporting is compared to theory of lower importance in practice,. It was rather sufficient to report the relevant performance measures in timed intervals to the employees and to the management. This could also be ensured by additional reports and didn't necessarily have to be realized within the existing report structures. The regularity of the reports and the existence of a determined responsible for the compilation of the reports seemed to be more important.

In the context of the realization of EE-CSI three out of five managing directors in company A participated in the project team (I-3). One of the directors was appointed as environmentally responsible during the project term. By the participation of the environmental responsible in all further meetings with the top management (step "initial action") the high meaning which the subject has for the enterprise was signalized.

The experiences in company B have been similar. The responsible for the main location of the enterprise who is simultaneously the son of the CEO represented the subject in the step "initial action" informed vis-à-vis all employees and management members. The feedback and ideas of the employees concerning the measures were continuously positive.

As already described, the case study was interrupted in company C. Initiatives could not exceed the environmental management sector. The inclusion of all employees was not possible.

The experiences of the three case studies point out that aside the inclusion of key users of the performance measures the inclusion of the top management (Epstein: element leadership) is from decisively important. Particularly in the context of the determination of strategic aims and top-level performance measures EE-CSI requires the participation of the top management.

2. Results of the implementation of EE-CSI

The positive and negative results (in each case top 3) of the implementation are shown in the following table.

TABLE 4: POSITIVE AND NEGATIVE RESULTS OF EE-CSI

Case study	Positive Results	Negative Results
Company A	• 7 new environmental targets and 11 top-level performance measures developed • EE-CSI was utilized for internal and external communication • Short- and long-term improvements identified	• Implementation of performance measures difficult due to a lack of experience • Not everyone knew about the process • Realization depended on one operational person
Company B	• 5 new environmental targets and 13 top-level performance measures developed • Main customer was keen on the actions • Short- and long-term improvements identified	• New performance measures lost within a mass of existing indicators and reports • Extent of the approach discouraged the project team partly • No enthusiasm for measuring
Company C	• 6 new environmental targets and 14 top-level performance measures developed • Workshops fostered a structuring of current environmental actions • Results supported a ISO 14.001 audit	• Actions were limited on the environmental management department • No leadership engagement • No integration in reporting processes and systems

V. CONCLUSION

The starting point of the analysis was the question: how do the characteristics of SMEs influence the design and implementation of EPM systems?

The analysis of the design requirements has shown that particularly those requirements have to be respected which sustain SMEs in the derivation of performance measures from the strategy and which provide them with actual and target values. In the foreground are, similarly to the design of traditional PM systems, particularly conditions in clarity and simplicity [38]. The precise EPM design is additionally characterized by the features of the environmental performance measures. Particularly the information requirements of external stakeholders in the EPM design have to be respected.

The implementation has shown that EE-CSI allowed the enterprises to apply an EPM. The implementation success thereby depends to a great extent on the consideration of the elements which have been suggested by Epstein. EE-CSI does not result in a "pro-active" environmental strategy, but can have activating effects by showing strategic fields of action. The integration in the existing PM systems in order to avoid a parallel and independent environmental performance dimension turned out to be less important than it is from the perspective of theory. It can be said that it was sufficient to report the relevant performance measures in regular intervals to the employees and to the management. It was also possible to ensure this aspect by the use of additional reports and it was not obligatorily necessary to realize it by using the already established report structures. Therefore, an important implementation requirement, which had not been mentioned in literature until now, could be identified. The involvement of key users also seemed to be important in the realized case studies. Even more important was the participation of the top management. If this participation is not given, the probability is high that the implementation will not be finished, comparable to company C.

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References

[1] M. Hudson, A. Smart, and M. Bourne, "Theory and practice in SME performance measurement systems", *International Journal of Operations & Production Management*, vol. 21, pp. 1096-1115, 2001.

[2] P. Garengo, St. Biazzo, and U. S. Bitici, "Performance measurement systems in SMEs: A review for a research agenda" *International Journal of Management Reviews*, vol. 7, pp. 25-47, 2005.

[3] E. Kasanen, K. Lukka, and A. Siitonen, "The Constructive Approach in Management Accounting Research", *Journal of Management Accounting Research*, vol. 5, pp. 243–264, 1993.

[4] K. Lukka and S. Jönsson, "There and back again: Doing interventionist research in management accounting", in *Handbook of Management Accounting Research*, vol. II, C.S. Chapman, A.G. Hopwood, M. D. Shields, Eds. Amsterdam et al.: Elsevier, 2007, pp. 373–398.

[5] K. Lukka and S. Jönsson, 2007.

[6] E. Kasanen, K. Lukka, and A. Siitonen, 1993.

[7] K. Lukka, "The key issues of applying the constructive approach to field research," in *Management Expertise for the New Millenium*", in *Commemoration of the 50th Anniversary of the Turku School of Economics and Business Administration*, Turku, 2000, pp. 113–128.

[8] K. Lukka and S. Jönsson, 2007, p. 376.

[9] E. Labro and T. S. Tuomela, "On Bringing More Action into Management Accounting Research. Process Considerations Based on Two Constuctive Case Studies," *European Accounting Review*, vol. 12, pp. 679–697, 2003.

[10] J. Elliot, "Action research for educational change", Philadelphia: Open University Press, 1991.

[11] U. Suojanen, "Action Research, available online: http://www.metodix.com/en/sisallys/01_menetelmat/02_metodiartikkelit/suojanen_toi, 13.12.2012. 2005.

[12] R. K. Yin, "Case study research. Design and methods," 4th ed. Los Angeles, Calif: Sage Publications, 2009.

[13] R. K. Yin, 2009.

[14] M. Hudson Smith, and D. Smith, "Implementing strategically aligned performance measurement in small firms", *International Journal of Production Economics*, vol. 106, pp. 393-408, 2007.

[15] P. Reason and H. Bradbury, "The SAGE Handbook of Action Research - Participative Inquiry and Practice", 2nd ed. Los Angeles, Calif: Sage Publications, 2008.

[16] D. J. Greenwood and M. Levin, "Introduction to Action Research - Social Research for Social Change", 2nd ed. Los Angeles, Calif: Sage Publications, 2007.

[17] K. Lukka and S. Jönsson, 2007.

[18] M. Hudson, A. Smart, and M. Bourne, 2001.

[19] E. Günther and S. Kaulich, "The EPM-KOMPAS: an Instrument to Control the Environmental Performance in Small and Medium-sized Enterprises (SMEs)", Business Strategy and the Environment, vol. 14, pp. 361-371, 2005.

[20] M. J. Epstein, "Making Sustainability Work", Sheffield: Greenleaf, 2008.

[21] M. J. Epstein and A. R. Buhovac, "Solving the sustainability implementation challenge," *Organizational Dynamics*, vol. 39, pp. 306 - 315, 2010.

[22] F. Iraldo, F. Testa, and M. Frey, "Environmental Management System and SMEs: EU Experience, Barriers and Perspectives," in *Environmental Management*, S. K. Sarkar, Ed., pp. 258, 2010.

[23] Hudson et al. 2001.

[24] Epstein 2008.

[25] Iraldo et al. 2010.

[26] Günther and Kaulich 2005.

[27] P. Rao et al., "Environmental indicators for small and medium enterprises in the Philippines: An empirical research Original Research Article," *Journal of Cleaner Production*, vol. 14, pp. 505-515, 2006.

[28] W. Altham, "Benchmarking to trigger cleaner production in small businesses: drycleaning case study Original Research Article," *Journal of Cleaner Production*, vol. 15, pp. 798-813, 2007.

[29] D. M. Hussey and P. Eagan, "Using structural equation modeling to test environmental performance in small and medium-sized manufacturers: can SEM help SMEs?", *Journal of Cleaner Production*, vol. 15, pp. 303-312, 2007.

[30] S. Moore and S. Manring, „ Strategy development in small and medium sized enterprises for sustainability and increased value creation", *Journal of Cleaner Production*, vol. 17, pp. 276-282, 2009.

[31] Hudson et al. 2001.

[32] Epstein 2008.

[33] W. Kirsch, D. Seidl, and D. van Aaken, „Betriebswirtschaftliche Forschung", Stuttgart: Schäffer-Poeschel, 2007.

[34] Epstein 2010.

[35] P. Horváth and S. Berlin, "Green Target Costing - Getting ready for the Green Challenge", *Cost Management*, vol. 26, pp. 25-36, 2012.

[36] L. Lankoski, "The Link between Environmental and Economic Performance - The Basic Links", in *Managing the Business Case of Sustainability*, St. Schaltegger, M. Wagner, Eds. Sheffield: Greenleaf, 2006, pp. 32-46.

[37] St. Schaltegger, "How Can Environmental Management Contribute to Shareholder Value? The Environmental Shareholder Value Approach", in *Managing the Business Case of Sustainability*, St. Schaltegger, M. Wagner, Eds. Sheffield: Greenleaf, 2006, pp. 47-62.

[38] Garengo et al. 2005.

Challenges of integrating MFCA into current corporate accounting

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Abstract: **Experience drawn from several EMA (Environmental Management Accounting) and MFCA (Material Flow Cost Accounting) case studies shows, that „normal“ accounting information systems simply don't offer the opportunities needed to actually integrate the data requirements of ISO 14051 into financial and cost accounting, stock management and production planning. The paper visualizes the linkages between current information systems and where there are blind spots regarding MFCA integration and establishing of a mass balance. It draws on case studies from Austria with companies applying SAP and less advanced systems used in Serbia, Egypt, Morocco, Tunisia, Costa Rica, Honduras, Mexico, Vietnam and Cambodia. The paper goes on to argue, that first the mass balance should be implemented on the system boundary of the company within the (hopefully existing) stock management system, before more detailed analysis on the level of processes should be attempted, as the later needs much more complex adoptions to information systems currently available on the market.**

I. INTRODUCTION

Environmental Management Systems (EMS), Environmental Management Accounting (EMA) and Material Flow Cost Accounting (MFCA) have received increasing awareness and implementation in recent years [1] - [3]. However, experience from several EMA and MFCA case studies [4] - [14] shows, that most production companies have still not implemented information systems, that allow them to establish a mass balance on a regular level and thus monitor the consumption of materials and energy. This is partly due to the fact that current accounting information systems simply don't allow for monitoring of this data without additional records and system changes.

II. METHODOLOGICAL APPROACH

The core part of EMA and MFCA is the establishment of a mass balance. This can be done for different system boundaries. While MFCA is often implemented on a case study level for specific production processes [2] in a bottom up approach, the papers argues, that there is good reason for starting with existing information systems like financial and cost accounting, stock management and production planning and at the system boundary of the company (top down), as much information is available only for this system boundary (if available at all).

The common design and application of these tools is explained as well as their linkages. This is documented by several case studies worldwide. The paper goes on to describe the adoptions to these tools needed in order to provide better MFCA information on a regular basis.

To assess costs correctly, an organization must collect not only monetary data but also non-monetary data on materials use, personnel hours and other cost drivers. EMA places a particular emphasis on materials and materials-driven costs because:
(1) use of energy, water and materials, as well as the generation of waste and emissions, are directly related to many of the impacts organizations have on their environments and
(2) materials purchase costs are a major cost driver in many organizations [15].

Under the physical accounting side of EMA, according to IFAC [1] an organization should try to track all physical inputs and outputs and ensure that no significant amounts of energy, water or other materials are unaccounted for. The accounting for all energy, water, materials and wastes flowing into and out of an organization is called a “materials balance,” sometimes also referred to as “input-output balance,” a “mass balance” or an “eco-balance” [15] - [18]. Many organizations perform energy balances and water balances separately from other materials balances. As this terminology implies, the underlying assumption is that all physical inputs must eventually become outputs – either physical products or waste and emissions –and the inputs and outputs must balance.

Definitions of the various Materials Input categories are given below. They follow the structure published by IFAC [1], but provide additional explanations regarding their set up in corporate information systems.

1. *Raw and Auxiliary Materials*

Raw and Auxiliary Materials are Materials Inputs that become part of an organization's final physical product or by-product. Raw Materials are the major product components (for example, the wood used in furniture manufacturing); Auxiliary Materials are the more minor product components (for example, the glue used in furniture manufacturing). Any water that becomes part of an organization's final product is covered separately in the “Water” category. Raw Materials are typically monitored by stock management as well as in production planning systems (PPS), but they are not recorded on cost centres (CC). This is the core reason that hinders wide spread application of MFCA.

2. *Packaging Materials*

Packaging materials are Materials Inputs intended for use in shipping an organization's final products. In Europe, where in several countries fees are levied on the amount of packaging put on the market, the volumes are very well monitored and recorded like raw materials, even in PPS. In other regions this is generally not the case.

3. Merchandise

Some businesses purchase items that are then directly sold again as products, with little or no additional processing. These Materials Inputs are categorized as merchandise. Since merchandise does not run through any kind of production line, they tend to be only recorded in financial accounting (FA) and are not well monitored.
However, in some organizations, there actually may be significant waste related to repacking and dealing with merchandise. In addition, if these materials are not monitored on stock with their actual volumes but are added to the final product, it may become impossible to actually consistently calculate the mass balance.

4. Operating Materials

Operating Materials are Materials Inputs that an organization purchases and uses but do not become part of any physical product delivered to a customer. Examples include office supplies, building cleaning supplies, lighting fixtures, chemical catalysts, equipment cleaning solvents etc. For non-manufacturing organizations, most Materials Inputs will be these types of Operating Materials.
Because Operating Materials do not become part of any physical product, they automatically become a form of Non-Product Output (Waste and Emissions) when they leave the organization.
As they don't become part of the product, they are not monitored in PPS, by their consumption should be recorded in stock management and on cost centres. However, unfortunately, very often they are posted into direct consumption without being monitored on stocks with their volumes and actual consumption. From the examples given above it can be seen, that even though their purchase value may be not significant, their environmental impact may very well be.

5. Water

The Water category includes all the water an organization uses, from all sources, such as rainwater, groundwater, surface water from rivers and lakes, regardless of how the water is obtained (for example, private wells or the public water supply system). In some manufacturing sectors, such as food processing, water may be part of the final physical product (much like Raw and Auxiliary Materials), while other water is never intended to go into a final product but is used for other purposes, such as cooling or cleaning (much like Operating Materials). Thus, some water may leave a manufacturing organization in the form of physical product, but the remainder will leave as Waste or Emissions.

Water is in a separate category from other input materials because it is particularly important from an environmental perspective and because accounting systems often manage water flow information differently from other materials flow information. Its consumption is typically not recorded in CCs, PPS or on stock management systems.

6. Energy

The Energy category includes all the energy, of all types, an organization uses: electricity, gas, coal, fuel oil, district heating and cooling, biomass, solar, wind and water. Energy is viewed as an Operating Material, in that the Energy is never intended to become part of a physical product but is instead used for running equipment, etc. Like an operating material it is never included in PPS, but hopefully recorded on CCs. Solid energy carriers like coal would also be recorded on stock management.

7. Overview of recording of material inputs in corporate information systems

As can be seen from the table below, raw and auxiliary materials as well as packaging are typically recorded on stock management and production planning systems, but not on cost centres. This is the main hindrance for application of MFCA. Operating material as well as water and energy consumption ideally is recoded on cost centers, but seldom monitored on stock management. Only financial accounting (FA) records all data on material input, however most often only in monetary terms and with no clear disaggregation functions.
Still, this is the main reason for starting top down with financial accounting, as this requires “only” disaggregation of existing accounting and ensures seeing the whole picture.

TABLE 1: OVERVIEW ON INFORMATION SYSTEMS AND MATERIAL INPUTS

Information systems for I/O	**FA**	**CC**	**Stocks**	**PPS**
Raw Materials	y	no	Y	y
Auxiliary Materials	y	no	Y	y
Packaging	y	no	y	y
Operating Materials	y	y	?	no
Merchandise	y	no	y/?	?
Energy	y	y	no/(y)	no
Water	y	no	no	no
Waste	y	?	no/?	no

III. RECOMMENDATIONS

The recommendations below relate to the information systems dealt with above.

Recommendations for financial accounting:

- Clearly define the material groups (raw, auxiliary, packaging, operating materials, energy, water, waste and record the related materials purchased on separate accounts.

- Record changes in stock not on one aggregated account but poste them to each defined material account separately.
- Record invoices not only in monetary terms, but also with volumes (preferably tons).

Recommendations for stock management:

- Clearly define the material groups (raw, auxiliary, packaging, operating materials, energy, water, waste and record them under separate material numbers.
- Establish a clear aggregation logic from material numbers to sup-categories to financial accounts.
- Record not only raw materials, but ALL material inputs and waste on stock management.
- Record all materials in tons, so that they can be aggregated. Don't use volumes such as pieces, boxes, etc. as this information is useless. Yyou might need to install a scale, which is anyway necessary to monitor maximum shelf weight.
- Record not only materials put on stock, but also send to production, as well as losses on stock.

Recommendations for production planning systems:

- Clearly define the material groups (raw, auxiliary, packaging) monitored by the PPS.
- Make sure, that ALL product specifications are included in the PPS recipes.
- Check consistency between materials consumed according to stock management and material consumed according to production statistics/PPS on a yearly, better monthly basis.

Recommendations for cost accounting:

- Clearly define the material groups monitored (operating materials, energy, water, waste and record them on separate accounts (ideally the financial accounts are mirrored in cost accounting).
- Investigate, where in the production process/cost centers a measuring of raw material/product/PSS specification flows is feasible.
- Define interfaces for data checkpoints with the engineering information systems (e.g. water meters, scales in production, etc.).
- Investigate, if waste volumes can be recorded on a cost centre or shift basis and levied back.

IV. Conclusion

It comes as no surprise, that practically all EMA and MFCA case studies reveal, that companies don't have information systems in place, that allow them to establish a mass balance on a regular basis for different system boundaries. The recommendations to improve information systems focus on stock management and production planning tools, as well as interfaces between cost accounting and technical production monitoring tools.

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References

[7] IFAC, Environmental Management Accounting, International Guidance document, IFAC, International Federation of Accountants, New York, August 2005
[8] ISO, ISO 14051, Material Flow Cost Accounting, Geneva, 2012
[9] Schaltegger St., Burrit R. Corporate environmental Accounting: Issues, Concepts and Practices, Greenleaf, 2000
[10] Jasch, C., Institut für Ökologische Wirtschaftsforschung, Vienna, Austria, Environmental and Material Flow Cost Accounting - Principles and Procedures, (Eco-Efficiency in Industry and Science, Vol. 25), Springer, Heidelberg, New York, 2009
[11] Jasch Ch., Schnitzer H., Environmental Management Accounting – Pilottesting and Case studies, on behalf of the ministry for transport, innovation and technology as well as the ministry for agriculture and environment, published as research report 29/02 of the IÖW, the methodology part is available for download at www.ioew.at .
[12] Jasch Ch., Landa I., Ramos R., Contabilidad de gestion medioambiental, Como beneficiarse de la proteccion medioambiental, IHOBE, Bilbao, 2003
[13] Jasch Ch., Danse M., Environmental Management Accounting pilot projects in Costa Rica, in Bennet M., Rikhardson P., Schaltegger S. (Eds.) Implementing Environmental Management Accounting: Status and Challenges, Kluwer Academic Publ. , Dordrecht, NL, 2005
[14] Jasch Ch., Lavicka A., Pilot project on Sustainability Management Accounting with the Styrian automobile cluster, Journal of Cleaner Production, Volume 14 Number 14 2006
[15] Jurgis Kozimieras Staniskis, Zaneta Stasiskiene, Christine Jasch, Cleaner Technologies – Environmental Management Accounting, Investment Appraisal and financing, Nova Science Publishers, New York, 2008
[16] Monkoe L, Jasch Ch, Waste reduction program based on IFACs EMA guidance in Danisco A/S, in S. Schaltegger, Leuphana Universität Lüneburg, Germany; M. Bennett, University of Gloucestershire, Business School, Cheltenham, UK; R.L. Burritt, University of South Australia, Adelaide SA, Australia; C. Jasch, Institut für Ökologische Wirtschaftsforschung, Vienna, Austria (Eds.), Environmental Management Accounting for Cleaner Production (Eco-Efficiency in Industry and Science, Vol. 24), Springer, Heidelberg, New York, 2008
[17] Jasch C., Performing Environmental Management (EMA) and Material Flow Cost Accounting in SMEs, UNIDO, Vienna, 2009
[18] Jasch C., UNIDO, MED-TEST, Transfer of Environmental Sound Technology in the South Mediteranean Region, Performing Environmental Management (EMA) and Material Flow Cost Accounting (MFCA) in SMEs, Unido, Vienna, 2009
[19] Jasch C., Ayres D., Bernaudat L., Environmental Management Accounting (EMA) Case Studies in Honduras – an integrated UNIDO Project, ISEA Issues in Social and Environmental Accounting, Vol. 4 No 2, December 2010, p 89 – 103, Solo, Indonesia
[20] La, Tran Bac, Benefit of Environmental management Accounting: Improvement of Environmental Performance in Vietnam Seafood Companies, 2011
[21] M. Strobel, *Flow Cost Accounting* Institute for Management and Environment, Augsburg 2001
[22] Audit and Reduction Manual for Industrial Emissions and Waste, United Nations Environment Program and United Nations Industrial Development Organization, Paris, 1991
[23] German Environmental Protection Agency/German Environment Ministry, Eco-controlling manual (available only in German), Munich: Vahlen Verlag, 1995
[24] Environmental Protection Agency of Baden-Würthemberg, Corporate material on energy flow management, improving eco-efficiency via sustainable reorganization (available in German only), Karlsruhe, 1999

Linking Sustainability Reporting, Integrated Reporting and EMA

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Abstract: **The paper describes the different definitions and tools currently applied for assessing corporate environmental aspects and impacts as well as related internal and external costs. By differentiating definitions, system boundaries and fields of application, the intention is to provide a foundation for the further discussion and application of the different capitals, especially the "environmental or nature capital", as suggested for Integrating Reporting by the IIRC, the International Integrated Reporting Council.**

I. INTRODUCTION AND DEFINITIONS

Environmental Costs comprise internal corporate costs as well as external costs to society [1], [2]. **Environmental Accounting (EA)** is a broad term thus used in a number of different contexts, such as [1]:

- assessment and disclosure of environment-related financial information in the context of financial accounting and reporting;
- assessment and use of environment-related physical and monetary information in the context of Environmental Management Accounting (EMA);
- estimation of external environmental impacts and costs, often referred to as Full Cost Accounting (FCA);
- accounting for stocks and flows of natural resources in both physical and monetary terms, that is, Natural Resource Accounting (NRA);
- aggregation and reporting of organization-level accounting information, natural resource accounting information and other information for national accounting purposes; and
- consideration of environment-related physical and monetary information in the broader context of sustainability accounting.

The two broad categories of accounting that typically take place within an organization are management accounting (MA) and financial accounting (FA). In general, FA tends to refer to accounting activities and the preparation of financial statements directed to external stakeholders, while MA focuses on providing information to organization management for internal decision making.

At the *organization level*, EA takes place in the context of both management accounting (assessment of an organization's expenses for pollution control equipment; revenues from recycled materials; annual monetary savings from new energy-efficient equipment) and financial accounting (evaluation and reporting of the organization's current environment-related liabilities).

Companies are interested in their actual costs. Costs incurred elsewhere are of little interest for corporate decision making. Therefore, the focus of Environmental Management Accounting, EMA, has been on the establishment of a mass balance for production companies and the calculation of the production costs of non product output [3] - [13]. This information provides a strong incentive to reduce waste and emissions and increase production efficiency.

The **EMA definition** given by the United Nations Expert Working Group on EMA distinctively highlights both the physical and monetary sides of EMA and clearly separates Management Accounting from Financial Accounting. According to the UN group [2] EMA is broadly defined to be the identification, collection, analysis and use of two types of information for internal decision making:

- physical information on the use, flows and destinies of energy, water and materials (including wastes) and
- monetary information on environment-related costs, earnings and savings.

External environmental costs on the contrary are costs of environmental damage and degradation, which don't show up in the profit and loss or cost accounts of the originator(s) and have to be born by the public or others, e.g. health costs due to polluted air and water, reduced living quality of environments.

Financial Accounting is mainly designed to satisfy the information needs of external stakeholders*,* such as investors, tax authorities and creditors, all of whom have a strong interest in receiving accurate, standardized information about an organization's financial performance. Financial reporting is regulated by national laws and international standards, which specify how different financial items should be treated. For example, should certain expenditures be capitalized or expensed and how should different kinds of liabilities be reported.

Environmental Management Accounting (EMA) has sometimes been critisized for its focus on corporate internal costs only. However, the tools for corporate accounting, and especially financial accounting due to their purpose of providing an equal and unbiased information basis to shareholders and financial authorities rely on information based on actually flows of money, while the estimates of external costs to society are calculated on the basis of avoided costs and revealed or stated personal preferences.

Financial Accounting will never include external costs due to the financial international reporting standards. But financial accounting does include expenses previously external, which have been internalized via economic instruments as taxes, fees, clean up obligations and permits.

Management Accounting may make use of information on external costs under specific circumstances. But it is questionable to what degree information on external costs can or should be provided by companies, as

- they are seldom the sole contributor to an external environmental impact and as
- the tools for estimating external costs are mainly designed to assist governments in applying various economic instruments like permits, fees, taxes and other incentives in order to internalize these external costs.

II. TOOLS TO ASSESS ENVIRONMENTAL ASPECTS AND IMPACTS AN RELATED COSTS

Monitoring of environmental aspects and impacts is based on environmental performance indicators. ISO 14031 [14] already 20 years ago clearly separated the indicator categories for [15]

- The operational system, based on a physical mass balance material inputs and outputs, which is also the core part of ISO 14051 Material Flow Cost Accounting. The non product output of the mass balance consists of waste and emissions, which are annual flow based indicators. They are not directly linked to the impact on the environment.
- The environmental impact or condition indicators, which monitor the status of the environment outside the company. ISO 14031 states, that these indicators are mostly assessed by national Environmental Protection Agencies, as a single company is seldom the sole contributor to an environmental impact. Most of these indicators are flow based (e.g. air emissions, noise, dust, at a specific point of time), while some directly monitor the status of specific environmental stocks (number of species, water quality of rivers).
- The environmental management indicators, which don't monitor the environment as such, but the efforts to reduce environmental aspects and impacts, e.g. training hours of employees, number or share of sites with environmental management systems.

The indicators for the operational and the management system have been included into the Sustainability Reporting Guidelines developed by the Global Reporting Initiative [16], together with other, mostly flow based, annual performance indicators for the economic and environmental performance, labour practices and decent work, human rights, society and product responsibility.

While financial accounting for several hundred years has succeeded in calculating monetary annual profit by assessing flow based (profit and loss account) as well as stock based (balance sheet of assets and liabilities) indicators, most other sciences have not developed consistent schemes for the aggregated assessment of the stock of their resources (e.g. human capital, nature capital) [17].

The concept of Intellectual Capital Reporting or “Wissensbilanz” as applied in Austria and Germany [18] - [20] is mostly based on flow related indicators and doesn't attempt to aggregate human and intellectual capital into one condensed figure.

Likewise, the SEEA system of environmental economic accounting applied by statisticians worldwide in the last years [21] developed highly sophisticated and detailed indicator systems for monitoring flows and partly stocks of environmental aspects on a national level but refrains from an aggregated monetized aggregation [22].

The current SEEA consultation draft for ecosystem accounting [21] clearly describes the methodological approach for monetizing the value of ecosystems. It is based on calculating the value of production, nature regulation and cultural services provided by ecosystems, not by assessing the value of nature as such. The direct and indirect values of these services are calculated by estimating the benefits to different stakeholders, e.g. by willingness to pay surveys [22]. This approach is highly important e.g. for political decision making, but again, it is not an appropriate tool neither for the assessing of the stock value of nature, nor for corporate decision making.

And it is highly subjective. The range of services provided by ecosystems is randomly or purposely selected and never reflects a complete picture. Take e.g. clean air. Nature is proving us with the service of clean air, so that we are able to breath. Without this service, humankind would cease to survive on earth. However, this service is hardly ever monetized in related studies, and if so, based on increased health care costs for areas with significant air pollution, which doesn't show the “whole value” of this services, only how much should be corrected from GDP data, as it is not really increasing welfare if more people need medical care. It is vital for governments to take care of clean air via legislation and other economic instruments but it is seldom of relevance for companies to calculate such a monetized figure. Certainly it is of relevance for companies to monitor and reduce their air emissions in physical terms.

Recently, corporate Sustainability Reporting is moving towards Integrated Reporting, in an attempt to condense communication about how an organisation´s strategy, governance performance and prospects lead to the creation of value over time. The prototype framework provided by the International Integrated Reporting Council mainly sees the providers of financial capitals as its audience [24]. Based on Porritt [25] it distinguishes between financial, manufactured, human, intellectual, nature, social and relationship capital. It calls for integrated thinking, described as the “ability of an organisation to understand the relationships between its various operating and functional units and the capitals the organisation uses and affects” (IIRC, 2012). The fundamental concept of the IIRC is based on “describing, and measuring where practicable, the material components of value creation and, importantly, the relationships between them, resulting in an broader explanation of performance and outcomes than traditional reporting". This does NOT require monetization. It currently doesn't even differentiate between stocks and flows and doesn't relate to the frameworks and definitions developed by ISO 14000 series.

III. RECOMMENDATIONS AND CONCLUSION

The concept of the different capitals in Integrated Reporting will spur interest in methodologies and case studies for assessing internal and external environmental aspects, internal and external costs and related performance indicators for stocks as well as flows, in physical as monetary terms.

The recommendation goes for gaining experiences with applying the tools available and not mixing them right away, without a clear definition of system boundaries and concepts.

The ISO 14000 Series of Standards for Environmental Management as well as the SEEA System for National Environmental Economic Accounting have developed helpful definitions and methodological frameworks, which should be made use of for Integrated Reporting.

Financial accounting will never directly include external costs, but externalities can be calculated by applying different tools, if necessary. EMA projects likewise should clearly separate between internal and external costs, distinguish between stock and flow related concepts, as well as physical and monetised performance indicators. It certainly makes sense for organisations and environmental protection, when companies install environmental management systems, record their mass balances and reduce inputs as well as outputs, perform environmental impact assessments for planned investments and product life cycle assessments to reduce the environmental impact of their products. But it is doubtful, if a monetization of these tools really adds input to the decisions regarding reduction of environmental impact. In my experience the high level aggregation into one figure, regardless if monetized or artificially calculated "green dots" actually disguises the areas of significant impact and is more a tool for "easy marketing communication".

All the tools described above have their specific fields of application, but it is questionable, if a monetisation of all aspects, impacts and values from the perspective of a financial investor is needed from companies or even desired.

REFERENCES

[1] IFAC, Environmental Management Accounting, International Guidance document, IFAC, International Federation of Accountants, New York, August 2005
[2] United Nations Division for sustainable Development, Department of Economic and Social Affairs, Jasch Ch., Environmental Management Accounting, Procedures and Principles, (United Nations publication, Sales No. 01.II.A.3), 2001
[3] Bundesumweltministerium/Umweltbundesamt (Hrsg.), Handbuch Umweltkostenrechnung, Vahlen-Verlag, München 1996.
[4] Fichter, K. / Loew, T. / Seidel, E. (1997): Betriebliche Umweltkostenrechnung. Methoden und praxisgerechte Weiterentwicklung, Berlin, Heidelberg 1997
[5] Hessisches Ministerium für Wirtschaft, Verkehr und Landesentwicklung (Hsg.): Flusskostenmanagement. Kostensenkung und Öko-Effizienz durch eine Materialflussorientierung in der Kostenrechnung (Leitfaden), Wiesbaden 1999
[6] Jasch, C., Institut für Ökologische Wirtschaftsforschung, Vienna, Austria, Environmental and Material Flow Cost Accounting - Principles and Procedures, (Eco-Efficiency in Industry and Science, Vol. 25), Springer, Heidelberg, New York, 2009
[7] Landesanstalt für Umweltschutz Baden-Würthemberg (Hrsg.), Betriebliches Material- und Energieflußmanagement, ÖkoEffizienz durch nachhaltige Reorganisation, Karlsruhe, 1999
[8] Strobel, M. / Wagner, F. Flusskostenrechnung als Instrument des Materialflussmanagements, in: UmweltWirtschaftsForum, 7. Jg., Heft 4-1999, S. 26-28.
[9] Schaltegger St., Burrit R. Corporate environmental Accounting: Issues, Concepts and Practices, Greenleaf, 2000
[10] Schaltegger St., Hahn T., Burrit R., Environmental Management Accounting – Overview and main approaches, in Seifert, E., & Kreeb M., (Edt.), Environmental Management Accounting and the Role of Information Systems, Kluwer, The Netherlands, 2000
[11] Todd, R. "Zero-Loss Environmental Accounting Systems", in B.R.Allenby and D.J. Richards (eds.), The Greening of Industrial Ecosystems, National Academy Press, Washington, D.C., 1994. 191-200
[12] Wagner, B. / Strobel, M. (1999): Kostenmanagement mit der Flusskostenrechnung, in: Freimann, J. (Hg. 1999): Werkzeuge erfolgreichen Managements. Ein Kompendium für die Unternehmenspraxis, Wiesbaden 1999, S. 49-70.
[13] White, A. (1991): EPA journal, "Accounting for Pollution Prevention", July-September (1993), pp. 23-25; White, A. / Becker, M. / Goldstein, J., Total Cost Assessment: Accelerating Industrial Pollution Prevention Through Innovative Project Financial Analysi, With Applications to the Pulp and Paper Industry, prepared for U.S. E.P.A, Office of Pollution Prevention, December 1991
[14] White, A. / Becker, M. / Savage, D.S., (1993): Pollution Prevention Review, "Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention" Summer 1993: 247-259
[15] ISO, ISO 14031, Environmental Management – Environmental Performance Evaluation – Guidelines, International Standardisation Organisation, Geneva, 2000
[16] Jasch Ch., Rauberger R., A Guide to Corporate Environmental Indicators. On behalf of the German Federal Ministry for the Environment and the German Federal Environmental Agency in Bonn, December, 1997.
[17] GRI, Sustainability Reporting Guidelines, Version 3.1., www.globalreporting.org
[18] Schaltegger S.; Sturm, A., Öko-Effizienz durch Öko-Controlling : zur praktischen Umsetzung von EMAS und ISO 14'001 ; mit Anwendungsbeispielen der Unternehmen Flumroc AG, Mohndruck GmbH, Bank Sarasin & Cie., Schäffer, Poeschel Stuttgart, 1995
[19] Mertins, K.; Alwert, K.; Heisig, P. (Hrsg.) Wissensbilanzen – Intellektuelles Kapital erfolgreich nutzen und entwickeln. Berlin, Springer 2005
[20] Alwert, K.: Bornemann, M; Kivikas, M: Wissensbilanz – Made in Germany. Leitfaden 1.0. Herausgegeben durch das Bundesministerium für Wirtschaft und Technologie BMWi Berlin, 2004. http://www.bmwi.de/BMWi/Navigation/Service/publikationen,did=41128.html
[21] Koch G, Leitner KH, Bornemann M., Measuring and Reporting Intangible Assets and Results in a European Contract Research Organization. Berlin (Joint German-OECD Conference, Benchmarking Industry-Science Relationships, October 16 – 17, 2000, Berlin
[22] United Nations, Department of Economic and Social Affairs, Statistics Division, Revision of the System of Environmental-

Economic Accounting (SSEA), SEEA Experimental Ecosystem Accounting, Consultation Draft, 2012
[23] Hein L., et.al.., Spacial scales, stakeholders and the valuation of ecosystem services, Ecological Economics, 57 (2006) 209 – 228, www.sciencedirect.com
[24] IIRC, Integrated Reporting Prototype Framework, 2012, www.theiirc.org
[25] Porritt J., Capitalism as if the World matters, Earthscan, London, Sterling, 2007

Adoption of the Material flow cost accounting (MFCA) approach to integrate physical and monetary data in small enterprises for waste-reduction decisions. Evidence from Italy.

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***Abstract*: Nowadays one of the main issue concerning organization's activities is their significant impact on natural environment in terms of resource depletion, waste and wastewater generation, air emissions. These environmental burdens are not accounted clearly (or are not accounted at all) in the financial statements of the organizations, because a traditional accounting system does not reveal environmental costs that are then inappropriately hidden in overhead accounts. This leads to inaccurate decision-making based on inaccurate environmental or waste cost information. The success of organizations depends on the quality of their decision-making process through the availability of an integrated data management system that combines separate data management systems of its various divisions.**

A pilot project based on a Italian small enterprise which is operating in the plastic sector, leader in rubbish bags production, have been carried out. The main aim has been to test the Material Flow Cost Accounting (MFCA) methodology in order to verify and assess the efficiency of the production process. The pilot project began in early 2011 and is intended to have a continuous application over the years. The final aim is to create a new internal database by integrating both economic and physical data, useful for waste decision-making and the optimization of the production process.

In the case study, authors have faced several organizational and accounting difficulties in applying the MFCA methodology. Generally, the SMEs have traditional accounting thinking, which accounts only monetary information and a lack of a clear flow chart of the production process in physical unit and/or a lack of independent cost centres emerge. Basing on company financial sheets and on the existing literature, assumptions and estimates have been done.

The goal has been to underline the economic value of the physical amounts associated with manufacturing process in order to show the economic value of material losses. In the current economic slowdown, this could allow to reduce these losses and, especially for a small enterprise, to avoid considerable costs, reorganizing and optimizing better the management of the material flow process. The findings highlight that the company has to improve and optimize its manufacturing process primarily for decreasing its material and energy costs. Improving the efficiency of raw material could reduce the related costs and wastes. Results also confirm the powerfulness of the MFCA method in identifying physical and monetary hidden flows for environmentally and economically conscious decision-making.

INTRODUCTION

Nowadays one of the main issue concerning organization's activities is their significant impact on natural environment in terms of resource depletion, waste and wastewater generation, air emissions. These environmental burdens are not accounted clearly (or are not accounted at all) in the financial statements of the organizations, because a traditional accounting system does not reveal environmental costs that are then inappropriately hidden in overhead accounts. This leads to inaccurate decision-making based on inaccurate environmental or waste cost information. In the environmental management accounting theory, Material flow cost accounting (MFCA) is a powerful tool that records material and monetary flows and makes clear inefficiency in productive process by using physical and monetary information [9]. The objective of MFCA is to motivate and support the efforts of organizations to enhance both environmental and financial performance.

The authors have carried out a case study within Sfrecola Materie Plastiche s.a.s. company (SMP), operating into the industrial district of Barletta, in Apulia Region (South part of Italy),which produces rubbish bags in recycled polyethylene.

The goal has been to launch a pilot project testing the MFCA methodology within a SME organization, in order to verify and assess the efficiency of the production process, reconsidering in deeper and strategic way both economic and environmental impacts. The pilot project began in early 2011 and is intended to have a continuous application over the years. The final aim is to create a new internal database by integrating both economic and physical data, useful for waste decision-making and the optimization of the production process.

The objective of this pilot project has been twofold: *a)* to verify the usefulness of MFCA to reorganize the management accounting system and *b)* to optimize the manufacturing process from a technical and economic point of view visualizing the cost of inefficiencies in production process, in particular the costs of wasted materials.

MATERIAL AND METHODS

All the data have been standardized by the authors referring to 1,000 tons of raw materials.

The phases of the production process can be summarized as follow:

a) Mixing phase;
b) Extrusion;
c) Thermo-welding and cutting;
d) Packaging phase.

a) The mixing phase starts in a sort of silos, opened at the top, in which polyethylene resins in form of pellets, masterbatch and other additives (dying, colouring, perfuming, fragrances) always in the form of granules are introduced.
b) The subsequent extrusion phase is performed by an extruder. The extruder consists essentially in a cylinder in nitride iron alloy in which internally two worm screws rotate; in correspondence of the inlet of the cylinder there are a loading hopper and a dispenser while in the outlet of the cylinder a "chain" or "matrix" is placed. The extruded product can also be sent in closed moulds ("Injection Moulding Technique"), or blown in order to obtain thin films ("Blown Film Extrusion Technique"). Inside the extruder the mixing granules (polyethylene resins, masterbatch and additives) pass through different thermal (170-200 °C) and mechanical cycles.
In the case study, the Company uses the Blown Film Extrusion Technique, in which, as mentioned, the extruded product is subsequently blown so as to obtain polymeric films ranging between 15-500 mm of thickness.
Subsequently, the film passes through a cooling ring and is pulled upwards by means of rollers for stabilizing the geometry and the morphology of the film. At the end of the process a semi-finished product of the form of a coil weighting 140-150 kg is obtained.
c) The film is send to the thermo welding area, in which the film in pre-fixed size is cut down and then welded. At the end of this phase, the finished product is examined in order to verify the quality and conformity of the finished product.
d) The finished product is packaged and stored in a specific area.

The analysis has consisted in applying the current MFCA methodology in three main steps.
First step, to record in physical units all the data coming up from the production process in order to estimate peculiar inputs and outputs of each phase. The material flow balance of all production process has been realized. This has been carried out through interviews, direct monitoring and analysis of managerial reports and financial balance sheets.
Second step, as the enterprise does not have a management organization subdivided in cost centres, starting from the mapping of the material flow balance of production process and considering the typology of the manufacturing process, the authors have assumed that the cost centres coincide with the quantity centres. These are the following:

- Dry mixing and Extrusion
- Cutting, Welding and Packaging.

Third step, according to the relevant literature [1]-[8] the MFCA method has been applied identifying the main cost categories:

- Material Costs
- System Costs
- Energy Costs
- Waste management costs

It should be noted that the total cost of material losses has been obtained as the sum of the cost of material losses of each quantity centre, throughout the whole manufacturing process.

CALCULATIONS

The Authors firstly have identified the cost centres (Dry mixing and Extrusion and Cutting/Welding and Packaging) and then have calculated the following cost categories: Material Cost (MC), System Cost (SC) and Energy Cost (EC). The allocation of these cost categories has been based on the ratio material content in products / material losses. All the data have been standardized referring to 1,000 tons of raw materials and then monetary information have been calculated. Finally the MFCA flow chart data and the relative cost matrix (figure 1 and 2) have been estimated.

As shown in figure 1, the cost items are represented in columns and the cost centres are disposed in rows. Previously, it was noted that according to ISO 14051, waste management costs of material losses generated at each quantity centre have been included. In this case study, these waste management costs are referred to costs for outsourced activities (e.g. recycling). Considering the first quantity centre, dry mixing and extrusion phase, the total new input cost accounts for 900,452 €, of which 786,100 € of MC (which is 87% of the total), 38,634 of SC and 75,718 of EC. Then, the input costs have been allocated on the ratio of material content in products and material losses. Ratios have been calculated on the basis of the analysis of the manufacturing process and company formulas. It has been estimated that 2.5% of the *total input costs* in the first cost centre is represented by material losses, which corresponds to 30,011 €. Considering the second cost centre (Cutting, Welding and Packaging) it has been calculated that the *total new input costs* account for 39,754 € of which 27,877 € of SC and 11,877 € of EC, whereas the MC is null. The *new input costs* of the second cost centre refer only to System Costs and Energy Costs while do not have *new input Material Costs*. To these data, the 97.5% of the *total input costs* coming from the first cost centre, equal to 877,941 €, has been summed, totalling 917,695 €. For this second quantity centre it has been estimated that the material losses account over 15% of the total input costs of the second quantity centre, which corresponds to 144,013 €.

Figure 2 shows the MFCA cost matrix summarizing the analysis carried out within the company.

The material costs of products are equal to the material costs produced in the last quantity center. The material costs of material losses have been obtained summing the costs of material losses throughout the whole manufacturing process (i.e. for all quantity centres).

It has been found that costs for material loss account for near 13% of input costs, more than 80% of which are related to the input material. Furthermore the majority of the material costs comes from the "Dry mixing and

Extrusion" process instead the "Cutting, Welding and Packaging" phase has produced a considerable quantity of waste. As Figure 2 shows the share of total wastes costs on total costs is more than 4%.

RESULT AND DISCUSSION

In this case study the authors have highlighted that starting from 1,000 tons of raw materials, 850 tons of finished product are produced, which correspond roughly to 43 billion of rubbish bags of the weight of 20 g each. In addition to these data the company can visualize production in monetary and quantitative terms, identifying cost and quantity centres associated to the mass flow balance. As shown in the Materials and methods section, the costs related to production flow have been calculated.

After drawing the material and energy flow chart of the process allocating the relating costs between positive and negative products, it turns out a total negative product cost equal to 130,525 € representing almost 14% of total cost. The overall amount of negative product costs is represented by material costs equal to 109,863 €, system costs equal to 8,681 € and energy costs equal to 11,980 €. For this negative products the company incurs waste management costs equal to 43,500 €.

CONCLUSION

In the case study, authors have faced several organizational and accounting difficulties in applying the MFCA methodology to Sfrecola Materie Plastiche company. Since this is a small company, authors have noted the following issues:

1) the lack of a clear flow chart of the production process in physical unit: the preliminary stage of the project was to draw the graph of the production process, indicating the relevant flows of materials and energy involved; then, authors were able to make assumptions and estimates about the organization of the activity;

2) an accounting database set according to traditional accounting thinking which accounts only monetary information leaving out the physical flows involved in the manufacturing process. Such accounting system hides inappropriately environmental costs into overheads accounts;

3) the lack of an organization in independent cost centers: the authors have carried out assumptions and estimates, also on the basis of the existing literature.

Based on the MFCA calculation, it is possible to recommend to the company to mainly concentrate on a better optimization of the manufacturing process. In the manufacturing enterprises, material costs represent a very significant cost item. Improving the efficiency of raw material could reduce the related costs and wastes. This optimization could also depends on an effective integration of internal ERP data systems, which requires a systematic collection of both material and energy flows, and financial data.

REFERENCES

[1] LfU, Landesanstalt für Umweltschutz, Baden-Württemberg (Hrsg.), *Betriebliches Material- und Energieflussmanagement, OkoEffizienz durch nachhaltige Reorganisation*, Karlsruhe: October 1999.

[2] M. Strobel and C. Redmann, *Flow Cost Accounting,* IMU (Institute für Management und Umwelt), Augsburg, 2001.

[3] METI Ministry of Economy, Trade and Industry, *Guide for Material Flow Cost Accounting (Ver.1)*, Environmental Industries Office, Environmental Policy Division Industrial Science and Technology Policy and Environment Bureau, Japan, 2007.

[4] M. Nakajima, "The New Development of Material Flow Cost Accounting (MFCA): MFCA Analysis in Power Company and Comparison between MFCA and TPM (Total Product Maintenance)", *Kansai University of Business and Commerce*, vol. 10, pp. 57-86, 2008.

[5] T.H. Chang, and T.C. Wang,. "Using the fuzzy multi-criteria decision making approach for measuring the possibility of successful knowledge management", *Information Sciences*, vol. 179, n. 4, pp. 355-370, 2009.

[6] C. Jasch, *Environmental and Material Flow Cost Accounting: Principles and Procedures*, Springer: New York, 2009.

[7] Y. Onishi, K. Kokubu, and M. Nakajima, "Implementing material flow cost accounting in a pharmaceutical company", in *Environmental Management Accounting for Cleaner Production,* S. Schaltegger, M. Bennett, R.L. Burritt, and C. Jasch, (Eds.), Netherlands: Springer, 2009, pp. 395-409.

[8] ISO (International Standard Organization), ISO 14051 – Environmental management – Material flow cost accounting – General framework, ISO: Geneva, 2011.

[9] K.J. Hargroves and M.H. Smith, *The Natural Advantage of Nations: Business Opportunities, Innovations and Governance in the 21st Century*, CRC Press: London, 2012.

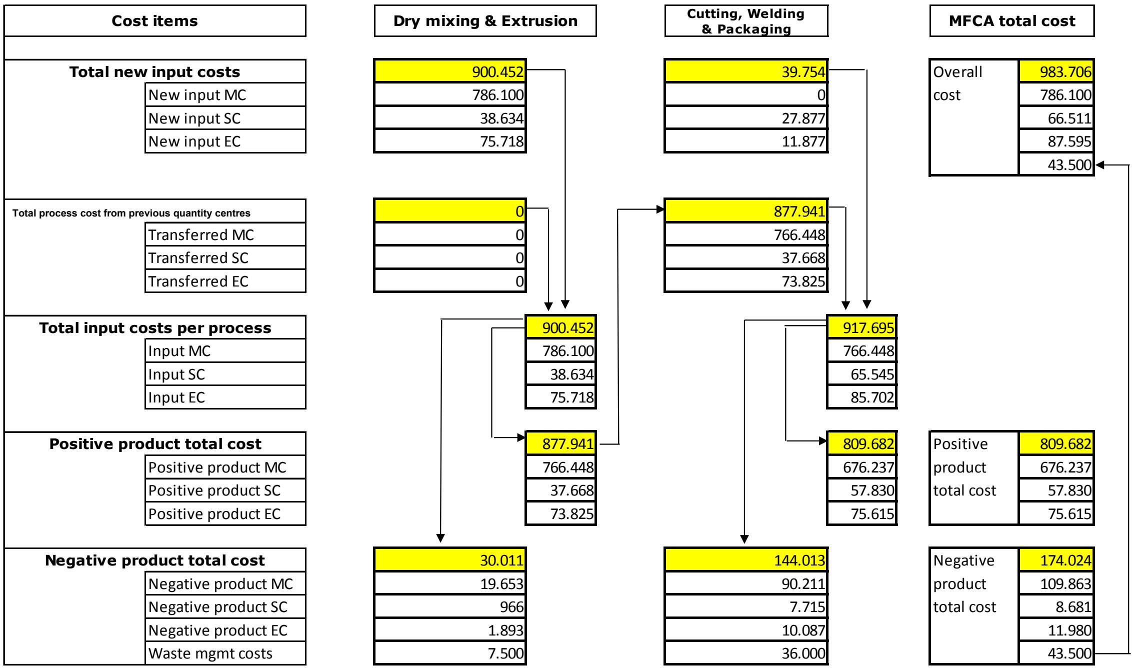

FIGURE 1: MFCA FLOW CHART WITH DATA.
Figures have been altered for publication (Authors' elaboration and adaptation from [3])

	Material Cost (€)	Energy Cost (€)	System Cost (€)	Waste recycling cost (€)	Total (€)
Products	676.237	75.615	57.830		809.682
(Positive products)	*68,7%*	*7,7%*	*5,9%*		*82,3%*
Material loss	109.864	11.980	8.681		130.525
(Negative products)	*11,2%*	*1,2%*	*0,9%*		*13,3%*
Wastes/Recycled products				43.500	43.500
				4,4%	*4,4%*
Sub-total	**786.101**	**87.595**	**66.511**	**43.500**	**983.707**
	79,9%	***8,9%***	***6,8%***	***4,4%***	***100,0%***

FIGURE 2: MFCA COST MATRIX.
Figures have been altered for publication (Authors' elaboration and adaptation from [3])

Applying Material Flow Cost Accounting in Recycling and Waste Disposal Companies

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Keywords:
material flow cost accounting, waste management, recycling, reducts, sensitivity analysis

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Justification of the paper

In accordance to the ISO standard 14051, Material Flow Cost Accounting (MFCA) can be applied by all companies using material and energy, independent of size, branch or field of action. The instrument is seen as especially useful for manufacturing companies, but it can also be implemented in other sectors including primary and service industries (EN ISO 14051, 2011).

However, the economic system does not only consist of manufacturers. Sustainable Development also calls for a recycling management which is carried out primarily by recycling and disposal companies. These companies do not only use production factors for which they have to pay a certain price. A substantial input factor are the so-called reducts which are input objects from an upstream company (like waste or waste water) that are economically characterized by the earning of revenues. The problem is that conventional MFCA only regards costs. As a result, existing MFCA cannot be applied by recycling or disposal companies, except waste receipt results in costs[1] or revenues are disregarded. This is, of course, a considerable drawback that hampers the diffusion of MFCA – especially against the backdrop of recycling management becoming more and more important for a sustainable economy. Therefore, this paper aims to discuss the possible application of MFCA in recycling and waste disposal companies and to provide a possible solution by including reducts into the MFCA method.

Methodology and theoretical framework

The research questions are as follows:

- Are recycling and waste disposal companies an additional possible application field for Material Flow Cost Accounting?
- Which problems or methodical challenges may arise when applying the MFCA in the recycling and waste industry?
- How can these methodical issues be solved?

In order to answer the posed research questions the structure of costs and revenues of recycling and waste disposal companies are analysed with the help of an enhanced production theory model based on Harald Dyckhoff[2] (Dyckhoff, 2000 and 2006). A theoretical framework for the inclusion of reducts and the connected revenues into the existing methodology of the MFCA is developed. The theoretical framework, its significance and its practical deployability will be examined by means of an example case – the application of the MFCA in a waste digestion plant with an attached composting plant.

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[1] This is the case when waste is considered as a material with a positive economic value.
[2] See figure 1.

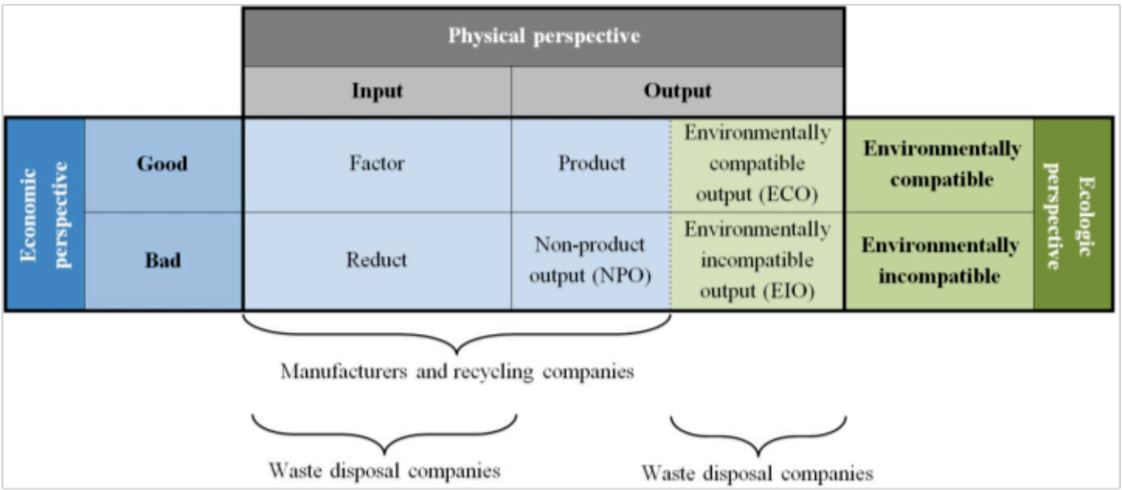

Fig. 1. Enhancement of the input and output categories for production and reduction (based on Dyckhoff, 2000, 2006).

Results and discussion

Especially in respect of the extension of the MFCA to a supply chain or a product life cycle where also recycling and waste disposal companies (will) play an essential role, MFCA can also be applied in the waste industry, however, special methodical issues have to be considered.

One of these issues is the fact that recycling and waste disposal firms earn revenues for accepting waste as an input object. It is very essential to not substract or net the incoming costs and revenues. Reduct flows and the associated revenues have to be calculated separately.

Furthermore, the output objects and the definition of what is a desirable and undesirable output category have to be reviewed.[3] One crucial insight from the case study is that an altered definition of system boundaries can lead to considerable differences concerning the results of MFCA.

A main finding is that a sensitivity analysis should be included in MFCA projects, especially where the definition of appropriate system boundaries and the output categories is not quite clear.

References:

Dyckhoff, H., 2000. Grundzuege der Produktionswirtschaft – Einfuehrung in die Theorie betrieblicher Wertschoepfung, 3th edition, Springer, Berlin, Heidelberg.

Dyckhoff, H., 2006. Produktionstheorie, 5th edition, Springer, Berlin, Heidelberg, New York.

METI – Ministry of Economy, Trade and Industry of Japan 2007. Guide for Material Flow Cost Accounting, (ver. 1), Tokyo.

ISO – International Organization for Standardization, 2011. ISO 14051, Environmental management – Material flow cost accounting – General framework, Geneva.

[3] As the main purpose for a waste disposal company is not to produce a good (hence the output categories product and non-product do not apply to waste disposal companies), but to produce an output which is compatible to the natural environment, the production of environmental compatible output (ECO) is desirable and can therefore be listed under the umbrella category 'good', whereas the undesirable output of a waste disposal company is the environmental incompatible output (EIO).

IT-supported Material Flow Cost Accounting – Case Studies from the Aluminum Industry and Implications for Methodology

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Abstract: **Material Flow Cost Accounting (MFCA) is an instrument with a considerable potential for accomplishing transparency of material (and energy) flows and corresponding costs as well as for decision support in order to enhance material (and energy) efficiency. Recognizing this potential, this paper addresses the implementation of the methodology of ISO 14051 within the IT-tool Umberto®. For illustration, two case studies are taken from the collaborative research center SFB 692 'High-strength Aluminium-based Lightweight materials for Safety components' (HALS) – the manufacturing of an extrusion recipient and the anodizing of aluminum parts. From the case studies several implications for methodological enhancements of both, the IT-tool and the ISO standard will be derived. As a result, the paper contributes to the empirical validation as well as the methodological enhancement of MFCA.**

I. INTRODUCTION

Because material and energy costs often represent a large share of costs, industrial enterprises strive for an increase of material (and energy) efficiency. To support this, MFCA has been developed [1]-[3]. According to ISO 14051, MFCA is intended to improve transparency of material flows and energy consumption, to support decisions and to enhance material- and energy-related coordination and communication within organizations. Results of literature review and market research showed that up to now no software solutions specialized on MFCA exist. However, because Umberto® provides flow modeling components as well as a cost accounting module, it might have the potential for supporting MFCA and, thus, it is chosen for analysis. Drawing on two case studies referring to industrial partners of SFB HALS, it is shown in which way the IT-tool might be used to perform MFCA in general and with respect especially to energy flows. The experiences gained from the case studies are used to derivate implications for both, Umberto® and the methodology of MFCA and to develop proposals for improvement. As a base for analysis, the methodology of MFCA is exposed in section II. Section III contains the case study of manufacturing an extrusion recipient, used for the demonstration of the support of MFCA by Umberto®. The second, energy-focused case is presented in IV. Section V deals with implications before conclusions are drawn in VI.

II. METHODOLOGY OF MFCA

According to [4], the general procedure of MFCA consists of three main steps, which are embedded in a Plan-Do-Check-Act-Cycle (PDCA-cycle) by ISO 14051: flow structure modeling, quantification of flows, and evaluation (cost appraisals of the quantified flows) [3].

Flow structure modeling of material flows includes the specification of system boundaries and a time period, the determination of quantity centers, and the identification of inputs (e. g., materials, energy) and outputs (products, material and energy losses) for each center [3]. According to ISO 14051, energy flows are not separately modeled (for the modeling of energy flows in MFCA see [4], [5]). Quantity centers can be spatial or functional units (e. g., material storages, production units, or disposal systems) which store, process, or otherwise transform materials [6]. Extending this interpretation to some degree, ISO 14051 refers to the term of process and determines that processes like receiving, assembling, and packing as well as storages can be defined as quantity centers.

Based on the flow structure, the *quantification of* material *flows* in physical units such as mass, length, volume, or number of pieces can be realized. As a result, an input/output balance is created for each quantity center [3].

Within the third step of MFCA, material flows are quantified in terms of monetary units (as so-called flow costs) as a base for *evaluation* in terms of *cost appraisals* of the quantified flows. ISO 14051 differentiates between different categories of cost (similar to [2], [7], [8]):

- *Material costs* have to be calculated "for a substance that enters and/or leaves a quantity centre" [3] and, thus, for products as well as for material losses.
- *Energy costs* are costs for electricity, fuels, steam, heat, compressed air, and others. They should be calculated for each quantity center on the basis of the measured or estimated energy use [3].
- *Waste management costs* are costs "of handling material losses generated in a quantity centre" [3]. They comprise costs for activities like reworking of rejected products, recycling, tracking, storage, treatment or disposal of air emissions, wastewater, and solid waste [3], [9]. They are allocated only to material losses.
- Finally, *system costs* represent all costs of handling inhouse material flows except for material, energy, and waste management costs [3]. For example, this includes costs of labor, depreciation, and maintenance. They are accounted for quantity centers and should be allocated to products and material losses by using appropriate criteria. Simplifying, the mass criterion can be used (for a closer look at system costs see [4]).

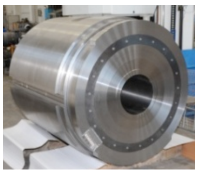
Further steps of the PDCA-cycle of ISO 14051 are, among others, MFCA data summary and interpretation, e. g., using material balances, material flow cost matrices or Sankey diagrams, the communication of MFCA results, and the identification and assessment of improvement opportunities. However, the following discussion will focus on the three main steps (see also [10]).

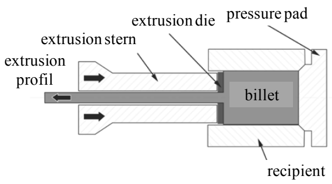
III. Case Study: Manufacturing of an extrusion recipient

1. Brief description of IT-tool and case

IT-tools for a comprehensive support of Material Flow Cost Accounting are supposed to enable both, the modeling and the evaluation of material (and energy) flows. For modeling material flows, several IT-tools had been developed, for example Aspen Plus® and Umberto®. Since Aspen Plus® is focused on chemical processes (and therefore not suitable for economical analysis of diversified material-related processes within the SFB 692), Umberto® was chosen for analysis. Besides its components for flow modeling, visualization, and life cycle assessment, Umberto® provides a cost accounting module. Thus, the question arises whether and how a MFCA according to ISO 14051 can be performed by this IT-tool. To answer this question, Umberto®'s potential for MFCA is described and analyzed primarily on the base of ISO 14051 (and with respect to the version Umberto® 5.6).

For this purpose, the case study of the manufacturing of an extrusion recipient is used. An extrusion recipient (figure 1(a)) is a tool for the direct or indirect extrusion (figure 1(b) shows the indirect process variant) of billets into specific profiles – here: aluminum billets, e. g., for the automotive industry. This tool often consists of three components: liner, liner holder, and mantle [11]. All these components have to pass through the manufacturing steps of drilling, preprocessing, tempering, and finish-turning before they are joined by shrink-fitting.


(a)



(b)

FIGURE 1: (A) EXTRUSION RECIPIENT AND (B) INDIRECT EXTRUSION PROCESS [10], [12], [13].

2. Flow Structure Modeling

For modeling material flows, Umberto® applies the following elements [14] (see figure 3):

- *Transitions*, symbolized by squares, represent processes which transform materials or energy and, thus, also quantity centers corresponding with these processes. If a more detailed analysis of a transition is desired, a subnet for this transition can be created.
- *Places*, symbolized by circles, firstly can represent inputs or outputs of the considered system and, thus, system boundaries. Secondly, they can also stand for storages of materials (or energy). Thirdly, they serve as connections between transitions.
- *Arrows* connect transitions with places and specify the flow direction.

Flow structure modeling in Umberto® (resulting in a so-called material flow network) begins with the specification of *system boundaries* by the definition of input and output places bounding the network [14]. Then, the *time period* has to be fixed. Umberto® provides a period of one year by default. However, users can define other time periods, reaching from one day up to several years. In the case of recipient manufacturing, the system boundaries are defined by the places of providing the raw material (P1-P3) and the finished recipient (P20) as well as different waste outputs (P27-P33) (figure 3). It is assumed that the time period spans one year and thereby comprises the typical manufacturing cycle of approx. 3-4 months.

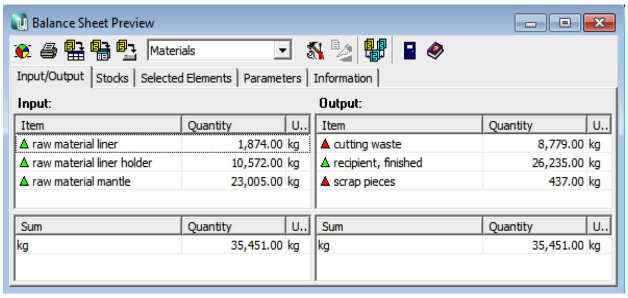
For the *determination of quantity centers* in Umberto®, a transition has to be inserted for each quantity center representing a step of recipient manufacturing (T1-T17, figure 3). Furthermore, the processes of dealing with different waste categories (which cause waste management costs but also generate revenues in this case) are also modeled by transitions (T18-T24). Storages as another possible type of quantity centers according to ISO 14051 are not explicitly considered in this case. In Umberto®, they rather would have been represented by places.

For the *identification of inputs and outputs for each quantity center*, a list of materials (e. g., raw materials, energy (defined as "material" in Umberto®), semi-finished products, final products, and waste/emissions) has to be created and material types have to be defined. Umberto® distinguishes between three material types: good, bad, and neutral. Flows of good (bad) materials are symbolized by green (red) arrows, neutral materials (being irrelevant for the economical evaluation, e. g., oxygen in the atmosphere [14]) are neglected here. Based on the material list, each material can be assigned to a quantity center (transition) – as an input or output (or both).

The flow structure can be modeled with different levels of detail. To reach a high level, processes are decomposed in sub-processes or activities (by using subnets).

3. Quantification of Material Flows

For the quantification of inputs and outputs of quantity centers and, thus, the material flows, in Umberto® different options exist: so-called basic units are "kg" and "kJ" by default, besides, other physical units (e. g., pieces, gram, or cubic meters) can be represented by self-defined basic units or "display units" (representing input or output data). Afterwards, for each quantity center (transition) input/output relations have to be specified either with coefficients or by non-linear functions. Thus, it is possible to take economies of scale into account. Additionally, the inputs and/or desired outputs of the material flow system have to be entered. By linking inputs/outputs with coefficients/functions, the flow structure model is enhanced to a quantity flow model comprising the quantities of flows [5], [7]. In Umberto®, these quantities of flows can be assigned to the arrows and/or symbolized by the width of the arrows (see the Sankey diagram of the material flow network of recipient manufacturing (kg) in [10]). In line with this, for each transition, section or subnet in the material flow network or even the entire network, material balances ("Balance Sheets") can be displayed [14]. Figure 2 shows the quantified input and output of the whole material flow network. Raw materials are on the input side. The finished recipient as well as different waste categories are displayed on the output side.



Balance Sheet Preview

Input/Output | Stocks | Selected Elements | Parameters | Information

Input:

Item	Quantity	U..
raw material liner	1,874.00	kg
raw material liner holder	10,572.00	kg
raw material mantle	23,005.00	kg
Sum	**Quantity**	**U..**
kg	35,451.00	kg

Output:

Item	Quantity	U..
cutting waste	8,779.00	kg
recipient, finished	26,235.00	kg
scrap pieces	437.00	kg
Sum	**Quantity**	**U..**
kg	35,451.00	kg

FIGURE 2: EXEMPLARY BALANCE SHEET PREVIEW FOR THE MATERIAL FLOW NETWORK OF RECIPIENT MANUFACTURING.

4. *Evaluation of Material Flows*

Based on the previous steps, the quantification of the material flows in monetary units can be realized. Therefore, Umberto® provides a cost accounting tool which supports Full Cost Accounting as well as Variable Cost Accounting (Direct Costing). In contrast, ISO 14051 does not differ between fixed and variable costs and, thus, implicitly refers to Full Cost Accounting. The following explanation also refers to Full Cost Accounting.

For cost accounting, a procedure with seven steps is proposed in the Umberto® User Manual [14]:

- Establishing a cost plan that defines all material flow-relevant "cost type groups" (e. g., material, energy, waste management, and system costs), "cost types", and cost drivers.
- Specifying "standard market prices" of materials.
- Determining (non-material) costs of the various quantity centers on the base of the defined cost drivers.
- Selecting or defining rules or coefficients for the allocation of quantity center costs to material flows. Thereby, Umberto® provides the option for a differentiated cost allocation. Thus, e. g., waste management costs can be allocated solely to waste while other cost center costs are assigned to products as well as waste.
- Calculating the total costs of single quantity centers (transitions) as well as the material flows of a subnet or the entire flow system.
- Selecting a reference flow whose costs shall be displayed.
- Editing the data to display them in a balance sheet.

Besides supporting the third step of MFCA, Umberto® provides a basis for the MFCA data summary and interpretation and communication of MFCA results. For reporting, the tool facilitates the display of Sankey diagrams (with quantity or cost flows), material and cost balances, and ratio systems. However, material flow cost matrices [3], [7] cannot be visualized.

Figure 3 shows a Sankey diagram for the material flow network. Here, the width of the arrows symbolizes the amount of (dummy) costs. The (in Umberto® red colored) arrows connecting T1-P28/P29, T2-P31, T3-P33, T10-P27, T11-P30, and T12-P32 represent the costs of material losses as one significant result of MFCA. A comparison of the Sankey diagram of material flows (in kg) [10], and figure 3 shows differences between the relative quantities and costs of product and loss flows. For example, the incoming and the outgoing arrow in T5 have the same width in the Sankey diagram of quantified material flows [10], assuming that there are no quantity differences. In figure 3, the outgoing arrow is wider than the incoming one because of added system costs. As a second example, it can be seen that cutting waste in P28 is less cost-intensive than cutting waste in P27. The relation of quantities (kg) is nearly 4:1 while the relation of costs in figure 3 is approximately 2.5:1. This is explained by the increasing value of materials within material flows.

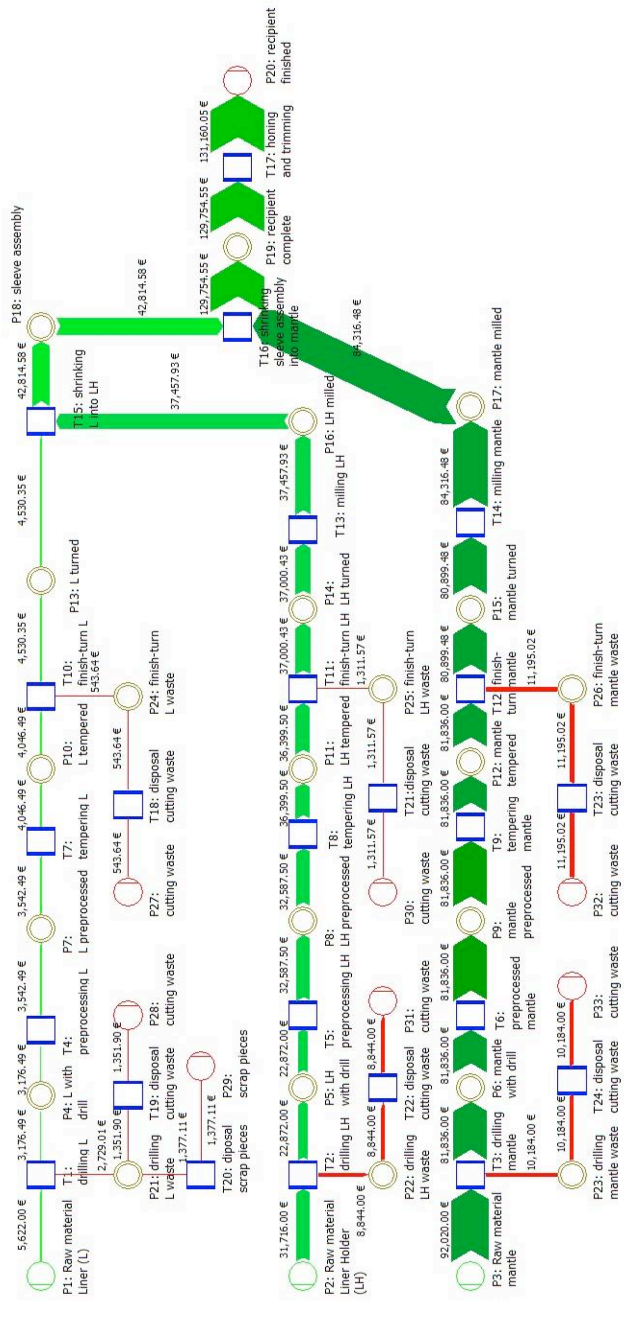


FIGURE 3: SANKEY DIAGRAM FOR THE MATERIAL FLOW NETWORK OF RECIPIENT MANUFACTURING.

Additionally, in a "Balance Sheet" the costs can be displayed differentiated according to cost types as well as variable (proportional) and fixed costs. Figure 4 refers to the whole flow system; separate balances for product or waste flows or specific subnets can be created, too.

In the case of recipient manufacturing, these and the other results can be used, inter alia, to identify and reduce inefficiencies, evaluate design alternatives and prepare decisions concerning the sales prices of scrap.

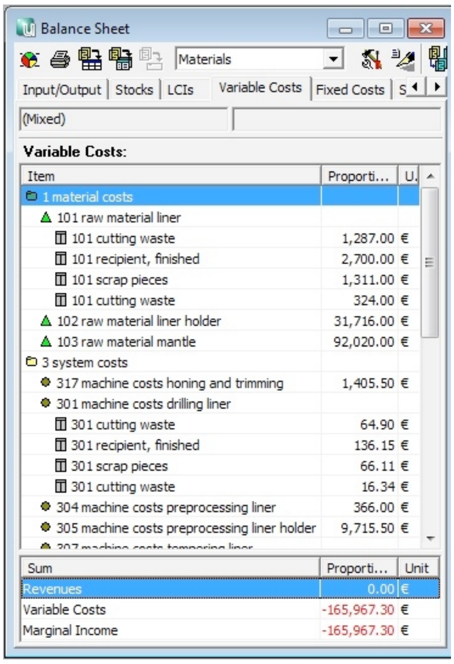


FIGURE 4: BALANCE SHEET OF (DUMMY) COSTS OF RECIPIENT MANUFACTURING.

IV. CASE STUDY: ANODIZING OF ALUMINUM PARTS

1. *Brief description of anodizing and case*

Anodizing can be defined as "Forming a conversion coating on a metal surface by anodic oxidation; most frequently applied to aluminum" [15]. Thereby, anodic oxidation is an energy absorbing electrolytic process which enhances protective characteristics such as corrosion resistance and hardness of aluminum alloys [15], [16]. These characteristics, among others, enable aluminum alloys to compete with steel alloys, e. g., within the automotive industry (for the example of aluminum screws see [17]). Besides, anodizing is also used for coloring and, therefore, for decorative purposes [15]. From an economical point of view it has to be noted that energy is a main consumable "material" within anodizing processes (besides chemicals such as acid sulfur and azotic acid and water). Thus, an economical evaluation of anodizing processes faces the challenge of evaluation of energy flows.

For anodizing of aluminum parts (each approx. 30 mm long, 20 mm diameter) in the investigated case [19], an *automat* and a *hand-feeding device* can be used alternatively. Thus, it has to be decided whether to purchase either a new automat or a new hand-feeding device. This decision can be supported by an economic comparison with a specific focus on energy costs, taking different ways of energy supply into account. Beside decision support, a higher level of transparency and the optimization of the energy system are further objectives.

2. *Flow Structure Modeling*

For the alternative of using an *anodizing automat*, *system boundaries* are defined, inter alia, by the places of providing natural gas (P1) as well as fresh water (P2) for a block heating station (T1) which produces electrical as well as thermal energy (see figure 5). Both energy types are necessary for the anodizing process (T4), in which raw aluminum parts (P4) are anodized (P10). Besides, electrical energy is provided in terms of grid power (P3). The part of thermal energy which is not used for anodizing serves as energy for space heating (P8). The water which is heated by the block heating station and caught in a warm water buffer storage (P4) is partly used in several (pretreatment) steps within the anodizing process (e. g., degreasing, bating). The other part of warm water is cooled by absorption refrigeration (T3) for usage in the anodic oxidation step of the anodizing process. Finally, waste water has to be treated and disposed (P9). The anodizing process is realized several times a day. However, it is again assumed that the *time period* spans one year.

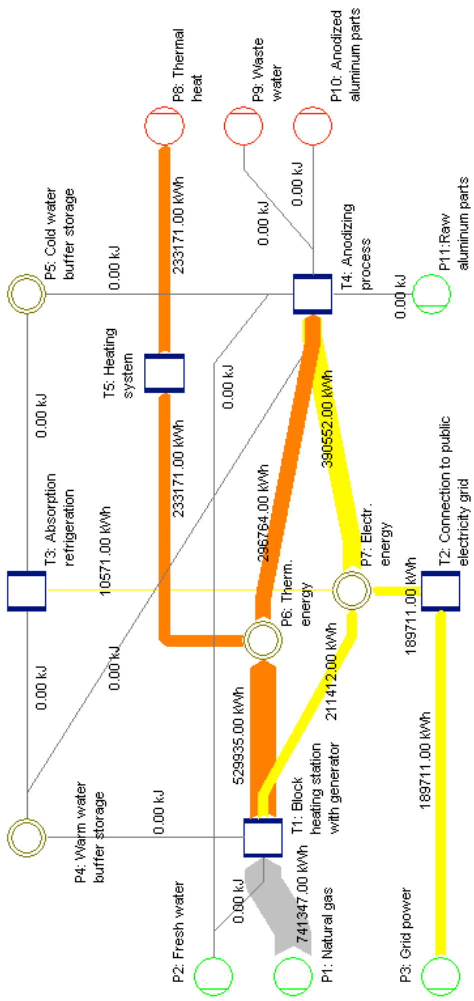


FIGURE 5: ENERGY FLOWS (ANODIZING AUTOMAT).

T1, T3, and T4 represent *quantity centers*. Furthermore, both, the connection to the public electricity grid (T2) and the heating system (T5) are modeled by transitions. The explanations before show that *identified inputs and outputs for each quantity center* are types of energy (thermal, electric), "types" of water (e. g., fresh, warm) and raw or anodized aluminum parts. Chemicals as another input of the anodizing process are neglected in the model. For a higher level of detail of flow structure, e. g., T4 could be decomposed into sub-processes.

3. Quantification of Material and Energy Flows

Similar to material flows (see section III.3), in Umberto® quantified energy flows can be displayed by Sankey diagrams – as shown in figure 5 for the anodizing case (using the display unit "kWh"). These energy flows are necessary to anodize approx. 9,465 kg aluminum parts, consuming 871 m^3 fresh water. By analogy to the quantification of material losses (e. g., waste water in P9), energy losses have to be quantified in order to show potentials for increasing energy efficiency. Basically, energy losses can be expected in each process (quantity center), and the specific question arises how to quantify these losses. A potential energy loss is thermal energy (warm water) which is produced by the block heating station (T1) but not used for anodizing (T4). However, this thermal energy is used for space heating (P8) (except for summer time) and, thus, energy use is already improved to some degree. Here, it is a simplification that the amount of energy of natural gas (P1) is completely transformed into usable thermal and electric energy (80-90 % are realistic), and the model could be refined.

Energy losses also occur in manufacturing processes. Their quantification requires the determination of the share of consumed energy which is embodied in the produced workpieces (the anodized aluminum parts). At this point it should be questioned whether this share of embodied energy is relevant for the analysis and should be included in the model. For increasing energy and cost efficiency of the exposed processes, it is abdicable and, thus, the corresponding input energy flows "end" in T4.

4. Evaluation of Material and Energy Flows

The quantification of the material and energy flows in monetary units and its display in a Sankey diagram shows a large amount of system costs (depreciation, imputed interest, costs for maintenance) in T4. Besides, energy costs are the second largest cost item in the model. Water costs are very low (because of own water sources). Because the aluminum parts are supplied by the customer for free, material costs are limited to costs of chemicals, which – like labor costs – are not displayed in the diagram. As typical results of MFCA, costs of waste water and thermal heat (also including the value of energy loss in summer time) are also displayed. Again, added system costs cause that the outgoing arrow is wider than the incoming arrow, e. g., in T1 (figure 6).

The results, firstly, can be used to prepare decisions concerning the energy supply in both investment cases. Here, the investment in a block heating station, in spite of additional system costs, decreased energy costs of the anodizing automat. This is considerably influenced by the fact that expensive grid power (0.12 €/kWh) is replaced by "cheap" natural gas (approx. 0.04725 €/kWh).

Secondly, for the investment decision, the (annual) costs of the network (anodizing automat) can be compared to the costs of the *hand-feeding device*. Operating this device, only grid power and fresh water can be used, since the block heating station and the absorption refrigeration can be combined with the anodizing automat but not with the hand-feeding device. On the one hand, system costs (of T1 and T3) are omitted then and even energy costs are lower (because of the lower energy consumption). On the other hand, labor costs are higher.

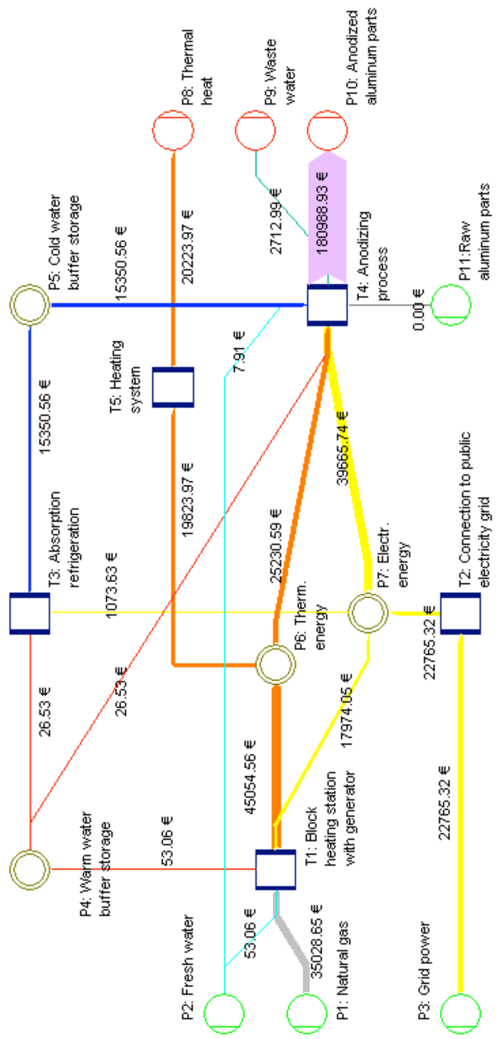


FIGURE 6: COST FLOWS (ANODIZING AUTOMAT).

In this case, the total amount of annual average costs of the anodizing automat, calculated by means of MFCA, is lower than the costs of the hand-feeding device. With this information, investment decisions (anodizing automat vs. hand-feeding device) could be supported. However, it has to be challenged, inter alia, if the physical output (anodized aluminum parts) can be assumed to be identical. In fact, this assumption is not valid because a hand-feeding device is needed for precision parts in any case. Additionally, if data like energy prices are uncertain, sensitivity analyses have to be recommended. Furthermore, it has to be considered that average annual costs cannot reflect time value of money. For a substantiated investment decision, MFCA has to be linked with dynamic investment appraisal methods [18]) and, thus, with the calculation of net present values.

V. Implications

The case studies showed that *Umberto® 5.6* proves to be useful for the flow structure modeling, quantification of material and energy as well as cost flows, and presentation of the overall results of MFCA. Furthermore, it has the potential for integrating Life Cycle Assessment and MFCA and, thus, ecological and economic evaluations on the base of specific flow networks. The tool can also be integrated with ERP-systems [20]. However, some features of the tool might be discussed and possibly refined:

- Materials can be classified as "good" or "bad". However, a bad output cannot be a cost unit (cost carrier) in Umberto®. For calculating costs of material losses – as a core result of MFCA –, even waste has to be typed as "good" output. In general, the terminology is partly different from those of MFCA (according to ISO 14051) causing the necessity of "translation".
- Energy is seen as material in spite of its (often) non-material character. In the second case study, water and the thermal energy embodied in the water had to be modeled separate from each other. For energy-intensive production systems, a refinement of the modeling options might be helpful.
- Cost appraisal does not acknowledge time value of money. It might support investment decisions to some degree (section IV), but costs (or corresponding cash inflows) from different periods cannot be discounted by the tool for calculating net present values.
- Finally, it would be interesting how Umberto® can be integrated with the various existing (traditional) cost accounting systems and IT-tools.

The case studies also showed that *methodology of MFCA* (according to ISO 14051) is suitable for improving transparency of material flows; first proposals for modeling of energy flows exist as well [4], [5]. Based on this, potentials for optimization of processes and flows can be disclosed. However:

- MFCA should be specified regarding the modeling and evaluation of energy flows and their (material) carriers. As a result, flow structures and allocation of costs could differ depending on the form of energy (e. g., thermal, electrical, potential). The quantification of energy losses is a challenge as well.
- The distinction between variable and fixed costs in Umberto® raises the question to what extent and in which cases this differentiation – neglected in ISO 14051 – might contribute to the support of decision making regarding material (and energy) consumption.
- The necessity of linking MFCA to dynamic appraisal has become obvious in the second case study.

VI. Conclusion

Whether Material Flow Cost Accounting will be widely accepted, depends on the success of carving out the benefit of using this instrument instead of or in addition to other cost accounting instruments as well as on the availability of appropriate IT-support. In this paper, two case studies from the aluminum industry were used to analyze the support of MFCA by Umberto® 5.6 and to derive implications for the methodology. As a result, on the one hand, the potentials of both, the IT-tool and methodology are demonstrated. On the other hand, suggestions for further enhancement are derived.

Acknowledgement

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References

[25] B. Wagner and M. Strobel, "Kostenmanagement mit der Flußkostenrechnung," in *Werkzeuge erfolgreichen Umweltmanagements*, J. Freimann, Ed. Wiesbaden: Gabler, 1999, pp. 49-70. [German]

[26] Japanese Ministry of Economy, Trade and Industry (METI), *Guide for Material Flow Cost Accounting*. Tokyo, 2007.

[27] DIN EN ISO 14051, *Environmental Management – Material Flow Cost Accounting – General Framework* (ISO 14051:2011), Berlin: Beuth Verlag GmbH, 2011.

[28] R. Sygulla, A. Bierer, and U. Götze, "Material Flow Cost Accounting, Proposals for Improving the Evaluation of Monetary Effects of Resource Saving Process Designs," in *Proceedings of the 44th CIRP Conference on Manufacturing Systems*, May 31 - June 03, 2011, Madison, Wis., USA, URL: http://msep.engr.wisc.edu/index.php/resources/cirp/category/1-sustainable-manufacturing.

[29] R. Sygulla, U. Götze, and A. Bierer, "Material flow cost accounting: A tool for designing economically and ecologically sustainable production processes," in *Technology and Manufacturing Process Selection: the Product Life Cycle Perspective,* E. Henriques, P. Peças, and A. Silva, Eds., accepted for publication.

[30] M. Strobel, "Flusskostenrechnung – Neue Wege des Materialfluss-Controlling auf der Basis von ERP-Systemen," in *controller magazin*, vol. 27 (2), 2002, pp. 200-204. [German]

[31] M. Strobel and C. Redmann, "Flow Cost Accounting, an Accounting Approach Based on the Actual Flows of Materials," in *Environmental Management Accounting: International and Institutional Developments*, M. Bennett et al., Eds. Dordrecht: Kluwer Academic Publishers, 2002, pp. 67-82.

[32] C. Jasch, *Environmental and Material Flow Cost Accounting. Principles and Procedures*. Heidelberg: Springer, 2010.

[33] T. Viere, A. Möller, and M. Schmidt, "Methodische Behandlung interner Materialkreisläufe in der Materialflusskostenrechnung," in *uwf*, vol. 18 (3-4), 2010, pp. 203-208. [German]

[34] A. Schmidt, B. Hache, F. Herold, and U. Götze, "Material Flow Cost Accounting with Umberto®," in *Energieorientierte Bilanzierung und Bewertung in der Produktionstechnik – Methoden und Anwendungsbeispiele*, Tagungsband zum 2. Methodenworkshop der Querschnittsarbeitsgruppe "Energetisch-wirtschaftliche Bilanzierung" des Spitzentechnologieclusters eniPROD, 14.11.2012 in Chemnitz, R. Neugebauer, U. Götze, and W.-G. Drossel, Eds. Auerbach: Verlag Wissenschaftliche Scripten, 2013, pp. 49–65.

[35] S+C ETS Extrusion Tooling Solutions GmbH, *Solutions for the extrusion industry*, Lindlar, 2012 (leaflet, sc-ets.de).

[36] U. Götze, S. Morgenstern, A. Schmidt, G. Strehl, and S. Zönnchen, "Kalkulation von Werkzeugen zur Herstellung aluminiumbasierter Leichtbauwerkstoffe am Beispiel von Strangpressrezipienten," in *MWT*, vol. 43 (7), 2012, pp. 636-647. [German]

[37] F. Ostermann, *Anwendungstechnologie Aluminium*, 2nd ed. Berlin, Heidelberg: Springer, 2007. [German]

[38] ifu Institut für Umweltinformatik Hamburg GmbH, *Umberto® User Manual Version 5*. Hamburg, 2011.

[39] J. R. Davis, Ed., *Metals Handbook*, 2nd ed., 3rd print. Materials Park, Ohio: ASM International, 2006, pp. 5; 505.

[40] M. Händel, D. Nickel, G. Alisch, and T. Lampke, "Hard anodizing of a coarse and an ultrafine-grained aluminium-copper alloy with incorporated alumina and silicon carbide particles," in *MWT*, vol. 41 (9), 2010, pp. 737-743. [German]

[41] M. Sieber, I. Scharf, M. Härtel, R. J. Hellmig, and T. Lampke, "Influence of anodic oxide coatings on screwing behaviour and

susceptibility to stress corrosion cracking of self-tapping aluminium screws," in *MWT*, vol. 43 (7), 2012, pp. 661-667.
[42] U. Götze, D. Northcott, D., and P. Schuster, *Investment Appraisal. Methods and Models*, Berlin, Heidelberg: Springer, 2008.
[43] C. Wendler, "Kostenorientierte Bewertung eines Anodisierprozesses", Chemnitz, 2013, unpublished.
[44] M. Strobel, and U. Müller, "Flusskostenrechnung – ein ERP-basiertes Instrument zur systematischen Reduzierung des Materialeinsatzes," in *Integriertes Umweltcontrolling*, M. Tschandl, M., A. Posch, Eds. Wiesbaden: Gabler, 2012, pp. 145-161. [German]

Application of Material Flow Cost Accounting (MFCA) in Ceramic Kitchenware Manufacturer: A Case Study of Small-to-Medium Enterprise Company in Thailand

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Abstract: **Material Flow Cost Accounting (MFCA) has become an International standard recently; however, the use of it has been very limited in Small-to-Medium-size enterprises (SME) in Thailand. This paper will present a case study of applying the MFCA technique to a ceramic kitchenware manufacturer where the majority of their products have been selling abroad. By adopting international environmental standard, this would be an incentive for improving a good image to the company internationally. The main raw material of ceramic kitchenware manufacturer is the soil which is both obtained locally and coming from various places. The waste of soil is one of the major wastes in manufacturing ceramic kitchenware products, along with the large energy consumption for the baking process, and high labor intensity. All of these factors contribute significantly to the overall production cost as well as to the environmental impact. The waste in soil in several ceramic kitchenware manufacturers can be over 50% of the input amount of soil in some of the product and the recycle process for nonconforming product is not cost-effective. Therefore, improving the utilization of the soil is one of the significant issues in this business. The energy cost has become an issue due to the fluctuation of the gas price in Thailand, the manufacturer needs to improve the use of energy consumption. The MFCA technique was used in this study for investigating the proportion of material cost (MC), energy cost (EC), and system cost (SC; related to labor cost) in the manufacturing process starting from receiving the raw material to dispatching the product to the customers. The processes that produce a lot of wastes were considered for improvement. One of the seven quality tools (7QC tools), the fish-bone diagram was used in obtaining the causes of the problems at the high-wasted processes for the manufacturer to find appropriate solutions for the problems.**

V.INTRODUCTION

Ceramic kitchenware manufacturer is one of the major types businesses in Thailand. The ceramic kitchenware products range from simple small salt-pepper bottle to highly decorated mug, plates, and so on. Ceramic kitchenware products was produced and shipped to main customers from many countries, in Asia, Europe, and North America. The main raw material for producing ceramic kitchenware products is soil which obtained locally or internationally. Soil usage inefficiency is one of the problems for most manufacturers that most of them face with higher production cost. In addition, the manufacturers have to deal with the fluctuation price of the LPG, which is the main source of energy used, coupled with the high-labour intensity. They need to improve their productivity as well as reduce the wastes in their manufacturing process significantly. Wastes in the manufacturing process usually come from inefficient use of soil and ineffectiveness in making the products, which results in non-conforming products. Wastes in small manufacturer can be as high as 50% of the soil input. In order to reduce that wastes, the manufacturer need to use internal decision making tool for locating and quantifying the sources of wastes in their processes. Material Flow Cost Accounting (MFCA) is one of the tools that can help the manufacturers. Also, it has become an international standard in 2011 in the ISO 14051 (environmental 14000 families), by adopting this standard, it could provide a good image to customers in many countries where environmental standards have been mandated in many types of products. This paper will provide a case study of applying MFCA technique to one of medium-size ceramic kitchenware manufacturer, located in Lampang, Thailand.

VI. MATERIAL FLOW COST ACCOUNTING (MFCA)

Material Flow Cost Accounting (MFCA) has become an international standard (ISO 14051) in 2011. According to Watanabe [1], the principles of MFCA can be summarized in four aspects:

1) Understand material flow and energy use
2) Link physical and monetary data
3) Ensure accuracy, completeness and comparability of physical data
4) Estimate and assign cost to material loss

In order to implement the MFCA technique, four major elements that must be identified are the following:

- Quantity centre: set measurement point
- Material balance: check balance between products and loss (material loss)
- Cost calculation: calculate costs
- Material flow model: set up a model that links multiple quantity centres

The implementation steps of MFCA, according to the ISO 14051 standards [2] can be summarized as follows;

- Involvement of management: like many quality standards, management team has to get involve in implementation by evaluating technique to match environmental and financial goals of the company, provides efficient resources, monitoring, reviewing, and doing the improvement.

- Determination of necessary expertise: all involved department experts need to get involves in obtaining necessary information.
- Specification of a boundary and a time period: scope of the implementation need to be addressed with a specified time frame.
- Determination of quantity centres: one or many manufacturing processes that affect to the material, energy, and system cost need to be identified as quantity centre.
- Identification of inputs and outputs for each quantity centre: clearly identify input of each quantity centre that could be materials and/or energy and output for each quantity centre.
- Quantification of the material flows in physical units: the unit used can be mass, length, volume, number of pieces, etc.
- Quantification of the material flows in monetary units: convert the input/output to monetary values of material cost (MC), energy cost (EC), system costs (SC), and waste management cost (WC).
- MFCA data summary and interpretation: summary in tables form such as a material flow cost matrix [2], graphical representation of negative and positive costs, etc.
- Communication of MFCA results: results presented in various kinds of communicational forms such as graph, tables, etc. Showed and review in managerial team.
- Identification and assessment of improvement opportunities: investigating the sources of problems for improvement in term of the financial and environmental aspects.

VII. MFCA DEMONSTRATION

In this research, the MFCA technique was applied to a medium-size kitchenware manufacturer, located in Lampang, Thailand. The line of producing a mug, shown in Figure 1, was selected for demonstration of the application of the technique.

FIGURE 1: A CERAMIC MUG PRODUCT

The mug shown in Figure 1 has the size of 17 oz. (vol.), was produced for a batch size of 2,050 pieces for this study. The materials used in this batch were soil (988 kg.), coating materials (5 kg.), slip liquid (2 kg.), ear mug (2,050 pieces), colour (2,080 THB), and packaging boxes (85 boxes). The manufacturing processes used for producing the mug were shown in Figure 2 and some of the processes were grouped in the same quantity centres as shown in the dashed-boxes. The process started from mixing and kneading the soil and water until the last step of inspection and packaging ceramic mug in shipping boxes.

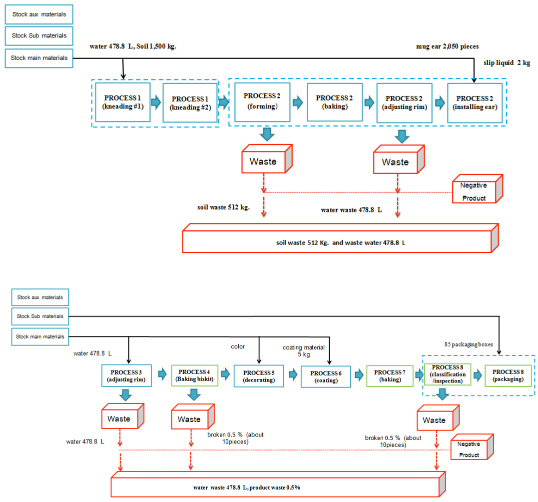

FIGURE 2: QUANTITY CENTRES FOR CERAMIC MUG PROCESSES

The next step was to construct mass balance table for each process/quantity centre, shown in Table 1-8. (Noted that 1€ ≈40 THB)

TABLE 1: MASS BALANCE TABLE (KNEADING)

Material Balance Table (kneading)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
kneaded soil	1500.00	kg	0.00	kg.	1500.00	kg.
Cost	21000.00	THB	0.00	THB	21000.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	21000.00	THB	0.00	THB	21000.00	THB
Total Quantity Percentage	100.00	%	0.00	%	100.00	%

TABLE 2: MASS BALANCE TABLE (FORMING)

Material Balance Table (forming)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
kneaded soil	1500.00	kg.	512.00	kg.	988.00	kg.
Cost	21000.00	THB	7168.00	THB	13832.00	THB
slip liquid	2.00	kg.	0.00	kg.	2.00	kg.
Cost	10.00	THB	0.00	THB	10.00	THB
mug ear	2050.00	kg.	0.00	kg.	2050.00	kg.
Cost	3075.00	THB	0.00	THB	3075.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	24085.00	THB	7168.00	THB	16917.00	THB
Total Quantity Percentage	100.00	%	29.76	%	70.24	%

TABLE3: MASS BALANCE TABLE (ADJUSTING RIM)

Material Balance Table (adjusting rim)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2050.00	pieces	0.00	pieces	2050.00	pieces
Cost	13832.00	THB	0.00	THB	13832.00	THB
					0.00	
Cost	0.00	THB	0.00	THB	0.00	THB
					0.00	
Cost	0.00	THB	0.00	THB	0.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	13832.00	THB	0.00	THB	13832.00	THB
Total Quantity Percentage	100.00	%	0.00	%	100.00	%

TABLE 4: MASS BALANCE TABLE (BAKING BISKITS)

Material Balance Table (baking biskits)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2050.00	pieces	10.00	pieces	2040.00	pieces
Cost	13832.00	THB	140.00	THB	13692.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	13832.00	THB	10.00	THB	13692.00	THB
Total Quantity Percentage	100.00	%	0.07	%	98.99	%

TABLE 5: MASS BALANCE TABLE (DECORATING)

Material Balance Table (decorating)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2040.00	pieces	0.00	pieces	2040.00	pieces
Cost	13692.00	THB	0.00	THB	13692.00	THB
color	4.00	กระป๋อง	0.00	กระป๋อง	4.00	กระป๋อง
Cost	2080.00	THB	0.00	THB	2080.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	15772.00	THB	0.00	THB	15772.00	THB
Total Quantity Percentage	100.00	%	0.00	%	100.00	%

TABLE 6: MASS BALANCE TABLE (COATING)

Material Balance Table (coating)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2040.00	pieces	0.00	pieces	2040.00	pieces
Cost	15772.00	THB	0.00	THB	15772.00	THB
coating materials	5.00	kg.	0.00	kg.	5.00	kg.
Cost	50.00	THB	0.00	THB	50.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	15822.00	THB	0.00	THB	15822.00	THB
Total Quantity Percentage	100.00	%	0.00	%	100.00	%

TABLE 7: MASS BALANCE TABLE (BAKING)

Material Balance Table (baking)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2040.00	pieces	0.00	pieces	2040.00	pieces
Cost	15822.00	THB	0.00	THB	15822.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	15822.00	THB	0.00	THB	15822.00	THB
Total Quantity Percentage	100.00	%	0.00	%	100.00	%

TABLE 8: MASS BALANCE TABLE (INSPECTION/PACKAGING)

Material Balance Table (inspection/packaging)						
Major materials	Input : material used		Output : waste (Negative product)		Output : company product	
	Quantity		Quantity		Quantity	
mug	2040.00	pieces	10.00	pieces	2030.00	pieces
Cost	15822.00	THB	158.00	THB	15664.00	THB
boxes	85.00	pieces	0.00	pieces	85.00	pieces
Cost	1700.00	THB	0.00	THB	1700.00	THB
Cost of Input materials			Cost of Output waste (Negative product)		Cost of Output : company product	
Total	17522.00	THB	158.00	THB	17364.00	THB
Total Quantity Percentage	100.00	%	0.01	%	99.10	%

Material cost (MC): calculation was carried out for each quantity centre based on the price of soil (14 THB/kg), coating material (10 THB/kg), slip liquid (5 THB/kg), ear mug (1.50 THB/piece), colour (a total of 2,080 THB), box (20 THB/box), and groundwater (0.0105 THB/L).

System cost (SC): calculation was based on each worker work 8 hours/day for 280 THB/day. The time for each process was measured, and number of workers per process was recorded. The system cost for each quantity centre = 35 THB/hour x measured working hour(s) x number of workers. For example, the kneading process required 1 worker, worked for 4 hours; therefore, the total system cost = 35x4x1 = 140 THB.

Energy cost (EC): electricity cost was 3.62 THB/kW-hour, LPG 29.56 THB/kg by average. The power consumption for each machine in the production line was record; for example, the machine used in the kneading process consumed 10 kW. When multiplying the power consumption of the machine by the measured working time and the electricity cost per kW-hour, the energy cost for the process was obtained.

Waste management cost (WC): the waste management cost was not included due to the waste from the process such as non-conforming product was carried it out by the third-party company with their own expenses.

After the mass balance for each quantity centre was computed, the ratio of mass of the product / mass of the input will be used in allocating positive, negative costs for material cost, energy cost, and system cost accordingly.

VIII. RESULT AND DISCUSSION

From the mass balance calculations mentioned in the previous section, the MFCA overall cost matrix is shown in Table 9 and the MFCA positive/negative graph is shown in Figure 3.

TABLE 9: MFCA OVERALL COST MATRIX

Costs	MC	SC	EC	TC
Total	21,000.00	8,099.00	7,022.71	36,121.71
	58.14%	22.42%	19.44%	100.00%
Positive	18,419.38	6,858.65	5,682.44	30,960.48
	50.99%	18.99%	15.73%	85.71%
Negative	2,580.62	1,240.35	1,340.27	5,161.23
	7.14%	3.43%	3.71%	14.29%

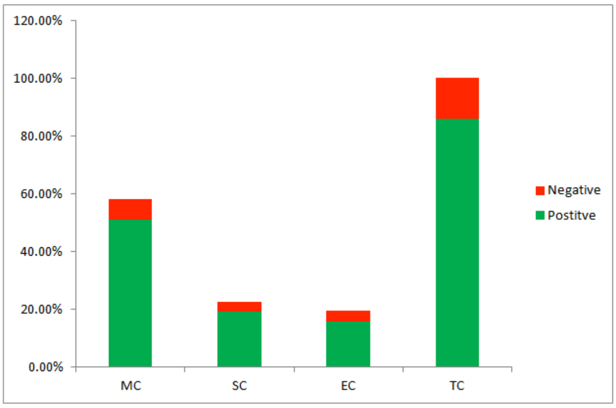

FIGURE 3: POSITIVE VS. NEGATIVE COSTS

From results in Table 9 and Figure 3, in the ceramic mug production line, the material cost accounted for 58.14% of the overall cost, followed with 22.42% of system costs, and 19.44% of energy cost. Considering the negative cost for material was about 7.14%, system cost of about 3.43%, and energy cost of 3.71%, the material cost was still the major contribution of the overall negative cost. The negative energy cost could be more severe if the LPG price increase significantly. Negative system cost showed that labour cost was still an important factor in this business. The overall 14.29% of negative cost should be controlled and reduced. From Table 1-8, it was shown that the forming process (Table 2) produced the most negative cost (7,168 THB). In order to reduce the wastes in this process, the causes of producing wastes must be identified.

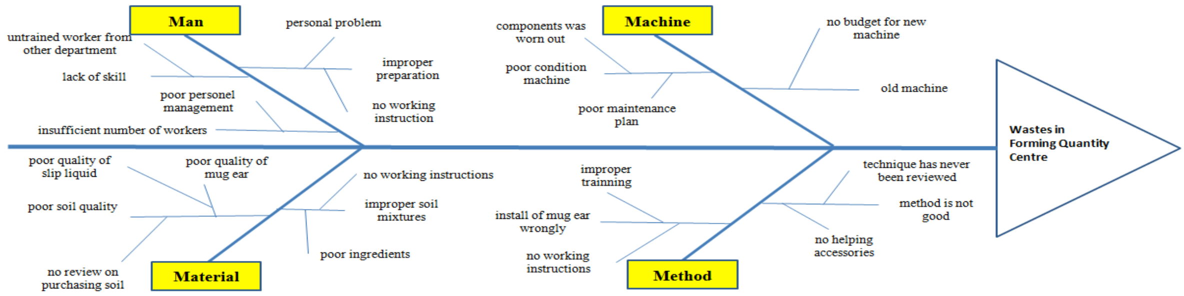

FIGURE 4: FISH-BONE DIAGRAM FOR WASTES IN FORMING QUANTITY CENTRE

Seven quality control tools (7 QC tools) are used in process control and improvement. According to Montgomery [3], the 7 QC tools consist of check sheet, fish-bone diagram (cause and effect diagram), graph, histogram, Pareto diagram, scatter diagram, and control charts. In this paper, the fish-bone diagram (4M: Man, Material, Machine, and Method) was used for investigating possible causes of negative products produced in forming quantity centre as showed in Figure 4.

From the fish-bone diagram in forming quantity centre, there are many possibilities that can help in reducing wastes in this quantity centre. Among many possible solutions, proper training of worker is a necessary step in ensuring a reduction of waste and a higher quality of the product. The source of material and the procedure of mixing soil and water/other ingredients should be a good starting point in reducing waste process also.

IX. Conclusion

The application of MFCA technique of making a ceramic mug of a medium-size ceramic kitchenware manufacturer, located in Lampang, Thailand had been demonstrated. Understanding and be able to obtain the process flow chart of manufacturing a product is very important for a correct analysis of MFCA. Quantity centres must be identified and all the material in/out of the quantity centre must be identified. Energy consumption of each machine, operating time of each machine/process, the number of workers of each process, unit cost of electricity, amount of money paid to worker are important for calculating material, system, and energy cost of the MFCA.

From this case study, the material cost is the major cost in this ceramic mug line. Negative total cost of 14.29% is high, and it should be reduced. The forming quantity centre produced the largest negative cost, so it should be investigated in more details about the causes of the problems. The seven quality control tools (7 QC tools), which are simple but efficient tools in finding causes of the problems for managerial teams in improving the quality as well as reducing wastes in manufacturing processes. It can be seen that proper training of worker, creating efficient working instruction are among many possible solutions for this company.

Acknowledgement

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References

[1] A. Watanabe, "Overview of ISO 14051 Module 2, Propharm Japan Co., Ltd.
[2] ISO 14051:2011 (E)
[3] D.C. Montgomery, Introduction to Statistical Quality Control, 5th edition, John Wiley & Sons, New Jersey, 2005

Application of Material Flow Cost Accounting Technique in Lost-Wax Casting Process

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Abstract: **This paper presents an application of Materials Flow Cost Accounting (MFCA) technique in lost-wax casting process at a case study company who is a manufacturer of aluminium components for factory automation. MFCA was used to identify inefficient process which has high negative product cost. Shell-removal and De-wax processes have been identified as processes that produce highest waste. Improvements were made to both processes by recycling of sand from shell-removal process and wax in de-wax process. Both improvements result in 2.19% reduction in cost.**

I. INTRODUCTION

Lost-wax casting process is a process in which a molten metal is poured into a mold made from wax model coated with ceramics materials. Lost-wax casting is very important process in the case study company who is a manufacturer of factory automation products including aluminum framing, drive units, and control devices. The product studied in this case is a SFJ-p71S type (Figure 1), which was previously produced by subcontractor. However, due to the rapid growing in demand, the company decided to make this product in-house.

FIGURE 1: SFJ-P71S CASTING PIECES.

Lost-wax casting consists of 14 processes. It starts from injecting wax models and runners with injection machines. Wax used to inject SFJ-p71S model is waxf20-6 type. For runner, reclaimed wax, which is a mixing of recycled waxf20-6 and new waxf20-6 at the ratio of 70:30 was used. The next process is the assembly where wax products and runner are assembled together (Figure 2) to form wax assemblies. One wax assemblies consists of 120 pieces of the SFJ-p71S wax models. The SFJ-p71S assemblies then go to shell forming process. In this process, each assemblies is coated with 7 layers of ceramics materials and dried in the controlled environment to form strong shell for casting process. The shell then pass through de-wax process where heat is applied to the shell so that wax is melted and drained away leaving hollow core for casting process. In the casting process, shell is warm up so that it has the same temperature with molten steel, then the molten steel is pour into the mold and wait until it cool down to the room temperature. After the mold is cooled down, shell is removed by hammer. The shell removed in this process is discarded leaving only casted work pieces. The casted work pieces then pass shot blast machine to remove the remaining ceramics shell, then they passes through cutting, polishing, grinding, washing, visual inspection and then packing.

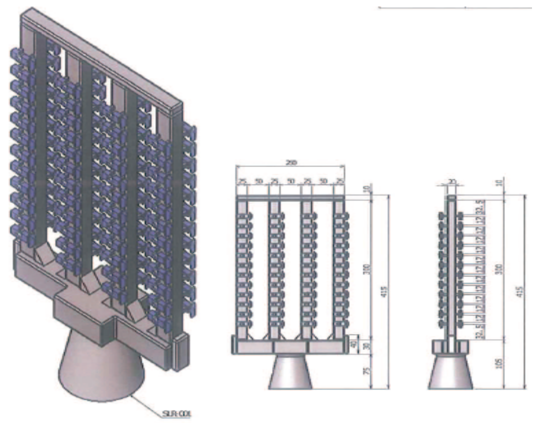

FIGURE 2: SFJ-P71S ASSEMBLIES.

Lost-wax casting process has begun its production in the case study for only 3 years, the process yield excessive waste in terms of materials, labor and energy. To solve this problem, MFCA was applied to lost-wax casting process. MFCA helps to identify the process that has high loss so that the effort for loss reduction can be focused on the right place. In this research, MFCA was applied to all 14 processes of lost-wax casting. Process which has highest loss was identified and improved.

II. MATERIALS AND METHODS

MFCA application started with constructing materials flow model to illustrate the production process, their input materials, company product (positive product) and material wasted (negative product). The quantity of input materials, positive product, and negative product were recorded in terms of mass. These data were used to draw materials flow chart. In this chart, materials were classified into main materials, sub materials and auxiliary materials. The quantity of input, positive and negative product were also shown in this chart.

Then material balance tables were constructed for each of the 14 processes. In these tables, quantity percentage of input and waste materials of each process were calculated. Most research calculates this percentage based on mass. However, in lost-wax casting process, as the shell consists of 7 layers of ceramics, the mass of shell is relatively high comparing to the mass of actual product. As a result, using mass to allocate cost in this case might misleading. Therefore, in this work, quantity percentages were calculated based on materials cost instead.

MFCA calculations were then performed by calculating material cost for positive and negative product. System cost and energy cost were allocated to product and waste by using quantity percentage obtained from the previous stage. Finally material flow cost matrix was used to summarize MFCA results.

III. THEORY/CALCULATION

Material Flow Cost Accounting technique (MFCA) is an environmental management accounting used to quantifying materials flow cost. It has been identified as one of the most promising method in environmental management accounting [1]-[2]. In contrast with the traditional system that automatically include cost of waste into product cost, MFCA observed waste as a kind of product, so called negative product, and their cost are calculated. Therefore MFCA helps in making decision of waste reduction by providing monetary information regarding the benefit of waste reduction [3]. The first edition of international standard for MFCA was published by ISO (ISO 14051) in 2011[4]. There have been reports of successful implementation of MFCA [5]-[6]. Also MFCA has been applied in integration with other techniques, for example, Environmental Management System (EMS) [7] and Enterprise Resource Planning (ERP) [8].

MFCA calculations in this research were based on the MFCA guideline [9]. However, quantity percentages used to allocate system cost and energy cost were calculated based on materials cost instead of mass.

IV. RESULTS

Figure 3 is the material flow model of the lost-wax casting process.

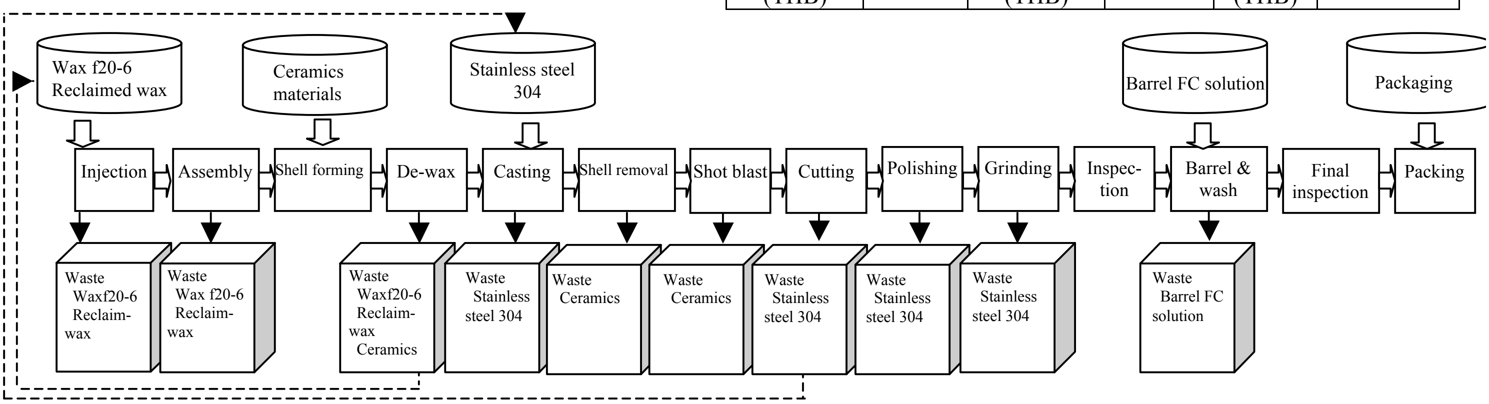

FIGURE 3: LOST-WAX CASTING MATERIALS FLOW MODEL.

As can be seen in Figure 3, recycling materials occur in two processes. The first one is de-wax process, where the wax melted out of the mold was mixed with new wax at the ratio of 70:30. This mixture, called reclaimed wax, was used as material input for runner injection. The second process is cutting process. In this process, negative product, such as runner, cut out at this stage was put back into casting process.

The next step is the data collection. Firstly, the mass of input materials and output materials (both negative and positive products) was collected. Secondly, data regarding energy consumption of each process is collected. This includes number of machines, and production time. These data were used to calculate energy cost of each process. Finally, system cost data was collected including number of worker, standard time, and labour wages per hour. Then, system cost of each process is calculated.

After data collection, 14 material balance tables were constructed to calculate quantity percentage for each process. An example of material balance table of injection process is shown in Table 1. Data used in material balance table is collected from one wax assemblies (120 workpieces) shown in Figure 2.

TABLE 1: MATERIAL BALANCE TABLE FOR INJECTION PROCESS

Material Balance Table (Injection Process)					
Input: material used		Output: waste		Output: company products	
Main materials	Quantity (g)	Waste (negative product)	Quantity (g)	Company products	Quantity (g)
Wax f20-6	0.396	Wax f20-6	0.072	Wax f20-6	0.324
Reclaimed Wax	1.044	Reclaimed Wax	0.05	Reclaimed Wax	0.994
Quantity percentage	100%	Quantity percentage	9.27%	Quantity percentage	90.73%
Cost of input materials		Cost of wasted materials (negative product)		Cost of materials used for positive product	
Total (THB)	200.38	Total (THB)	18.57	Total (THB)	181.81

From Table 1, there were two input materials in injection process, which were wax f20-6 and reclaimed wax with the mass of 0.396 and 1.044 gram respectively. Waste from this process was recorded at 0.072 and 0.05 gram for wax f20-6 and reclaim wax. Mass of positive products were calculated by subtracting mass of negative product from mass of input materials. Cost of materials were calculated by multiplying mass with their cost per gram. Quantity percentages were calculated based on materials cost. For example, quantity percentage of negative product = 18.57/200.38 = 9.27%. Quantity percentages of all 14 processes are shown in Table 2. Shell removal process has the highest cost and then de-wax process.

TABLE 2: QUANTITY PERCENTAGE OF EACH PROCESS

Process	Quantity percentage	
	Waste (%)	Positive (%)
Injection process	9.27	90.73
Assembly process	0.10	99.9
Shell forming	0.00	100
De-wax process	13.79	54.17
Casting	3.03	96.97
Shell removal	21.09	78.91
Shot blast	0.53	99.47
Cutting	0.00	16.25
Polishing	0.38	99.62
Grinding	0.60	99.40
Inspection	0.00	100.00
Barrel & wash	0.76	99.24
Visual Inspection	0.00	100.00
Packing	0.00	100.00

The next step is to allocate energy cost and system cost to positive and negative products. Figure 4 illustrates cost allocation of injection process using quantity percentage obtained previously.

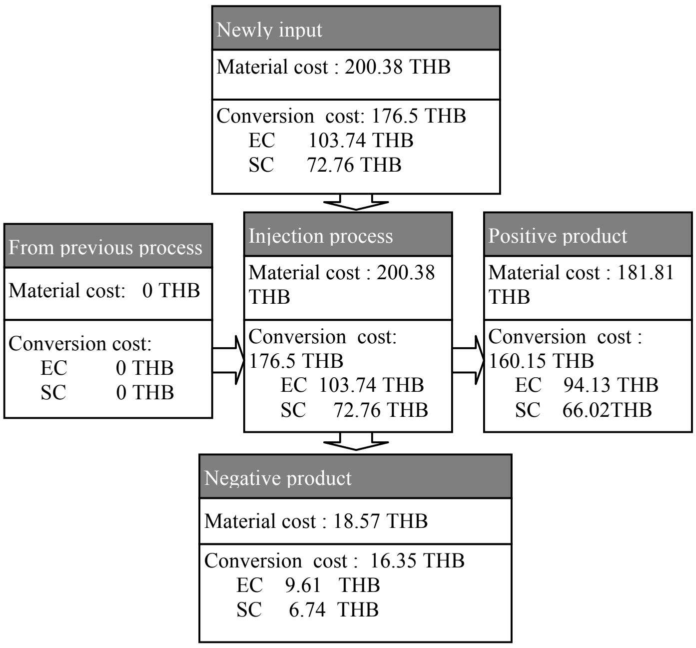

FIGURE 4: COST ALLOCATION FOR INJECTION PROCESS

Costs were allocated for all 14 processes the same way as shown in figure 4. Then costs were summed up from all process as presents in Table 3. From the 100% of the total cost, 66.22 % was made it to positive product while the rest 34.78% became the cost negative product.

TABLE 3: MATERIAL FLOW COST MATRIX

	Material cost	System cost	Energy cost	Total
Positive product	141.06	614.68	1579.27	2335.01
	3.94%	17.17%	44.11%	65.22%
Negative products	321.87	146.27	777.21	1245.36
	8.99%	4.09%	21.71%	34.78%
subtotal	462.93	760.95	2356.49	3580.36
	12.93%	21.25%	65.82%	100.00%

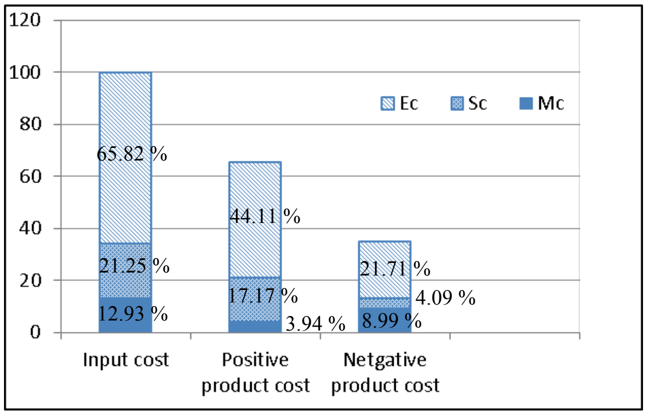

FIGURE 5: OVERVIEW OF MFCA CALCULATION RESULTS

Figure 5 shows the overview of MFCA calculation results. In can be concluded that energy cost has the highest proportion in comparison with system cost and material cost.

V. DISCUSSION

The processes that have highest waste, identified by MFCA, were the shell removal and de-wax processes. The causes of waste were summarised using cause and effect diagram, which leads to improvement of both process as follows

1. *Shell removal process improvement*

In shell removal process, shell was removed from the casted piece by hammer. Shell removed from this process (Figure 6a) is usually discarded. It is possible to grind the shell to the particle size of 0.7-1.0 mm and mix them with sand (Figure 6b). This ceramics mixture can be used again to form outer shell part for the new product as the outer shell only provide the strength to the shell. It does not have any effect on the roughness of the casting workpiece. However, it has not been tested before whether or not these recycled shells can provide enough strength for the outer part of the shell so that the shell do not break when heat is applied.

a) Before grinding b) After grinding

FIGURE 6: SHELL REMOVED FROM SHELL REMOVAL PROCESS

Three shells were form with these recycle materials to prove that they can be used in actual process. After the shells were successfully formed, there were tested in casting process. All three shells were able to pass the process without breaking. This helps to reduce cost of 26.42 THB per one mold. Approximately 167 molds are produced per year. Therefore, this improvement results in cost reduction of 52,594 THB per year. If this recycling material is to be used in long run, grinding machine should be bought. At the cost of approximately 150,000 THB, this grinding machine will breakeven in 3 years.

2. *De-wax process improvement*

De-wax is a process in which heat is applied to the mole to melt away the wax inside. The factory mix this melted wax with the new wax at the ratio of 70:30 and used this mixture for runner part. Runner has no effect on the quality of casted pieces as it only act as channel for molten steel to flow into mold cavities. Therefore, it is possible use mix reclaim wax with higher proportion. The only concern is if the new mixture is able to withstand the weight of the wax patterns attached to it to form wax assemblies. In order to test this, three mixing proportion shown in Table 4. was used to product 3 runners.

TABLE 4: MIXING PROPORTIONS FOR RECLAIMED WAX TESTED FOR RUNNER INJECTION

Workpiece number	Mixing proportion	
	Reclaimed wax	Wax f 20-6
1	100	0
2	80	20
3	70	30

Runner injected with the mixing proportion in Table 3 is shown in Figure 7. As can be seen, all runners have no significant difference visually.

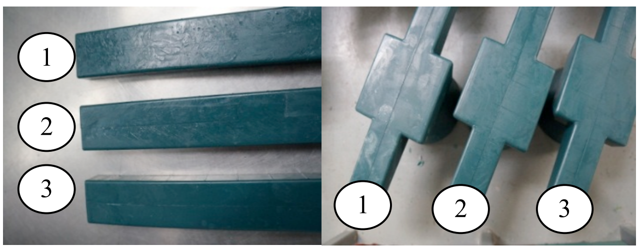

FIGURE 7: RUNNERS INJECTED FROM DIFFERENT RECLAIMED WAX MIXING PROPORTION

All runners were assembled with 120 wax pieces to form wax assemblies and all of them pass the test. Therefore, it is possible to use 100% reclaimed wax instead of 70% currently using.

After the improvements were made in both processes, the cost of 87.95 THB was reduced per one mold.

VI. CONCLUSION

Materials flow cost accounting technique was applied to lost wax process. Starting from visualise the process with materials flow model. Then quantity percentage for positive and negative products of each process were calculated based on materials value. Shell removal and de-wax process has been identified as process with highest negative product cost. Improvements were made to both process which results in less materials input and cost saving.

ACKNOWLEDGEMENT

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REFERENCES

[1] K. Kokubu, “Material flow cost accounting and conventional management thinking: Introducing a new environmental management accounting tool into companies” Interdisciplinary Perspectives on Accounting Conference (IPA), U.K. 11-13 July 2012.
[2] M. Nakajuma, “The new management accounting field established by material flow cost accounting (MFCA)” *Kansai University Rev Bus Commerce*. vol.8, pp. 1-22, Mar. 2006.
[3] K. Kokubu, “Material flow cost accounting in Japan: A new trend of environmental management accounting practices” Fourth Asia Pacific Interdisciplinary Research in Accounting Conference, Singapore, 4 to 6 July 2004.
[4] The international organization for standardization (ISO) “ISO 14051 Environmental management –Material flow cost accounting – General framework” first edition, 2011.
[5] J. Hyršlová, MPJ. Vágner, “Material Flow Cost Accounting (Mfca)–Tool for the Optimization of Corporate Production Processes” *Bus. Manag. Educ.*vol. 9(1), pp.5-18, 2011.
[6] METI Ministry of Economy, Trade and Industry, Japan “MFCA case examples” Available at: http://www.jmac.co.jp/mfca/thinking/data/MFCA_Case_example_e2011.pdf [Accessed 26 February 2013].
[7] M. B. Fakoya1 and B. van der Poll, “The feasibility of applying material flow cost accounting as an integrative approach to brewery waste-reduction decisions” *Afr. J. Bus. Manage,* vol. 6(35), pp.9783-9789, Sep. 2012.
[8] M. B. Fakoya, H. M. van der Poll, “Integrating ERP and MFCA systems for improved waste-reduction decisionsin a brewery in South Africa” J. *Clean Prod,* vol. 40, p.136-140, 2013.
[9] METI Ministry of Economy, Trade and Industry, Japan “Guide for Material Flow Cost Accounting (Ver.1)” http://www.meti.go.jp/policy/eco_business/pdf/mfca%20guide20070822.pdf [Accessed 25 February 2013].

The Application of MFCA in Textile Factory: A Case Study

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Abstract: **The application of material flow cost accounting (MFCA) technique in textile factory aims to present how MFCA plays a role in waste reduction. This study is carried out at one textile factory in Chiang Mai, Thailand as a case study. Following the procedure of MFCA, one type of shirt is selected to be studied. Then, positive and negative costs of each process can be identified starting from cutting, sewing, quality checking, dyeing and buttonhole drilling and packing processes. The results from cost analysis of overall processes show that there are 84.26% of positive cost and 15.74% of negative cost. Focusing on negative cost, the results show that the highest negative cost occurs at cutting process. After that, the quality control tools, Pareto chart and Cause-effect diagram, are used to identify the main source of negative cost at cutting process. Data collection and analysis indicate that there are three sources of the negative cost at cutting process that are material waste from cutting, trimming procedure and otherwise. Waste at cutting process occurs when workers place the shirt pattern on fabric before cutting is carried out. Formerly, the way to place all patterns generate big gap between each piece of pattern. The new procedure is proposed with reducing the gap when placing each pattern. The proposed procedure is tested by pilot lot and the data collection from this pilot lot is used in cost analysis. Again, MFCA procedure is applied and the results show that the positive cost is increased to 92.77% and the negative cost is reduced to 7.23% for overall processes.**

I. INTRODUCTION

Material Flow Cost Accounting (MFCA) is a management tool that can help organizations to better understand the potential environmental and financial effects of their used material and energy, and seek opportunities to gain both environmental and financial improvements.

The concept of manufacturing process improvement commonly concentrates on lead time reduction, waste or defect decreasing, and others which lead to increase productivity of any production line without interpreting the improvement in term of cost or monetary terms that is sometimes difficult for management persons to understanding the improvement results.

During the process of MFCA, material, energy and system costs are analyzed and classified as positive and negative costs. The operations with high negative cost are identified and improvement solutions are provided and implemented to reduce negative costs. Then, the results from improvement in term of cost reduction can be easier understood by management persons. The difference between MFCA and traditional cost accounting was presented in [1].

The applications of MFCA were presented in many research works. Many case studies of MFCA implementation in Japan were also addressed in [2].

For Thailand, MFCA is still not widely known by manufacturers so this research paper aims to present the application of MFCA in manufacturing process improvement of textile industry. One cloth factory in Chiang Mai province, Thailand, is selected to be a case study.

The organization of this paper is addressed as follows; the MFCA concept in section II, the case study in section III, results in section IV and conclusion and recommendation in section V.

II. MATERIAL FLOW COST ACCOUNTING (MFCA)

MFCA is one of the environmental management accounting methods aimed to reduce both environmental impacts and costs at the same time. MFCA seeks to reduce costs through waste reduction, thereby improving business productivity. The detail of MFCA is addressed in many sources and also published as international standard ISO 14051 [3] as well.

Procedures of MFCA implementation [4] are explained here.

1. Preparation

In preparation step, the following activities are carried out;

1.1. Determining target products, lines and processes.

1.2. Performing rough analysis of target processes and determining quantity centers.

1.3. Setting scope of MFCA study as model and period to analyze.

1.4. Determining materials to analyze and the methods of collecting their quantity data.

2. Data Collection & Compilation

There are four tasks in this step as follows:

2.1. Collecting and compiling the data of material types, input and waste quantities in each process.

2.2. Collecting and compiling the data of system (processing) cost and energy cost.

2.3. Determining the allocation rules for system and energy costs.

2.4 Collecting and compiling the data of machine operating status for each process (optional).

3. MFCA Calculation

During this step, MFCA calculation model is established and the collected data are input. The results from this calculation are confirmed and analyzed to indicate negative product costs and their causes by process.

4. Indentifying Improvement Requirement

Requirements for improvement, including material loss and cost reduction, are identified and listed during this step.

5. Formulating Improvement Plans

To set up improvement plan, the following activities should be carried out;

5.1. Examining the extents and possibilities of material loss reduction.

5.2. Calculating and assessing the cost cut effect through material loss reduction (MFCA calculation).

5.3. Determining priorities of improvements and formulating improvement plans.

6. Implementing Improvement

During this step, the improvement plans are implemented in the real situation. Data collection after improvement should be carried out to evaluated each plan in the next step.

7. Evaluating Improvement Effects

In this step, identification of the quantities of input and wasted materials following the improvement is done, and MFCA calculation is carried out again. The overall costs and negative product costs following the improvement are calculated, and used in evaluation of the improvement effects.

III. CASE STUDY

One small textile factory in Chiang Mai province, Thailand, was selected to be a case study. Products of this factory are traditional-style t-shirt, trouser and skirt. The production type is make-to-order. The number of employees is thirty workers from local area.

1. Target Product/ Process

Due to a variety of customer orders, the target product was one traditional style t-shirt as shown in Figure 1 because this product has high frequency and volume of customer orders during the study time period.

FIGURE 1: TARGET PRODUCT.

The production lot size of this product is 100 pieces per lot, so all calculations in MFCA analysis were calculated based on 100 pieces equal to one production lot size.

The operation steps of this product can be presented as Figure 2 starting from order releasing and ending with shipping products to customers.

From Figure 2, target processes were set as production phase including cutting, sewing, quality checking, dyeing & buttonhole drilling and packing processes.

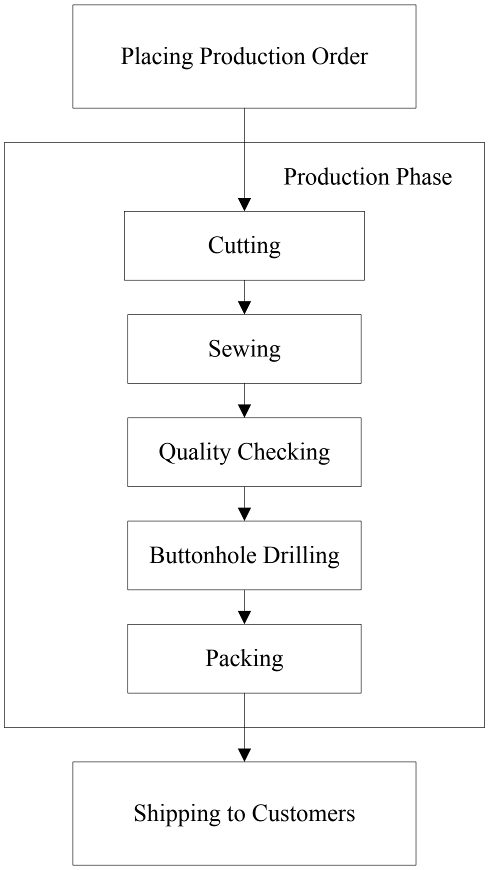

FIGURE 2: TARGET PROCESS FLOW.

2. Detail of Raw Material

To produce the target product, there are five raw materials used as presented in Table 1.

TABLE 1: RAW MATERIAL USED IN TARGET PRODUCT.

Type of Raw Material	
Fabric	Cotton 100 % 2 Ply White Fabric
Sewing Thread	White Cotton 100% Thread
Knitting & Weaving Yarn	White Spun Polyester Yarn
Button	Coconut Shell Button
Packing	Plastic Bags

3. Detail of Machines and Workers

The detail of machines and workers in each production process are presented in Table 2.

The data from the case study were used as input data in MFCA calculation and process improvement following procedures of MFCA implementation presented in section II. The results of this research were presented in the next section.

TABLE 2: MACHINES AND WORKERS IN EACH PROCESS.

Process	Machine	Worker (persons)
Cutting	Handheld Rotary Fabric Cloth Cutter	2
Sewing	1. Sewing Machine 2. Sergers Sewing Machine	14
Quality Checking	Coconut Shell Button	3
Dyeing and Buttonhole Drilling	Outsourcing	
Packing	Iron	10

IV. RESULTS

In this section, the results of MFCA implementation to the case study were presented.

1. Material Flow Model

Figure 3 presented the material flow model of this case study. Main material, cotton 100 % 2 ply white fabric, is firstly input to the production line at cutting process after that it is cut following the pattern shape. During cutting process, fabric rags are identified as material waste. In second process, sewing, there are two new sub materials, cotton tread and spun polyester yarn, input at this step. The third step is quality checking process. The fourth step is dyeing and buttonholes drilling that are outsourcing operation. The last process is final product packing. The finish products are put in plastic bags and ready to be shipped to customers.

2. Cost Calculation

Table 3 showed the cost calculation in quantity centres excluding the 4th process that is the outsourcing process.

From the cost calculation, there were three from four processes having negative cost that included cutting process with 16.36%, sewing process with 6.37% and quality checking with 0.09% comparing with their input cost.

Figure 4 showed the cost allocation of material, system and energy costs by classifying as negative and positive product costs. From this figure, the highest negative production cost ratio was at material cost sector that was 14.43% comparing with other sectors.

Figure 5 showed the cost allocation of input, positive and negative product costs by classifying as material, system and energy costs. From this figure, material cost is the biggest part of all product costs.

From the cost allocation, it can be concluded that the critical point of this production was the part of material cost due to large portion of the negative cost identified.

TABLE 3: MFCA COST ALLOCATION (IN THAI BAHT)
(NOTE: APPROXIMATELY 40 BAHT : 1 €)

1. Cutting Process	Invt. Cost	Newly Input	Output	
			Positive	Negative
Material Cost	-	7924.12	6627.57	1296.54
System Cost	-	84.00	70.26	13.74
Energy Cost	-	4.32	3.61	0.71
Total	-	8012.44	6701.45	1310.99
	100.00%		84.64%	16.36%
2. Sewing Process	Invt. Cost	Newly Input	Output	
			Positive	Negative
Material Cost	6627.57	291.96	6478.82	440.71
System Cost	70.26	2000.00	1938.40	131.86
Energy Cost	3.61	154.08	147.65	10.04
Total	6701.45	2446.04	8564.87	582.61
	100.00%		93.63%	6.37%
3. Quality Checking	Invt. Cost	Newly Input	Output	
			Positive	Negative
Material Cost	6478.82	-	6472.72	6.10
System Cost	1938.40	28.13	1964.67	1.85
Energy Cost	147.65	0.77	148.28	0.14
Total	8564.87	28.90	8585.68	8.09
	100.00%		99.91%	0.09%
4. Dyeing & Buttonhole Drilling Process are outsourcing.				
5. Packing Process	Invt. Cost	Newly Input	Output	
			Positive	Negative
Material Cost	6472.72	219.41	6692.13	-
System Cost	1964.67	112.50	3327.17	-
Energy Cost	148.28	13.83	162.12	-
Total	8585.68	345.74	10181.42	-
	100.00%		100.00%	0.00%

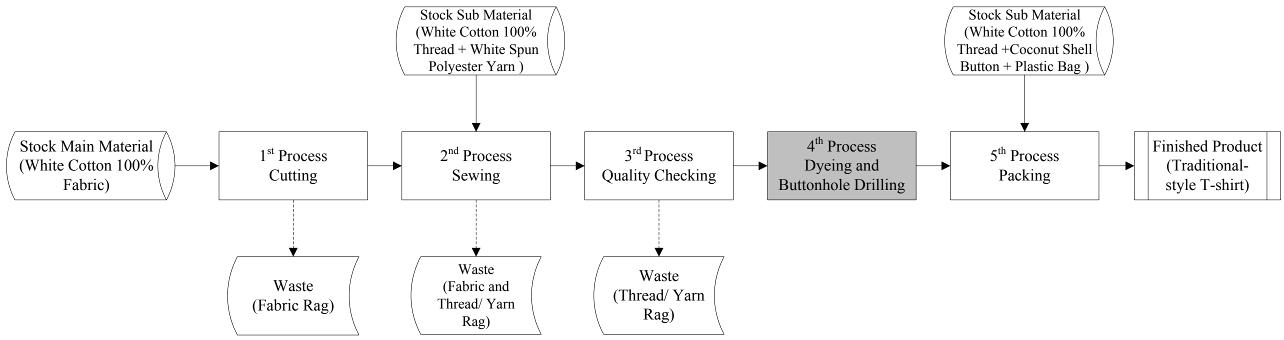

FIGURE 3: MATERIAL FLOW MODEL.

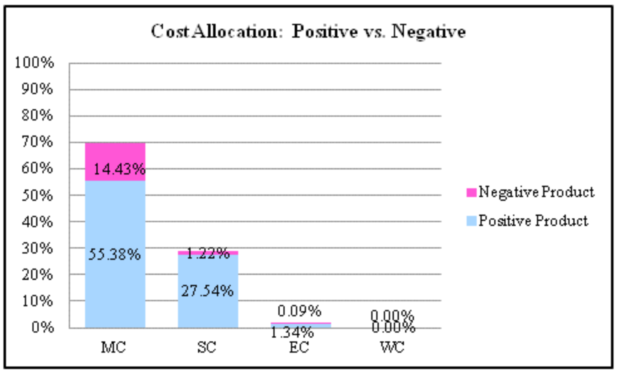

FIGURE 4: COST ALLOCATION POSITIVE VS. NEGATIVE.

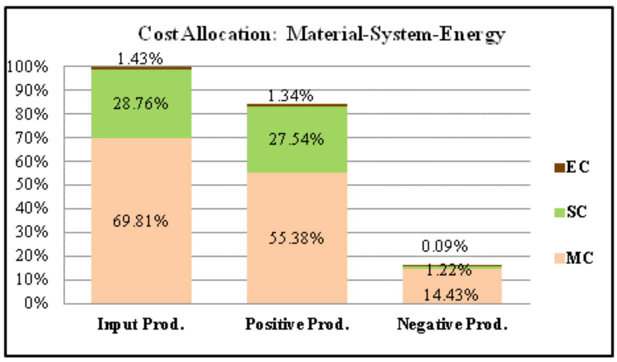

FIGURE 5: COST ALLOCATION MC-SC-EC.

3. *Indentifying Improvement Requirements*

The results of cost allocation showed that the critical point for improvement was the large portion of negative material cost. Negative material cost occurred at three processes as cutting, sewing and quality checking. Table 4 showed the comparison of negative material costs among three processes and the results showed that the highest negative material cost was identified at cutting process.

TABLE 4: PROCESS COST COMPARISON (IN THAI BAHT)
(NOTE: APPROXIMATELY 40 BAHT : 1 €)

Process	Input Material Cost (1)	Waste Cost (2)	Product Cost (3)	(2)/(1) %
Cutting	7,924.12	1,296.54	6,627.57	16.36% **
Sewing	6,627.57	427.91	6,199.66	6.46%
Others	511.37	18.90	6,472.72	3.70%

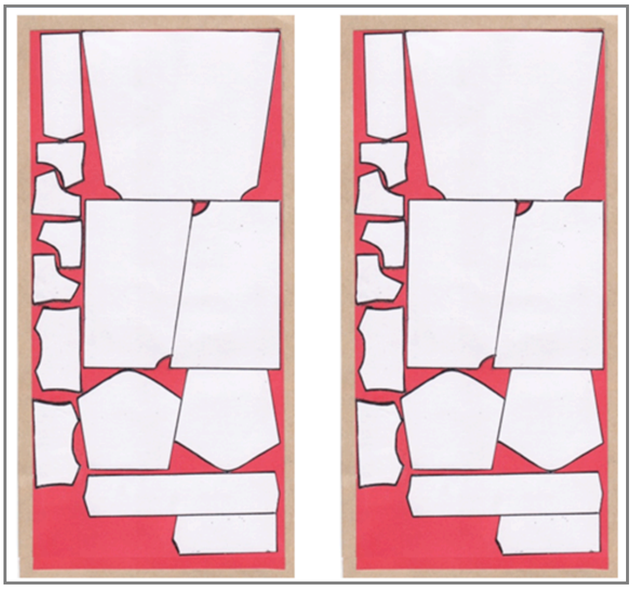

FIGURE 6: LAYING OUT PATTERN PIECES (AS IS).

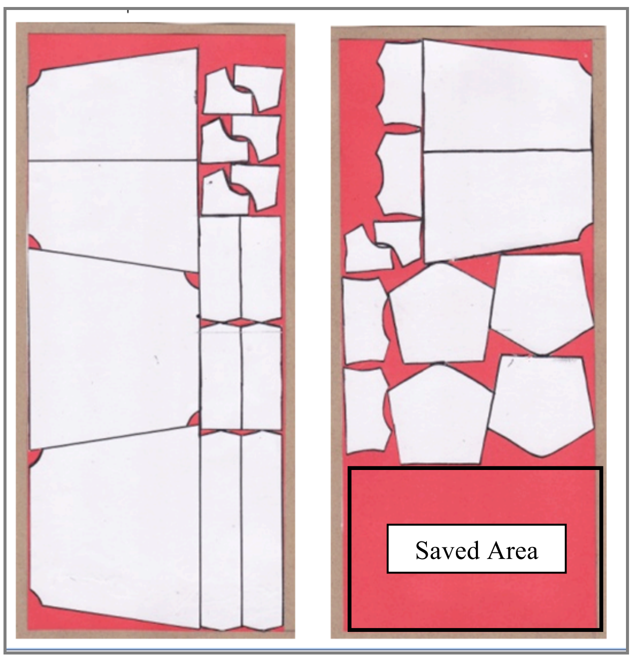

FIGURE 7: LAYING OUT PATTERN PIECES (IMPROVED).

Then, the improvement solution was set at cutting process. The major cause of waste material (fabric rags) occurred when workers performed cutting fabric. The operations in cutting process are firstly preparing fabric, secondly laying out sewing pattern pieces and lastly cutting fabric along designated cutting line. The operation of laying out pattern pieces is the source of fabric rags as shown in Figure 6 because workers are familiar with laying out one time for half body of t-shirt so one t-shirt need two times of laying out pattern pieces.

The improvement solution is to lay out pattern pieces by putting big pieces first and small pieces later as shown in Figure 7. By this procedure, there remains some fabric area that can be saved as the big part as indicated in Figure 7 (saved area).

4. Evaluating Improvement Effects

Then, MFCA calculation was carried out to evaluate the new working procedure in cutting process. The results were shown in Table 5 to 7.

Table 5 showed cost allocation at cutting process after the improvement. Positive cost was increased to 97.07% from 84.64% and negative cost was reduced to 2.93% from 16.36%.

TABLE 5: MFCA COST ALLOCATION AT CUTTING PROCESS (IMPROVED) (IN THAI BAHT)
(NOTE: APPROXIMATELY 40 BAHT : 1 €)

Cutting Process	Invt. Cost	Newly Input	Output	
			Positive	Negative
Material Cost	-	6827.71	6627.30	200.41
System Cost	-	84.00	81.54	2.46
Energy Cost	-	4.32	4.19	0.13
Total	-	6916.03	6713.03	203.00
	100.00%		97.07%	2.93%

TABLE 6: MFCA MATERIAL QUANTITY COMPARISON

		Input Prod.	Positive Prod.	Negative Prod.
As Is		272.40 m^2	213.12 m^2	59.28 m^2
		100%	78.24%	21.76%
To Be		234.71 m^2	213.12 m^2	21.59 m^2
		100%	90.80%	9.20%

TABLE 7: MFCA COST COMPARISON (IN THAI BAHT)
(NOTE: APPROXIMATELY 40 BAHT : 1 €)

	Input Prod.	Positive Prod.	Negative Prod.
As Is	12,083.12	10,181.42	1,901.70
	100 %	84.26%	15.74%
To Be	10,986.72	10,192.52	794.20
	100 %	92.77%	7.23%

Table 6 to 7 showed the results of material quantity and cost comparisons between current and improved situations. For material quantity, the input quantity was reduced from 272.40 m^2 to 234.71 m^2 that had the effect on input product cost decreasing from 12,083.12 to 10,986.72 Baht. The portion of positive product quantity was also improved from 78.24% to 90.80% that had the effect on positive product cost increasing from 84.26% to 92.77%. The portion of negative product quantity was consequently reduced from 21.76% to 9.20% that had the effect on negative cost decreasing from 15.74% to 7.23%.

V. CONCLUSION AND DISCUSSION

This research paper presented the application of MFCA in textile manufacturing as a case study. One textile factory located at Chiang Mai province in Thailand was selected to be studied. Firstly, target product was selected as one type of traditional-style t-shirt (lot size = 100 pieces) and target processes were set as fours process starting from cutting, sewing, quality checking and packing processes. After MFCA calculation, the large portion of negative cost was identified at cutting process. Then, operations study at cutting process showed that laying out pattern pieces step generated the highest portion of material negative cost. The improvement solution was provided to reduce material losses during laying out pattern pieces. New procedure to lay out pattern pieces was proposed by putting large pieces first and small pieces later. This method can help in reducing total negative product cost from 15.74% to 7.23% while reducing input material quantity (fabric) from 272.40 m^2 to 234.71 m^2.

The improve solution presented in this research paper is only one way that is possible to implement to the real working situation without any investment but only adjusting some working operation. There are still other improvement procedures but for some procedure the manufacturer need some investment such as making new pattern pieces with smaller edge width of each pattern piece or invest new cutting table bigger than the current table. When the improved solutions need some investment, the company should think about the return of investment for each alternative as well.

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REFERENCES

[1] M. Nakajima, "On the differences between material flow cost accounting and traditional cost accounting – Reply to the questions and misunderstandings on material flow cost accounting", *Kansai University Review of Business and Commerce*, No. 6, pp. 1-20, March, 2004.
[2] M. Nakajima, "Evolution of material flow cost accounting (MFCA) characteristics on development of MFCA companies and significance of relevance of MFCA", *Kansai University Review of Business and Commerce*, No. 11, pp. 1-20, March, 2009.
[3] *International Standard ISO 14051 First Edition 20011-09-15*, Reference No. ISO 14051:2011(E), www.iso.org
[4] Environmental Industries Office, Environmental Policy Division, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry, Japan, *"Guide for Material Flow Cost Accounting"*, http://www.meti.go.jp/policy/eco_business/index.html

MFCA as an interpretation of a material flow network with a special allocation approach and monetary valuation

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***Abstract*: MFCA is an evaluation of a managerial accounting system where the accounting method is built up on a physical quantity structure, it assesses the energy and material flows in monetary terms, and it carries out a quite specific allocation of the costs. When allocating costs, the MFCA method abstains from simply allocating them to cost units as is normally done in the case of straight cost accounting. In MFCA, costs are also allocated to the undesired output, hence to the wastes or residual materials. This produces a kind of special evaluation revealing the desired potentials for savings. The advantage of this interpretation of the MFCA method is that one is not tied to a monetary assessment. The potentials for saving do not have to be expressed in terms of Dollars or Euros. Any ecological assessment required can also be undertaken. Then the method is used, for example, to calculate what potentials for saving GHG emissions are hidden in inefficient energy and material flows.**

I. INTRODUCTION

The objective of Material Flow Cost Accounting (MFCA) is to determine potentials for saving by avoiding unnecessary wastes, residual substances, emissions – in general all non-productive energy and material flows [1]. The potential savings are expressed in cash terms, for example in Dollars or Euros, because the target group consists chiefly of manufacturing enterprises for whom cost issues are a core controlling factor.

For its calculations, however, the MFCA method needs to record the physical mass flows in a manufacturing company. In this point there is a great similarity with methods of industrial material flow analysis or even Life Cycle Assessments, in which interest is also focused on energy and material flows – though here more for ecological reasons.

MFCA can be interpreted as a special evaluation of a managerial accounting system:

- This accounting method is built up on a physical quantity structure,
- it assesses the energy and material flows in monetary terms, and
- it carries out a quite specific allocation of the costs.

A managerial accounting system that builds on a physical quantity structure is by no means a new method. It has already been described in many articles in the past [2]. The linking to material flow analyses has also been described in many cases [3]. However, a special role is played by the allocation of the costs, or to put it more precisely – the allocation of the effort or expenditure involved in production process [4].

II. BASICS

A central question in cost accounting is how the costs of a production "system" are to be allocated to products, or more precisely to cost units. The "system" can be an individual process, a number of processes or a company, or even a number of companies within a supply chain. The overall system should proceed from the linking of the sub-systems and as far as possible by using the same algorithms. It should be possible to expand the overall system at will and refine or simplify the depth of consideration.

The simplest case of such balancing is when we have one process and one product. All costs of the process then have to be borne by this product (see Figure 1). Various kinds of costs may be incurred – energy and material costs that are supplied from the exterior. These result from multiplying quantity by price. Labour and capital costs that are generally tied to the process are also incurred. In MFCA, these are termed "system costs". The product has to carry all these costs. Consequently the costs of the system are identical with the costs of the product.

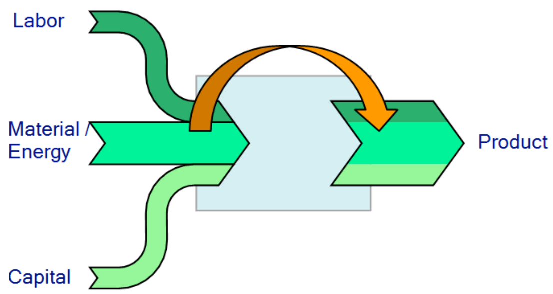

FIGURE 1: COST ALLOCATION IN A SINGLE PRODUCT CASE.

However, even with just two products, matters become difficult. If a process produces two products, there are two possibilities. Either the process can be divided into two processes and thus the cost components can be clearly allocated to the two products. However then we have the case already described – two one-product processes. Then we know which product causes which costs.

Or if this is not possible, we have a joint production process and here allocations become necessary (see figure 2). Extensive literature is available on the question of how costs are to be distributed in such coupling processes which we shall not discuss further here. For the sake of simplicity we can assume that the costs are to be distributed on the basis of the product weight. This corresponds to the customary procedure in an MFCA.

Then too, a single process with two products becomes two one-product processes.

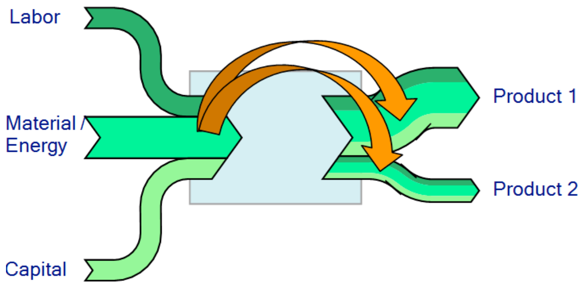

FIGURE 2: COST ALLOCATION IN A MULTI PRODUCT CASE.

This solution is expedient when it comes to passing on costs in a large system consisting of many processes. Each individual process can be identified as a linear activity or a linear technology. Then methods such as Koopmans activity analysis can be applied and the costs can be "routed" through the net. This makes it possible to draw conclusions about the costs of the whole system from the costs of an individual process and to determine the costs of the "system products". These may consist of several products (see figure 3). The accounting is performed by determining the quantity flows in the system and calculating the internal transfer prices of the material flows.

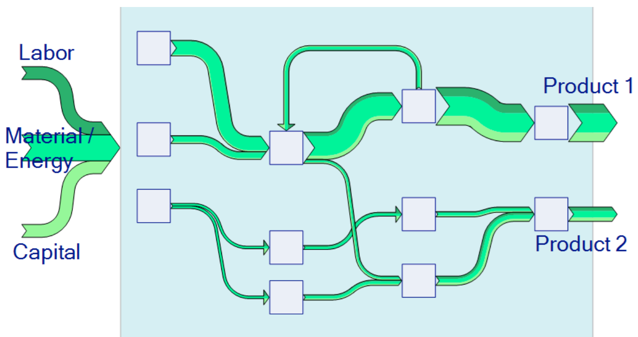

FIGURE 3: EXPENDITURES OF A WHOLE PRODUCTION SYSTEM.

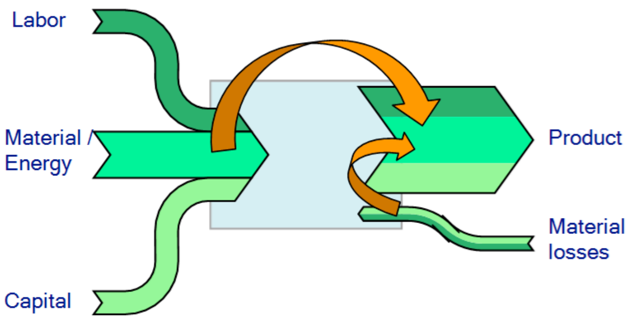

FIGURE 4: COST FLOWS AND NORMAL COST ALLOCATION OF MATERIAL LOSSES TO THE PRODUCT

This already produces a very powerful instrument for considering production structures in a company in detail. Normally in this case costs by material losses and waste treatment etc. are allocated to the product as cost unit (see figure 4). However, it is also possible to take production structures in supply chains into account. Under the aspects of calculation it does not make any difference – real prices are then used in place of the internal transfer prices.

III. MODELLING MFCA AS A JOINT PRODUCTION PROCESS

What does this have to do with MFCA? Material losses such as we know from the MFCA are often not taken into account at all in company cost accounting, or only when their disposal is connected with direct costs. Sometimes these losses or wastes even contribute additional proceeds through sale as secondary raw materials. But these material losses are the origin of inefficiencies.

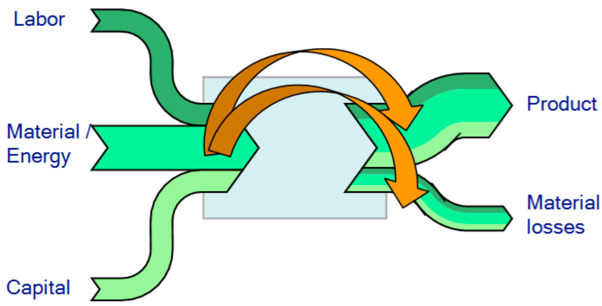

FIGURE 5: COST FLOWS AND THE MFCA-LIKE COST ALLOCATION OF MATERIAL LOSSES

Material losses could be treated as joint products. In other words, the material losses appear as cost units alongside the actual products. The costs of a process are distributed between both the product and the material loss (see figure 5). This is exactly what the MFCA does. All calculating algorithms from classic cost accounting can be applied to MFCA. The advantage lies in the fact that now the upstream costs and the costs of the entire system are divided up between product and material loss. It is then possible to ascertain at each point in the system what added value is lost due to material losses.

IV. EFFORT & BENEFIT GRAPHS AS GENERALISATION

At this point two generalisations make sense.

1.) Instead of costs we can now speak of effort. In the purely economic sense, costs are effort – costs of raw materials, energy, auxiliary materials and operating supplies. However, costs of labour and capital are also effort, which we join together in the MFCA as system costs. Effort is undesirable and we want to minimise it. We allocate this effort to the cost units (normally the products).

However, we can also interpret the effort ecologically. Emissions are the ecological effort of a process, which we also want to minimise and which we also allocate to the product. It is irrelevant whether the effort appears on the input or output side of a process. Only it counts that it is undesirable. CO_2 emissions represent such effort.

2.) Products typically occur on the output side of a production process. However, how do we act if a process (or a company) is there to process an input, e.g. a waste incineration plant or a recycling process? Instead of products we can then speak of benefits. The benefit of a process is desirable. We want to increase it. This may be the quantity of products on the output side, or the quantity of residual materials that we recycle on the input side.

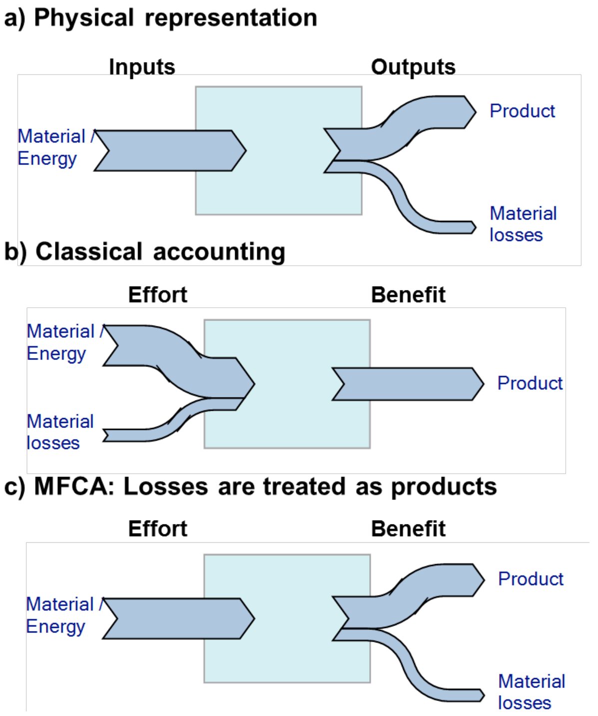

FIGURE 6: CHANGING FROM I/O GRAPHS TO EFFORT/BENEFIT GRAPHS

This results in a new constellation.

We do not consider a process as an entity of inputs and outputs, but instead as an entity of effort and benefit. A more extended production system is no longer shown as a network of input and output processes, but instead as a network of effort and benefit processes. Joint production processes exist when we have a process with several benefits and cannot break it down into any further detail.

What effort and benefit are is decided already at the physical (and not monetary) level. What material flows are desirable (= benefit) and what are undesirable (= effort)? The economic evaluation is only conducted when the quantities are valued with prices in Dollars or Euros. The physical quantities can, however, be evaluated in the same way with GHG emissions. Instead of the prices of purchased materials, the carbon footprint of the purchased materials is used. Instead of the other costs of a process (the system costs comprising labour and capital), the direct GHG emissions of the process are used in the calculations.

In this way the following can be achieved.

- A consistent production system – in-house in the company or within the supply chain – is built up on the quantity basis of material flows.
- It is decided on the physical quantity basis what is effort and what is benefit (what is desirable and what is not?). This defines an internal accounting logic. For any systems – in-company or within a supply chain – it is then possible to determine what system effort is necessary for a system benefit.
- Accordingly, in this quantity-based system the material flows are assessed with prices – and cost accounting results.
- If the assessment is carried out using carbon footprints and emission factors, carbon accounting results.
- In both cases it is then only necessary to take the system costs or the direct emissions into account as well, but this does not present any fundamental problem.
- Supply chain and in-company production differ only in the question of whether internal transfer prices or external market prices are used. The same applies by analogy for CO_2 analyses.

V. MFCA WITH THE NEW APPROACH

MFCA can be calculated simply with this approach. It is practically a special evaluation of normal cost accounting or carbon accounting. The difference lies solely in the fact that the material losses are treated like joint products. In other words, we forget that material losses are undesirable – on the contrary. They are assumed artificially as additional cost units. The effort is then divided between the actual products (or the actual benefit of the system) and the material losses on the basis of a certain allocation formula (e.g. physical quantities, but other criteria are also conceivable). Whether common cost accounting or an MFCA is conducted ultimately depends purely on the simple decision of whether the material loss is to be assumed as effort or benefit, as undesirable or desirable.

The advantage of this interpretation of the MFCA method is that one is not tied to a monetary assessment. The potentials for saving do not have to be expressed in terms of Dollars or Euros. Any ecological assessment required can also be undertaken. Then the method is used, for example, to calculate what potentials for saving GHG emissions are hidden in inefficient energy and material flows. This would be another kind of MFCA: “Material Flow Carbon Accounting”. Or what amount of raw material consumption (MFRA) or water consumption (MFWA) can be saved along the whole life of a product by improving efficiency.

MFCA, MF"CO_2"A or MFRA etc. are here just different forms of the assessment and result from the same physical quantity framework and the same and unique accounting methodology.

VI. CONCLUSION

This results in a concept with which MFCA can be integrated into normal cost accounting approaches as a kind of special evaluation. The advantage of this method lies in the fact that now the potentials of cost accounting can be used too. These concern for example the questions of how to determine internal transfer prices in complex systems, or how to handle recycling systems. In addition an MF"CO_2"A can be built up precisely by analogy with this. The economic and ecological assessments are carried out absolutely parallel as regards the methodology.

There is no problem in generalising or expanding these approaches. Instead of material it would be equally possible to consider energy. Instead of material products it would be possible to consider immaterial goods on the benefit side and thus expand the processes to services. Finally, instead of CO_2 or GHG, it is possible to analyze any other environmental effect provided that it depends in linear function on the material and energy flows in the system via emission factors.

If we embrace the unusual trick of turning material losses into a desired benefit and hence an artificial cost unit, it is possible to evaluate resource efficiency in economic and ecological terms.

ACKNOWLEDGEMENT

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REFERENCES

[1] ISO, *Environmental management — Material flow cost accounting — General framework*. International Standard 14051. Geneve: ISO, 2011.
[2] T. Spengler, *Industrielles Stoffstrommanagement*. Berlin: Erich-Schmidt-Verlag, 1998.
[3] A. Möller, *Grundlagen stoffstrombasierter Betrieblicher Umwelt-informationssysteme*. Bochum: Projekt-Verlag, 2000.
[4] M. Schmidt, "A production-theory based framework for analysing recycling systems in the e-waste sector" in *Environmental Impact Assessment Review,* vol. 25, 2005, pp. 505-524.

Economic-Ecological Optimization by Combining Material Flow Cost Accounting and Life Cycle Assessment

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Abstract: **Resource efficiency is still not mainstream in managerial decision making. Material Flow Cost Accounting (MFCA) combined with Life Cycle Assessment (LCA) can support a more resource efficient decision-making by identifying economic-environmental optimization potentials. MFCA considers economic efficiency with the underlying side-effect of ecological optimization. The focus of LCA is on environmental impacts rather than economic considerations. Hence, it is not self-evident that managers include the results in their decision making. By combining both methodologies, it is possible to identify economic and ecological optimization potentials and support more resource efficient decisions. The present study includes the results of a combined MFCA and LCA study for the production of a wood-based product. For LCA we exemplarily illustrate the results for the Global Warming Potential (GWP). Imminent research will also look at upstream parts of the life cycle. As the functional unit we chose the amount necessary to cover 1 m² of decorative surface. The case study represents a European production facility and firm data of 2010. Over several production steps the roundwood is processed to the wood-based product. Thereby, the by-products wood chips, industrial waste wood, and bark are manufactured as well. The wood chips are further used to produce the heat required to cook and dry the wood product, while the waste wood and bark are sold. The material flow cost results show that the costs are split almost equally between the product and its by-products. The GWP results indicate that the material loss is the main contributor to the GWP. While MFCA focuses on internalized environmental costs resulting from inefficiencies and reprocessing, life cycle assessment can visualize environmental impacts. Thus, a combination of both results can combine the advantages of both methodologies to optimize the use of natural resources, reduce environmental impacts, and increase economic performance. Future studies could further contribute to research by extending the scope of the study to the whole life cycle. Moreover, a broader picture on environmental impacts could be obtained by extending the analysis to other impact categories. The social dimension could be added to the assessment in analogy to the environmental flows in order to perform an overall sustainability assessment, for instance, by measuring impacts on health and safety. In order to support strategic decision making, prioritization approaches could be applied. Future research should further address allocation and internal transfer pricing options which strongly influence the results of the study.**

I. INTRODUCTION

Resource efficiency is still not mainstream in managerial decision-making. Yet, our actions impact our planet in a way that we are reaching the limits to growth and the planet cannot assimilate infinitely the effects caused by anthropogenic activities [1].

Based on a literature review, we conclude that life cycle oriented instruments mainly support decision making in the cleaner production discipline during research and development for capital intense investments or consumer products. As such instruments are not applied broadly in material intense process industries, we present an empirical study for a wood-based product.

For this reason, we present a case study from manufacturing by combining Material Flow Cost Accounting (MFCA) with Life Cycle Assessment (LCA) in order to support a more resource efficient decision making by identifying economic-environmental optimization potentials.

II. INDUSTRY PERSPECTIVE

In Germany, the idea of sustainable forest management can be traced back to the 12th century. The term “sustainability” as it is used today was introduced in 1713 by Hans Carl von Carlowitz for long-term forest management and based on the idea that only as many trees are felled as can grow over the same period [2].

While the supply side of forest products generally follows this principle, in recent years an increased demand for wood biomass for energy use is expected to give rise to increased competition to land use alternatives and alternate uses of wood, in particular the material use of wood [3]. In forest-based industries wood is often the most significant input and cost driver. For instance, in the sawmill industry the wood accounts for up to 65 – 70 % of the total costs, in paper making for more than 30 % [4].

Therefore, the forest-based process industry is looking for new pathways to increase resource efficiency. The present case study is a first step towards supporting a more resource efficient decision making by identifying economic-environmental optimization potentials.

Moreover, the study is motivated by the current developments and standardization efforts with regard to product category rules and environmental product declarations, as well as sustainable building certificates. This study can also serve to improve the cascade use of timber [5].

Hence, the goal of this study is to calculate the MFCA and GWP for a decorative surface and to detect all relevant influencing factors of the economic-environmental performance through the production process. Imminent research will also look at upstream parts of the life cycle.

III. MATERIAL AND METHODS

Material Flow Cost Accounting visualizes material flows in physical and monetary units and differentiates material costs, energy costs, system costs, as well as waste management costs [6]. This methodology considers economic efficiency with the underlying potential side-effect of ecological optimization.

LCA quantifies the material flows and the corresponding environmental impacts of processes, production lines, or services throughout their life cycles in physical units [7, 8]. The focus of LCA is on environmental impacts rather than economic considerations. Hence, it is not self-evident that managers include the results in their decision making.

When both methodologies are combined some peculiarities are to be considered. The inventory as part of MFCA and LCA can be considered as an MFA because it involves system definition and balances [9]. Moreover, LCA studies generally do not cover stock changes. Besides, system flows which are not directly linked to the production process are omitted.

By combining both methodologies, it is possible to identify economic and ecological optimization potentials and support more resource efficient decisions in various corporate compartments, such as accounting, product development, or process optimization.

IV. Study Design and Inventory

1. *Study Design*

The present study includes the results of a combined application of MFCA and LCA for the production process of a wood-based product.

The functional unit is the amount necessary to cover 1 m² of decorative surface. Decorative surface materials are mainly used in furniture and door production as well as in interior construction for the decorative design of a coated particle board or fiber board base [10]. The product system covers three representative wood species, namely ash, oak, and beech.

The case study represents a European production facility and firm data of 2010 as well as background data from the databases Ecoinvent V2.2 and GaBi Lean.

Over several production steps the roundwood is processed to the wood-based product. After procurement the roundwood logs are stored before they are graded and prepared for further processing. During the cooking process the logs are gently heated in water to soften the log, to smoothen the cut and the logs, and to bleach or partly leach the color of some wood species. Afterwards, the logs are further processed, dried to a moisture content of about 12 %, and cut to straighten edges and cut out major defects. Finally, the wood products pass quality management and are prepared for distribution.

Apart from the main wood product, also some by-products result from production, namely wood chips, industrial waste wood, and bark. The wood chips are further used to produce the heat required to cook and dry the wood product, while the waste wood and bark are sold. Figure 1 illustrates the production process on the basis of the roundwood which is the main input to production.

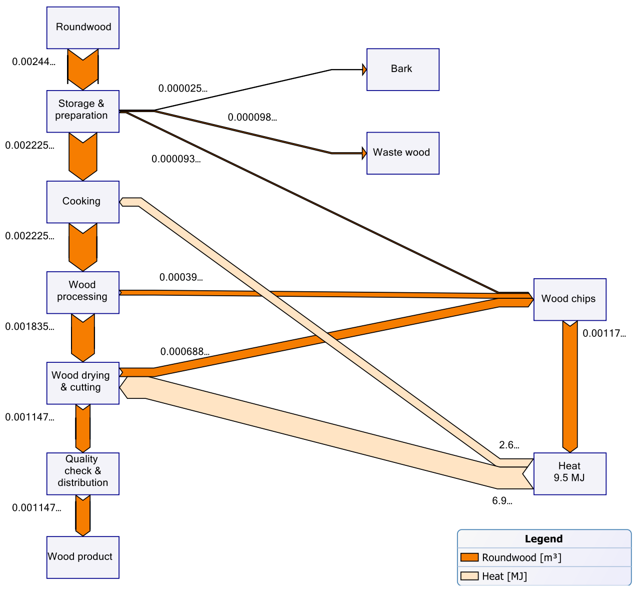

Figure 1: Production Process

2. *Inventory*

Table 1 summarizes the process flows included in this case study. They represent the most significant material, energy, system, and waste management flows. Not included are stock changes as well as costs of labor, depreciation, and maintenance. The waste management flows are given on the input side because they cause costs which have to be allocated adequately to subsequent processes, the product, and by-products.

Table 1: Inventory

Type	Flow
M	Roundwood
M	Diesel, refinery
E	Electricity, medium voltage, produktion RER, grid
E	Heat, natural gas, industrial furnace, > 100 kW
E	Heat, hardwood chips (industry), furnace 1000 kW
S	Liquefied petroleum gas
M	Lubricating oil
M	Power sawing (saw chain, gasoline, heavy fuel oil, lubricating oil)
M	Steel
WM	Wood ash
WM	Steel scrap
Abbreviations: Material (M), Energy (E), System (S), Waste management (WM), Carbon dioxide equivalent (kg CO2e)	

The wood product is produced from about twenty different wood species. However, the present study encompasses the three main species used, namely ash, beech, and oak. During storage and preparation the logs are transported within the log yard by forklifts which consume diesel. Electricity is consumed in all processes; it is allocated to each process step on the basis of company estimates. Heat is required for the cooking and drying processes. Most of the heat is produced from the by-product wood chips, while natural gas serves as a reserve. The heat is allocated to both processes based on the processing time. Liquefied petroleum gas is consumed during the indoor transport with forklifts. Lubricating oil and power saws are required during the log preparation. Steel bands and steel clips are used during the cooking process to hold the logs. A major part of the steel is recycled. The wood ash is a residue of the wood chips from the furnace.

V. Results

We first present the material flow balance, before summarizing the results for the MFCA and LCA. For LCA we illustrate exemplary the Global Warming Potential (GWP). A broader picture could be obtained by extending the analysis to other impact categories.

1. *Material Flow Balance*

The most import input flows are steel and diesel (by mass), water, recycled waste water and wood (by volume), as well as heat and electricity (by energy).

The material flow balance in Table 2 indicates that half of the roundwood enters the wood product. The other half represents the by-products wood chips, industrial residue wood, and bark. This indicates that the present case study is an example for a resource intense industry with an internal material recycling quota of about 50 %.

TABLE 2: MATERIAL FLOW BALANCE

Input flows		Output flows	
Energy	11.599 MJ	Wood product	0.0011 m³
Material	2.0799 kg	Wood by-products	0.0013 m³
System	0.0041 kg	Material loss	0.0143 kg
Waste management	0.0243 kg		

2. *MFCA results*

The costs of each process are allocated to the product and by-products on the basis of mass allocation, i.e. the case study represents a co-production process.

The heat from the wood chips involves an internal material cycle. In line with [6], the corresponding costs are calculated by subtracting the cost savings of the internal recycling in terms of the purchase price of the roundwood from the sum of the accumulated material flow costs and the related waste management costs. The total material flow costs, including the allocation of the heat costs from the wood chips, are calculated in a second iteration.

The main cost contributors include the roundwood, electricity, and heat from the wood chips. The material flow cost results in Table 3 show that the costs are split almost equally between the product and its by-products. The by-products industrial residue wood and bark are sold for a low revenue, which is accounted for in the MFCA.

TABLE 3: MATERIAL FLOW COST BALANCE

Input flows		Output flows	
Energy	0.0774 EUR	Wood product	0.3523 EUR (0.7282 EUR)
Material	0.6490 EUR	Wood by-products	0.3762 EUR (-0.0001 EUR)
System	0.0021 EUR	Material loss	0.0007 EUR
Waste management	0.0007 EUR		
Total	**0.7292 EUR**		**0.7292 EUR**

Annotation: The costs in brackets are the costs calculated by conventional cost accounting.

As shown in Table 3, material flow costs differ significantly from conventional cost accounting. In conventional cost accounting costs are allocated completely to the product, whereas MFCA allocates costs also to by-products and material losses. In this way, MFCA better traces material flows and indicates inefficiencies and material losses. [6]

3. *LCA exemplary for GWP*

The main emissions contributing to GWP result in particular from the processes drying, cooking, wood processing, and storage. These emissions arise from emissions to air, in particular from biotic carbon dioxide and other carbon dioxide, followed by methane and nitrous oxide.

The GWP is allocated analogously to MFCA on the basis of mass between the product and by-products. The internal material cycle is accounted for by subtracting the saved GWP of replaced wood chips from GWP of the wood chips accumulated during the production process.

In contrast to MFCA, the material loss (steel scrap, wood ash) is the main contributor to the GWP.

TABLE 4: GLOBAL WARMING POTENTIAL BALANCE

Input flows		Output flows	
Energy	12.7796 kg CO2e	Wood product	7.5922 kg CO2e
Material	0.5470 kg CO2e	Wood by-products	5.7648 kg CO2e
System	0.0304 kg CO2e	Material loss	12.7301 kg CO2e
Waste ma-nagement	12.7301 kg CO2e		
Total	**26.0871 kg CO2e**		**26.0871 kg CO2e**

VI. Discussion of Results

When comparing the above results it can be shown that impacts do not solely result from the wood product and its by-products, but also the material losses contribute significantly.

Thus, a combination of the results focuses on the advantages of the methodologies to optimize the use of natural resources and reduce environmental impacts.

The material flow balance already visualizes significant production inputs and can indicate if a resource intense production is at hand. MFCA can demonstrate internalized environmental costs as well as costs resulting from inefficiencies and reprocessing. LCA shows significant environmental impacts.

VII. Conclusion

The goal of the study was to demonstrate the advantages of assessing material flows with their related costs and environmental impacts. We could show the advantages of this multidimensional approach on the basis of MFCA and LCA. On the basis of this approach, organizations can identify economic-environmental optimization potentials and support more resource efficient decisions.

Future studies could further contribute to research by extending the scope of the study to the whole life cycle. In this way, it is possible to combine MFCA with Life Cycle Costing [10]. Moreover, a broader picture on environmental impacts could be obtained by extending the analysis to other impact categories. A social dimension could be added to the assessment in analogy to the environmental flows in order to perform an overall sustainability assessment, for instance, by measuring impacts on health and safety. In order to support strategic decision making, prioritization approaches could be applied. Future research should further address allocation and internal transfer pricing options which strongly influence the results of the study.

References

[1] Randers, J., 2012. 2052: A Global Forecast for the Next Forty Years. Chelsea Green Publishing.

[2] von Carlowitz, H.C., von Rohr, J.B., Jurist, W., von Carlowitz, H.C., von Carlowitz, H.C., von Rohr, J.B., von Rohr, J.B., 1732

[3] Köhl, M., Frühwald, A., Kenter, B., Olschofsky, K., Köhler, R., Köthke, M., 2009. Potenzial und Dynamik der Kohlenstoffspeicherung in Wald und Holz: Der Beitrag des deutschen Forst-und Holzsektors zum Klimaschutz. Tagungsband zum Symposium Waldstrategie 2020 des BMBELV. Landbauforschung vTI Agric.For.Res, 103-110

[4] European Commission, 05/02/2013. Wood, Paper, Printing - Renewable energy and the Forest-based Industries. 28/02/2013

[5] Arnold, K., von Geibler, J., Bienge, K., Stachura, C., Borbonus, S., Kristof, K., 2009. Kaskadennutzung von nachwachsenden Rohstoffen. Wuppertal Papers. WP180

[6] DIN Deutsches Institut für Normung e.V., 2011. Environmental management – Material flow cost accounting – General framework (ISO 14051:2011); German and English version EN ISO 14051:2011

[7] DIN Deutsches Institut für Normung e.V., 2006. Environmental management – Life cycle assessment – Principles and framework (ISO 14040:2006); German and English version EN ISO 14040:2006

[8] DIN Deutsches Institut für Normung e.V., 2006. Environmental management – Life cycle assessment – Requirements and guidelines (ISO 14044:2006); German and English version EN ISO 14044:2006

[9] Fischer-Kowalski, M., Krausmann, F., Giljum, S., Lutter, S., Mayer, A., Bringezu, S., Moriguchi, Y., Schütz, H., Schandl, H., Weisz, H., 2011. Methodology and Indicators of Economy□wide Material Flow Accounting. J. Ind. Ecol. 6, 855-876

[10] Institut für Holztechnologie gGmbH, 2010. IHD-Güterichtlinie für Dekorfinishfolien

[11] Viere, T., 2010. Methodische Behandlung interner Materialkreisläufe in der Materialflusskostenrechnung. uwf UmweltWirtschaftsForum. 3-4, 203

Effects of Quality Levels, Lot Size, WIP and Product Inventory to MFCA Cost-based throughout Supply Chain

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Abstract: **This paper apply the Material Flow Cost Accounting (MFCA) technique to quantify the total manufacturing cost of the whole supply chain by considering the material cost together with the system cost, energy cost and waste treatment cost incurred. Nowadays, parts and subcomponents are produced globally and shipped to various production sites. The allocation of inventory and the design of the supply chain model are very crucial to business continuity and success. The Economical Production Quantity (EPQ) or lot size that accounts for the transportation cost is considered. This paper studies an effect of the quality levels, lot size, work in process and stock supply inventory throughout the supply chain on the total cost calculated based on MFCA. This paper aims to concurrently design supply chain model by determining both the optimum production lot sizes of each unit and the transportations of the whole or partial lot such that the total manufacturing cost defined as the total positive cost of MFCA is maximized. This paper addresses another usefulness of the MFCA technique which that can be used to design the supply chain model and logistics management that yields the lowest total cost and highest positive product cost.**

I. INTRODUCTION

This paper apply the Material Flow Cost Accounting (MFCA) technique to quantify the total manufacturing cost of the whole supply chain by considering the material cost together with the system cost, energy cost and waste treatment cost incurred. Consider a supply chain model consisting of N stages which stage N represent an end user with demand of d units per year. The raw materials and components are produced and transported to the next stage for further processing as defined by its process flow chart. The production rates at each stage is defined by the processing time per unit; the cycle time of the production line. Unlike the serial production process that can be designed with balance such that the continuous flow can be obtained, the production rate of each unit in the supply chain can be different depending on their operation management strategy and business size. The allocation of inventory and the design of the supply chain model are very crucial to business continuity and success. Nowadays, parts and subcomponents are produced globally and shipped to various production sites. The manufacturer often store inventory to increase the service level of satisfying the customer as well as to cope with their product quality fluctuation. The finished product of a stage i^{th} is stored as inventory at the next stage, $i+1^{th}$, of the supply chain. The amount of this inventory type called supply chain stock will depend on the frequency and lead time from transporting the produced lot from the stage i^{th} to $i+1^{th}$. These inventories are defined as the work in process (WIP) *within the supply chain unit*. The more frequency of transporting the produced lot can lead to reduction of the WIP *within the process* but the transport cost can be increased. The frequency of the transportation within the supply chain units usually depend on the production lot size. The larger the lot size, the less frequent the transportation. This research is interested in determination of an Economical Production Quantity (EPQ) or lot size that accounts for the manufacturing cost, transportation cost and holding costs of inventories.

The traditional total manufacturing cost consists of the cost of material, cost of setup and production, cost of handling of the WIP and the finished product. Since the quality performance along the supply chain may not be perfect, the cost of handling WIP and the finished product can be categorized into positive and negative part according to the MFCA concept. This paper studies an effect of the quality levels, lot size, WIP and product inventory throughout the supply chain on the total cost calculated based on MFCA. This paper aims to concurrently design supply chain model by determining both the EPQ of each unit and the transportations of the whole or partial lot such that the total manufacturing cost defined as the total positive cost of MFCA is maximized. This paper addresses another usefulness of the MFCA technique which can be used to design the supply chain model. Section II presented literature reviews of the EPQ, the supply chain model and the application of MFCA in supply chain. Section III provides the mathematical representation of the problem whose numerical results and example are given in Section IV. The conclusion is given in Section V.

II. LITERATURE REVIEW

The MFCA is one of an important environmental management accounting tool which can be used to improve a manufacturing operation. The MFCA results in an identification of the loss and waste. Then the strategy of reducing the negative product can be formulated [1]-[6]. [7] presented an application of the MFCA in supply chain using simulation model to evaluate the supply chain performance based on MFCA concept. The result from the simulation model indicates a reduction of the production lead time, delayed orders and the WIP inventory. The improved conditions are resulted from decision making model without showing an explicit mathematical representation of the problem in terms of the EPQ, lot size, quality levels to the MFCA cost. The explicit calculation of total manufacturing cycle time, EPQ with transportation of constant sub-batches can be found in [8]-[9] and with varying number of sub-batches across all stages can be found in [10]-[13]. The lot size is still held constant and equal across all stage except in [11]. [14] provides excellent comprehensive review on lot sizing and [15] studied and derived some optimality properties of solution for a uniform lot size with uninterrupted an assembly-type series production supply chains. So topics of unequal lot sizes and quality levels across all stages have not been considered. [16]-[17] presented methodology on EPQ accounting for the quality levels with restricted to a single stage production. None of the works has addressed the cost in terms of MFCA concept. There is a need of designing the supply chain with considering the inventory but the logistics and transportation between units were not addressed. Therefore this paper provides a methodology to concurrently design supply chain model by considering EPQ for non-uniform lot sizes, WIP and transportation of sub-batches of varying number across all stages, as well as quality levels based on the MFCA technique. The objective function is to maximize the positive cost of the MFCA cost as in [7].

III. METHODOLOGY

1. Supply Chain and Production Modelling

First, consider the production and the cost variables of a presumed serial supply chain model in Figure 1 with the customer demand of d units per unit time, i.e., year.

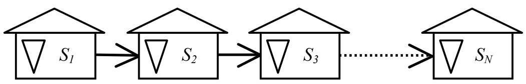

FIGURE 1: SUPPLY CHAIN MODEL.

For any stage i^{th}, let d_i, Q_i, P_i, l_i, f_i, b_i, s_i, I_i, h_i, MC_i, SC_i, EC_i, WC_i represent the adjusted production demand, production quantity/lot size, production rate, cycle time, quality level or fraction of defective of a process, number of transportation of sub-batch, setup cost, amount of supply chain stock inventory, holding cost/unit*time, unit material cost, unit system cost, unit energy cost and unit waste treatment cost. When six sigma quality levels is not installed, the production demand d must be propagated upstream for each supply chain unit to compensate for the discarding of defective product practically at the end of the production line. For example, consider the last supply chain unit, the N^{th} stage, with fraction of defective of 20%, $f_N = 0.2$. The manufacturer has to start the production with 150 units which later will be checked for quality and resulted in 120 conforming products. So $d_i = d \Big/ \prod_{j=i}^{N} \left(1 - f_j\right)$. This is different from the case of variable, non-constant/non-uniform lot size across all stage as in [11] since the demand are different among stages. Note that the output from the production of d_i units will be inspected for quality. The production rate (of conforming unit) is $P_i = \left(1 - f_i\right)/t_i \geq d_{i+1}$ and, in order to minimize the WIP, the final output is set to equal the d_{i+1}. Similar to Lean manufacturing concepts, this paper assumes that the supplier quality management program has been installed throughout the supply chain. So, the submitted lot of an intermediate product once received from upstream unit can be immediately processed without having gone through non-value added process of re-inspection/screening. Given an adjust production demand d_i the manufacturer is interested in determining the EPQ, Q_i, to minimize the production cost of the whole supply chain. This research defined the lot size of conforming output at each stage is defined as $Q_i\left(1 - f_i\right)$. We also assume the lot size is uniform between two connected stage, $Q_i\left(1 - f_i\right) = Q_{i+1}$, unlike the uniform lot size across all stages as in [10,12,13,14]. Note that this condition leads to the constant lot size, i.e., [12] if there is no removal of negative product/defective at each stage.

In order to shorten the manufacturing and logistics lead time, each production lot of conforming product of size $Q_i\left(1 - f_i\right)$ can be divided into b_i partial lot/sub-lots/sub-batches of size $Q_i\left(1 - f_i\right)/b_i$. Once the formation of the sub-batch is completed and available for shipment, it will be transported to the downstream supply chain unit with transport cost of T_i. This transport cost will be added to the energy cost of the unit i^{th}. This paper does not impose any logistics constraint, i.e., truck load or minimum load. According to the geographical distance between supply chain unit, this paper assumed the lead time of a sub-batch is an integer multiple of the sub-batch formation interval, $r_i Q_i / P_i b_i : r_i \in \bullet^{+}$. Therefore, each supply chain unit must hold buffer stock of minimum size $Min\, I_i$ during replenishment interval: the transportation of a sub-batch of size $Q_i\left(1 - f_i\right)/b_i$ from unit i^{th} to $i+1^{th}$. The smaller the size of the sub-batch, the more frequent the transportation which leads to potentially less buffer stock and inventory cost. However the logistics cost can be significantly increased. The total manufacturing cost of an end product is determined using MFCA technique based on the material flow model shown in Figure 2.

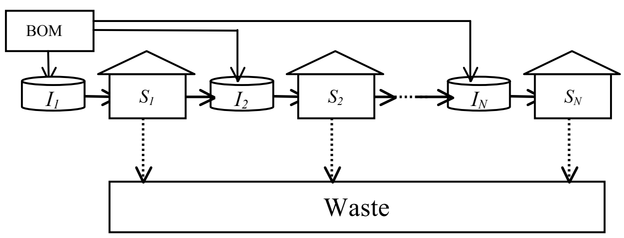

FIGURE 2: MATERIAL FLOW MODEL OF THE SUPPLY CHAIN.

2. MFCA Cost Modelling

Second consider the cost elements for the supply chain based on the MFCA technique. For a given product, the Bill of Material (BOM) information is used to determine the amount of newly input materials and the material based on the MFCA technique. For a given product, the Bill of Material (BOM) information is used to determine the amount of newly input materials and the material costs. So, this paper simply defines the material cost as the material cost per unit produced, the MC_i. Likewise one can get the manufacturing cost, the system and overhead and the energy expenses from the accounting. Likewise we define SC_i and EC_i in term of cost per unit produced. The newly input cost is the sum of the newly input of material, system and energy cost and waste treatment cost. The newly input material cost of a unit is the product of the adjusted production demand and the unit material cost, $d_i * MC_i$. The newly input of the energy is defined as $d_i * EC_i$ plus transportation cost $(d_i/Q_i)b_i * T_i$. Likewise, the newly input of the waste treatment cost is defined as $d_i f_i * WC_i$. The newly input for the system cost consists of (a) manufacturing and inspection costs which equal to $d_i * SC_i$ and (b) the holding costs of the inventories of two types; the WIP and the buffer stock.

The buffer stock of the stage i^{th} was defined as a separated quantity centre with only holding cost is added through the MFCA structure as system cost. The buffer size depends on the production rate of the two connected supply chain units. If $P_{i-1} > P_i$, the minimum size of buffer at stage i^{th}, $Min\, I_i = r_{i-1}Q_{i-1}(1-f_{i-1})/b_{i-1}$. When $P_{i-1} < P_i$, the $Min\, I_i$ depends on the logistics policy and management. This paper assumed that the transportation of a sub-batch will not cause any production interruption of the next unit when there is no buffer. This assumption assures that the next unit will continue the production once it is started. In practice, there is infeasible and uneconomical for a manufacturer to have interrupted production process. Therefore, based on the time-weighted inventory scheme, $Min\, I_i = (Q_{i-1}/P_{i-1} + Q_{i-1}(1-f_{i-1})/P_i b_{i-1} - Q_i/P_i)P_{i-1} + r_{i-1}Q_{i-1}(1-f_{i-1})/b_{i-1}$ $= Q_{i-1} + Q_{i-1}(1-f_{i-1})(P_{i-1}/P_i + r_{i-1})/b_{i-1} - Q_i P_{i-1}/P_i$. Therefore,

$$\begin{aligned} Min\, I_i &= r_{i-1}Q_{i-1}(1-f_{i-1})/b_{i-1} \quad : P_{i-1} > P_i \\ &= Q_{i-1} + Q_{i-1}(1-f_{i-1})(P_{i-1}/P_i + r_{i-1})/b_{i-1} - Q_i P_{i-1}/P_i \quad : P_{i-1} < P_i. \end{aligned} \tag{1}$$

The time-weighted buffer inventory at stage i^{th}, $Avg.Buffer_i^{TW}$, for one production cycle is approximated as

$$Avg.Buffer_i^{TW} = Min\, I_i * Q_i/P_i \tag{2}.$$

The holding cost of the buffer is the product of the average of buffer inventory and the holding cost.

For one production cycle, the WIP within each supply chain unit also contribute to the cost of holding inventory. The WIP depends on Q_i , f_i and b_i. The cost of holding WIP is the product of the time-weighted WIP inventory (WIP_i^{TW}) and the holding cost. The formulae of time weighted inventory from [8]-[9], [11]-[13] is extended to account for the quality level and is defined for one production cycle as

$$WIP_i^{TW} = (Q_i(1-f_i))^2\left(\frac{1}{b_i \max\{P_i, P_{i+1}\}} + \frac{1}{2}\left|\frac{1}{P_i} - \frac{1}{P_{i+1}}\right|\right) \tag{3}.$$

Next consider the MFCA for the whole period, i.e., one year. At a given stage i^{th}, the total newly input (TC_i^{NI}) is the sum of the total newly input material cost (TMC_i^{NI}), total newly input system cost (TSC_i^{NI}), total newly input energy cost (TEC^{NI}) and total newly input waste treatment cost (TWC_i^{NI}) and is defined as

$$\begin{aligned} TMC_i^{NI} &= d_i MC_i \\ TSC_i^{NI} &= d_i SC_i + \frac{s_i d_i}{Q_i} + \frac{h_i d_i}{Q_i}\left[Avg.Buffer_i^{TW} + WIP_i^{TW}\right] \\ TEC_i^{NI} &= d_i EC_i + \frac{d_i}{Q_i} b_i l_i \\ TWC_i^{NI} &= d_i f_i * WC_i . \end{aligned} \tag{4}$$

The total newly input (TC^{NI}) is the sum of the total newly input material cost (TMC^{NI}), total newly input system cost (TSC^{NI}), total newly input energy cost (TEC^{NI}) and total newly input waste treatment cost (TWC^{NI}) and is defined as

$$\begin{aligned} TC^{NI} &= TMC^{NI} + TSC^{NI} + TEC^{NI} + TWC^{NI} \\ TMC^{NI} &= \sum_{i=1}^{N} TMC_i^{NI} = \sum_{i=1}^{N} d_i MC_i \\ TSC^{NI} &= \sum_{i=1}^{N} TSC_i^{NI} = \sum_{i=1}^{N} d_i SC_i + \frac{s_i d_i}{Q_i} + \frac{h_i d_i}{Q_i}\left[Avg.Buffer_i^{TW} + WIP_i^{TW}\right] \\ TEC^{NI} &= \sum_{i=1}^{N} TEC_i^{NI} = \sum_{i=1}^{N}\left(d_i EC_i + \frac{d_i}{Q_i} b_i l_i\right) \\ TWC^{NI} &= \sum_{i=1}^{N} TWC_i^{NI} = \sum_{i=1}^{N} d_i f_i WC_i . \end{aligned} \tag{5}$$

To compute the positive cost, we use the allocation by fraction of defective. The (cumulative) positive cost (PC), at stage i^{th} is calculated as

$$PC_i = (1-f_i)\left[PC_{i-1} + TMC_i^{NI} + TSC_i^{NI} + TEC_i^{NI}\right] \tag{6}$$

where $PC_0 = 0$. When defective product is not removed from each stage, the adjusted demand are equal for all units, $d_i = d\Big/\prod_{j=1}^{N}(1-f_j)\ \forall i$. Also the time-weighted WIP inventory in (1) is reduced to the traditional formula provided by [12]. The negative cost (NC) can be obtained similarly.

3. Optimization Model

This research is aims to optimize the positive cost of the finished product. We posed no restriction on the sub-batch sizes, i.e., the geometric series pattern, even though it can lead to less WIP. Nonetheless, the unequal sub-size batch is not technically and managerially feasible yet increasing the logistics planning complexity. With defective product removed from each supply chain stage, the constrained optimization model is defined as

$$\begin{aligned} Max \quad & PC_N \\ s.t. \quad & Q_i\left(1-f_i\right)=Q_{i+1} \\ & \left(1-f_i\right)/t_i \geq d_{i+1} \end{aligned} \tag{7}$$

$$r_i, Q_i, b_i \in \bullet^{+},\ 0 \leq f_i < 1,\ t_i > 0\ \forall i\ .$$

When there is no product removal, the optimization model becomes unconstrained with constant lot size. In general, the lot size Q_i need not be constant.

IV. NUMERICAL RESULT

Consider a supply chain consisting of 4 stages where raw material was produced by a plant in China with production rate of 222,2222 units/year. This raw material will be first processed into bulk material, i.e., ingot by a production plant, defined as stage 1, in Thailand and sent to another nearby subsidiary manufacturing plant for shape forming process. Then it was sent to a joint venture plant for reinforcing and heat treatment processes. The last stage is the assembly process which has to satisfy demand of 50,000 pieces per year. The production and cost variables are shown in Table1. All monetary units are in Thai currency unit, Baht.

TABLE 1: THE PRODUCTION AND COST VARIABLES OF

Variables	Stage1	Stage2	Stage3	Stage4
P_i	600,000	85,714	400,000	250,000
f_i	5%	5%	5%	5%
s_i	2,000	3,000	1,000	1,500
l_i	1,000	1,200	1,200	1,500
h_i	1	1	1	1
r_i	1	1	1	1
IMC_i	4	4.2	4.4	4.6
SC_i	2	2	2	2
EC_i,	1.5	1.6	1.7	1.8
WC_i	0.5	0.5	0.5	0.5

Assume there is no defective product removal from stage. Without loss of generality, consider the case where production lot size Q_i is assumed to be constant with possible values of 1,000, 5,000, 10,000, 20,000, ..,50,000 units. For managerial purpose, the transportation is restricted to either transporting the whole lot or a half lot, $b_i = 1,2\ \forall i$ including the raw material whose transportation cost is included into the raw material price. Moreover the size of the transported material is equal to the production lot size. To reduce the stock of material supply at stage 1, it's economical divide each lot of raw material into half and transported half lot each time.

The optimal solution was found with the positive cost of 2,318,116 Baht per year with the total cost of 2,782,679 Baht which is about 83.30%. Table 2 shows optimal solution in terms of the EPQ, the optimal number of transporting the sub-batch, the time-weighted WIP and minimum supply stocks and the costs. Note that the material supply stock at stage 1 is high since the production capacity of the raw material is less than that of the usage demand at stage1. Then large supply stock is needed to assure uninterrupted production. This is the same at stage3 where large supply material stock is needed. So the needs to allocate the inventories within the supply chain are necessary. The optimal solution shows that it's most economical to transport sub-batches between bulk material forming plant, the shape forming plant and the joint venture plant. It's more economical to transport the whole production at a time among the reinforcing and heat treatment plant, the assembly plant and the customer. This design of the supply chain model and logistics management is proven to yield the lowest total cost and the highest positive product cost.

TABLE 2: THE OPTIMAL SOLUTION

Variables	Stage1	Stage2	Stage3	Stage4
WIP_i^{TW}	333	2,333	700	4,800
$Min\, I_i$	25,611	9,500	27,250	19,000
EPQ	20,000			
b_i	2	2	1	1
Holding cost				
WIP_i^{TW}	1,322	9,256	2,777	19,041
$Min\, I_i$	3,387	8,793	5,405	6,030
Transport cost	7,934	4,760	4,760	5,950

The material flow cost matrix in Table 3 indicates that the optimal solution yields a maximum of 83% positive product and 17% of negative product. The total cost of the whole supply chain for one year production is 2,782,680 Baht or equivalent to 55.65 Baht per unit. This solution will be used for management strategy planning for the wire woven mesh business.

TABLE 3: THE MATERIAL FLOW COST MATRIX

Cost	Stage1	Stage2	Stage3	Stage4	**Total**
Positive	583,133 *21%*	1,171,858 *42%*	1,738,706 *62%*	2,318,116 *83%*	**2,318,116** *83%*
Negative	70,361 3%	101,346 4%	131,180 5%	161,676 6%	**464,563** 17%
Total	653,494 23%	690,072 25%	698,028 25%	741,086 27%	**2,782,680**

V. CONCLUSION

Nowadays, parts and subcomponents are produced globally and shipped to various production sites. Unlike the serial production process that can be designed with balance such that the continuous flow can be obtained, the production rate of each unit in the supply chain can be different depending on their operation management strategy. The allocation of inventory and the design of the supply chain model are very crucial to business continuity and success. The manufacturer often store inventory to increase the service level of satisfying the customer as well as to cope with their product quality fluctuation. The amount of the inventory will depend on the frequency and lead time from transporting the produced lot from the one stage to the next. This paper studies an effect of the quality levels, lot size, WIP and product inventory throughout the supply chain on the total cost calculated based on MFCA. This paper aims to concurrently design supply chain model by determining both the optimum production lot sizes of each unit and the transportations of the whole or partial lot such that the total manufacturing cost defined as the total positive cost of MFCA is maximized. This paper addresses another usefulness of the MFCA technique which that can be used to design the supply chain model and logistics management that yields the lowest total cost yet the highest positive product cost.

REFERENCES

[1] ISO 14051, *Environmental management-Material flow cost accounting-General framework*, 2011.
[2] B. Wagner and R. Enzler, *Material flow management: Improving cost efficiency and environmental*, Physica-Verlag, 2006.
[3] S. Schaltegger and R. Burritt, *Contempory Environmental Accounting*, Greenleaf publication.
[4] M. Nakajima, "Evolution of Material flow cost accounting (MFCA): Characteristics on Development of MFCA Companies and Significance of Relevance of MFCA," *Kansai University Review of Business and Commerce*, vol. 11, pp. 27-46, 2009.
[5] M. Nakajima, "Environmental management accounting for sustainable manufacturing: Establishing management system of material flow cost accounting," *Kansai University Review of Business and Commerce*, no. 12, pp. 41-58, 2010.
[6] "Material Flow Cost Accounting: MFCA Case Examples 2011," Ministry of Economy, Trade, and Industry, Japan, 2011.
[7] X. Tang and S. Takakuwa, "MFCA-based simulation analysis for environment-oriented SCM optimization conducted by SMEs," *Proceedings of the 2012 Winter Simulation Conference*, 2012.
[8] A. Z. Szendrovits, "Manufacturing cycle time determination 0for a multi-stage economic production quantity model," *Management Science*, vol.22, no. 3, pp. 298-308, 1975.
[9] S. K. Goyal, "Economic batch quantity in a multi-stage *0*production system," *International Journal of Production* 1*Research*, vol.16, pp.267-273, 1977.
[10] A. Z. Szendrovits, A. Drezner, "Optimizing multi-stage production with constant lot size and varying numbers of batches," *Omega The International Journal of Management Science*, vol. 8, no.6, pp. 623-629, 1980.
[11] Z. Drezner, A. Z. Szendrovits and G. O. Wesolowsky, "Multi-stage production with variable lot sizes and transportation of partial lots," *European Journal of Operation Research*, vol.17, pp.227-237, 1984.
[12] S. K. Goyal and A. Z. Szendrovits, "A constant lot size model with equal and unequal sized batch shipments between production stages," *Engineering Costs and Production Economics*, vol.10, pp.203-210, 1986.
[13] R. W. Bogaschewsky, U. D. Buscher, G. Lindner, Optimizing multi-stage production with constant lot size and varying number of unequal sized batches," *Omega The International Journal of Management Science*, vol. 29, pp. 183-191, 2001.
[14] R. Jans and Z. Degraeve, "Modelling industrial lot sizing problems: a review," *International Journal of Production Research*, vol. 46, no. 6, pp. 1619-1643, 2008.
[15] W. Ho, · J. C. Pan, Y. Hsiao, "Optimizing multi-stage production for an assembly-type supply chain with unequal sized batch shipments," *Journal of Optimization Theory and Applications*, vol. 153, pp. 513-531, 2012.
[16] J. C. Tsou, S. R. Hejazi and M. R. Barzoki, "Economic production quantity model for items with continuous quality characteristic, rework and reject," *International Journal of Systems Science*, vol. 43, no.12, pp. 2261-2267, 2012.
[17] Y. P. Chiu, C. K. Lin, , H. Chang, and V. Chiu, "Mathematical modelling for determining economic batch size and optimal number of deliveries for EPQ model with quality assurance," *Mathematical and Computer Modelling of Dynamical Systems*, vol. 16, no. 4, pp. 373-388, 2010.

Minding the gap between Sustainable Supply Chain and Firm Performance: A global overview

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Keywords: **Sustainable supply chain management, sustainable supply chain performance, environmental performance, corporate social responsibility, sustainability, Granger causation.**

I. Introduction

Supply chain management (SCM) stands as an important subject for determining how to incorporate environmental and social considerations and practices into corporate policy in order to achieve sustainability (Ashby et al., 2012). Under this scenario, sustainable management of supply chains has become a core strategic factor for companies around the world (Seuring, 2012).

Although the literature contains many studies on SSCP, these hypothesized relationships are still underdeveloped (Ashby et al., 2012). There fore, the link between sustainable supply chain and firms' financial performance is an important subject that is still unclear. This paper aims to investigate this connection in order to provide empirical evidence about the relationship between these two constructs.

II. Material and Methods

Multivariate measures of both sustainable supply chain performance and financial performance are employed to conduct Granger causality tests on a large, diverse sample of 3,900 firms in a time-frame of eight years (from 2004 to 2011).

III. Results

The results indicate that, in general, there is bidirectional causality between sustainable supply chain performance and firms' margins and revenue. However, the link between firms' profitability and sustainable supply chain performance is unidirectional. In addition, the negative effects of the recent financial crisis altered the link between the studied constructs. Finally, a wide diversity in the relationship patterns between sustainable supply chain performance and corporations' financial performance emerges when the full sample is divided into the different geographical regions of world and the different economic sectors as specified by the Global Industry Classification Standard (GICS) system.

IV. Discussion

This research puts forth recommendations for improving several processes, such as having stakeholders evaluate the sustainable supply chain performance of companies around the world and managers test the outcomes of incorporating environmentally oriented processes into firms' strategic policy

V. Conclusion

The most important findings is the support for a significant, bidirectional causation between SSCP and firms' margins (FP-MA) and revenue (FP-RE). This relationship remained true for firms' profitability (FP-PR) during bull markets but not during the financial crisis.

The relationship between FP and SSCP has been found to have spread worldwide (slack resource).

SSCP has significant impact on FP. This relationship is more significant when is measured through their margins (FP-MA). Operational costs are a relevant key factor which determines margins, this research emphasizes that SSCP allows companies reducing costs (specifically those related with environmental expenditures) by developing new technologies.

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Controlling Resource Flows to improve Low-carbon Supply Chains- with the help of Material Flow Cost Accounting (MFCA)

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***Abstract*: Resource and material flows are at the core of today's environmental and social problems. From the extraction of raw materials to the production of goods, to their consumption and disposal, these flows have far reaching environmental and social effects – from soil depletion to global warming, from health issues to social conflict. It is vital for a sustainable society to control these resource flows and their effects.**

***Keywords*: Material Flow Cost Accounting (MFCA), Low-carbon supply chain, Resource Flows**

I. INTRODUCTION

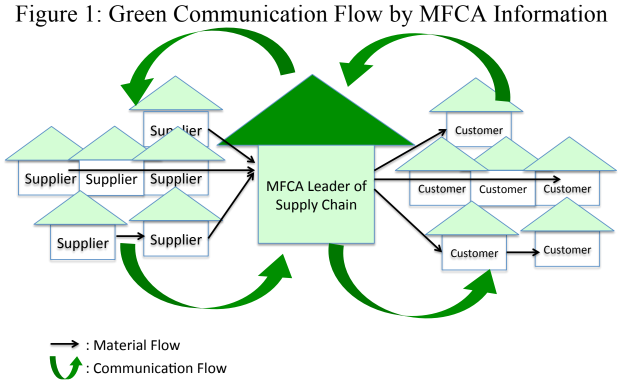
MFCA, developed within the framework of Environmental Management Accounting (EMA), today is a tool that in a broader sense is aimed at sustainable production mainly by improvement of material efficiency, reduction of social tension and increasing profitability along material flows [2], [6], [7] & [10]. Starting in Japan originally from an in-company point of view we recently extended the MFCA scope across the company limits to the supply chain [5]. Considerable material losses along the supply chain could be detected, including their causes and sources, upstream as well as downstream. In some cases we were able to improve material efficiencies along the supply chain. In other cases we encountered reluctance to cooperate more closely with supply chain partners. To gain a better insight we performed a survey of many Japanese companies and analyzed present cooperation practices and existing management information concerning the supply chain. In this presentation we will show a resulting framework to introduce MFCA based management to the supply chain.

II. USEFULNESS AND SIGNIFICANCE OF MFCA IN SUPPLY CHAIN

In further case examples we extend the MFCA scope from Supply Chain Analysis to Life Cycle Analysis (LCA). The extended MFCA can, in addition to the loss of production material, further show carbon emissions, not only from within the company but also to close suppliers and along the up- and downstream life cycle. We develop the basic methodology for an extended MFCA in order to evaluate and reduce carbon emissions along the supply chain from cradle to grave. The resulting information from this extended analysis is also apt to serve as a basis to widen present corporate internal and external reporting systems and introduce environmental and social data in addition to the so far predominant monetary information. This widened information basis is a prerequisite for a more sustainability oriented corporate decision-making and fiscal taxing system, for a lasting customer and community relationship. In the end, global standards to control resource flows and their economic, environmental, and social impacts, will be essential.

Figure 1 shows a model of MFCA in supply chain. When we introduce MFCA in supply chain, we need a company of MFCA leader from our researches [5] & [8]. In theoretical research, when many companies introduce MFCA in each in-process and each company combine each MFCA information, MFCA can be introduced in supply chain. But in practice, a company of MFCA leader who want to expand MFCA viewpoint into own supply chain is important because suppliers usually recognize MFCA as cost information and hate to show cost issues to customers.

Figure 1: Green Communication Flow by MFCA Information



In Japanese case examples of MFCA in supply chain [4], cost information isn't shown to upperstream and downstream companies in successful case examples. And companies of MFCA Supply Chain project share technological subjects and problems to generate material losses in each process, and they discuss about how to reduce technologically them in common. In Japan, each supplier has generally closer and longer relationship of production technology in business. They could think to share directly or indirectly profit for each other, when a supplier can improve some technological losses. They are linked on technological value chain.

As a result of our research, once a company and a supplier introduce MFCA, they will start to discuss about how to reduce material losses. Therefore, we developed to research about structure of supply chain in Japan to introduce MFCA into supply chain. In the next section, we try to analyze about the present situation of supply chain in Japan. This questionnaire research focuses on the contents and strength of collaboration between buyer and supplier to improve material yield rate, CO2 emission in supply chain.

III. MFCA IN SUPPLY CHAIN BASED ON QUESTIONNAIRE RESEARCH IN JAPAN

We assume a MFCA leader will introduce it into supply chain. Though the MFCA leader could be a buyer as well as a supplier, we assume he/she is the buyer here.

It is necessary to make a supplier understand the significance of MFCA in order to introduce it into supply chain smoothly. The MFCA leader explains it to a supplier proactively and must obtain his/her agreement. Generally, the supplier feels resistance in offering all information to the buyer when a buyer and a supplier collaborate for the purpose of cost reduction. However, in introduction of MFCA, a supplier does not necessarily have to give a buyer cost information [1]. There is a possibility that MFCA causes less uneasiness for suppliers in comparison with a conventional tool. We decide to investigate the relations between buyer and supplier from the viewpoint of the buyer to consider whether the MFCA leader introduce MFCA into supply chain in cooperation with a supplier.

We designed the questionnaire to assess the status of the relationship between buyers and suppliers. The main purpose of this questionnaire is to understand information-sharing between buyers and suppliers because it is difficult to have a reliable relationship without information-sharing. To research their relationship, we asked the following questions. First, how well do buyers know the strength and depth of information-sharing with suppliers on product development? Second, how well do they share information with suppliers?

We sent a set of questionnaires by post to managers or persons in charge of purchasing departments in all the listed manufacturing companies in Japan, a total of 1,561 companies/sites, in February 2012. As a result, we received 356 responses, a rate of 22.8%. We could not find non-response bias in the companies that responded. Table 1 gives a breakdown of the companies by industry

Table 1: Category of Industry and Companies

Category of industry	Number of responses		Number of mailings	
	Number	Ratio	Number	Ratio
Transportation Equipment	26	7.3%	104	6.6%
Non-Ferrous Metals	8	2.2%	38	2.4%
Electric Appliances	73	20.5%	283	18.1%
Electric Power & Gas	3	0.8%	22	1.4%
Iron & Steel	9	2.5%	54	3.5%
Textiles & Apparel	7	2.0%	58	3.7%
Oil and Coal Products	2	0.6%	13	0.8%
Precision Instruments	15	4.2%	50	3.2%
Foods	19	5.3%	131	8.4%
Metal Products	24	6.7%	94	6.0%
Machinery	70	19.7%	236	15.1%
Chemicals	54	15.2%	210	13.4%
Pharmaceuticals	7	2.0%	56	3.6%
Pulp & Paper	5	1.4%	24	1.5%
Other Products	19	5.3%	107	6.9%
Rubber Products	6	1.7%	19	1.2%
Glass & Ceramics Products	9	2.5%	64	4.1%
Total	356	100.0%	1563	100.0%

1. Present condition of purchasing department and information-sharing on product development

This section gives an outline of the information-sharing situation when a buyer revises a procurement cost. First, we have to know about the purchasing department's target. They prefer to avoid a rise in procurement cost because they have selected "procurement cost increase" as a factor that prevents an objective from being met (Table 2). However, while constant cost is important, when selecting suppliers, they base their decisions foremost on quality (Table 3).

Table 2: Most Problematic Factor for Target Achievement

	Number of Answers	Ratio
Delay of delivery date	45	12.6%
Procurement cost increase	230	64.6%
Non-constant quality	65	18.3%
Environmental damage	3	0.8%
Others	10	2.8%
No response	3	0.8%
Total	356	100%

Table 3: Most Important Factor in Choosing Suppliers

	Number of Answers	Ratio
Environment	4	1.1%
Delivery	13	3.7%
Price	104	29.2%
Quality	225	63.2%
No response	4	1.1%
Total	356	100%

Second, we discuss revising or negotiating their procurement cost. Table 4 shows how many times a year companies revise prices. All the companies that responded to our questionnaire revise their costs once or more times[1].

[1] In addition, we must be notice that 13.5% of companies revise the cost more than 5 times.

Table 4: Number of Times Procurement Cost is revised per Year

	Number of Answers	Ratio
1	132	37.1%
2	94	26.4%
3	6	1.7%
4	26	7.3%
Over 5	48	13.5%
No response	18	5.1%
Total	356	100%

The collaboration does not occur if a buyer focuses only on procurement cost. In that case, they will convey to suppliers their requirement definition on their given cost. We understood that 62.1% (Table 5) of buyers let a supplier participate in definition of requirements.

Table 5: Negotiating Criteria

	Number of Answers	Ratio
Negotiate only price	115	32.3%
Discuss requirement definition	221	62.1%
No response	8	2.2%
Others	12	3.4%
Total	356	100%

In addition, we consider cost revision and requirement definition. In the case of the revision of the procurement price, the sales and marketing department often participates (Table 6, 92.1%). It is natural that they would participate in the first step about the procurement price.

Table 6: Negotiating Department for Procurement Cost

	Numbers of Answers	Ratio
Sales & marketing	328	92.1%
Production	6	1.7%
Production engineering	0	0.0%
Production management	7	2.0%
Product design	1	0.3%
Target costing	1	0.3%
Accounting	0	0.0%
Product planning	1	0.3%
Others	7	2.0%
No response	5	1.4%
Total	356	100%

Next, we assumed that production, production engineering, and product design departments account for most participation in requirement definition, but the responses showed otherwise. In the case of the definition of requirements, they participate 38.4% of the time (Table 7).

Table 7: Department of Suppliers Attending Requirement Definition Meeting

	Number of Answers	Ratio
Sales & marketing	198	38.4%
Production	54	10.5%
Production engineering	82	15.9%
Production management	8	1.6%
Product design	148	28.7%
Target costing	3	0.6%
Accounting	0	0.0%
Product planning	12	2.3%
Others	7	1.4%
No response	3	0.6%
Total	515	100%

2. Level of information-sharing for cooperative activity with suppliers

Here we look the level of information-sharing. We asked how information is shared with suppliers. Nearly half of the companies know a supplier's material yield ratio (41.0%), and the remaining ones do not know it (55.6%). Next, many companies try to improve the ratio for suppliers.

Table 8: Acquaintance with Your Supplier's Material Yield Rate

	Number of Answers	Ratio
Known	146	41.0%
Not known	198	55.6%
No response	8	2.2%
Invalid	4	1.1%
Total	356	100%

When we look at a breakdown, 134 companies perform an improvement activity, whereas 146 companies know the ratio. However, 17 of 134 companies do not know it. In other words, in the collaborating companies, they do not conduct information-sharing and may require only the ratio improvement.

Table 9: Implementation of Cooperation to Improve Material Yield for Suppliers

	Number of Answers	Ratio
Yes	134	37.6%
No	213	59.8%
No response	7	2.0%
Invalid	2	0.6%
Total	356	100%

In addition, only 8.7% of companies grasped the CO2 emissions of the supplier (Table 10). In the preliminary interview of buyers' companies, they replied about their selection criteria for suppliers. Buyers confirmed that suppliers obtained ISO14001 or underwent an environmental consideration procedure on the production process.

Table 10: Acquaintance with Your Supplier's CO2 Emissions

	Number of Answers	Ratio
Yes	31	8.7%
No	318	89.3%
No response	5	1.4%
Invalid	2	0.6%
Total	356	100%

However, they do not grasp the CO2 emissions related to the component they purchase. Nevertheless 38.2% of them want to reduce cooperatively the supplier's CO2 emission, there is only 6.5% companies that they implement to reduce cooperatively supplier's CO2 emission (Table 11 and 12).

Table 11: Expectation of Reducing Cooperatively the CO2 of the Suppliers

	Number of the Answers	Ratio
Yes	128	38.2%
No	180	53.7%
No response	26	7.8%
Invalid	1	0.3%
Total	335	100%

Table 12: Implementation of Cooperation to Decrease CO2 Emission for Suppliers

	Number of the Answers	Ratio
Yes	23	6.5%
No	320	89.9%
No response	12	3.4%
Invalid	1	0.3%
Total	356	100%

To improve the recognition of MFCA may resolve the above problem. As it stands now, most companies have not introduced MFCA; furthermore, many are unaware of the concept. The recognition of MFCA is very high in the environmental department, but more than 70% of the companies responded that they are unaware of the concept (Table 13 and 14).

Table 13: Recognition of MFCA

	Number of Answers	Ratio
Yes	88	24.7%
No	262	73.6%
Invalid	6	1.7%
Total	356	100%

Table 14: Introduction of MFCA

	Number of Answers	Ratio
Introduced	7	2.0%
Not introduced	241	67.7%
Not introduced but interested in	28	7.9%
Not introduced but considered	10	2.8%
Unclear	64	18.0%
No response	5	1.4%
Invalid	1	0.3%
Total	356	100%

MFCA is a tool that can help to achieve the two purposes of environmental load reduction and cost reduction. If purchasing departments with authority to choose a supplier recognize MFCA, it may help improve MFCA introduction.

It is necessary to make the buyer company recognize that MFCA is a tool contributing to both environmental load reduction and cost reduction in order to introduce MFCA into supply chain. As a result of the above considerations, the purchasing department and the sales department operate at the point of contact between buyer and supplier, and they take a central role in negotiations.

The buyer chooses a supplier based on quality, but procurement cost is important as well. We must let the purchasing department of the buyer understand the effect of MFCA to introduce MFCA into supply chain.

IV. CONCLUSION

In our questionnaire research, we explain that there are some needs of cooperation between buyers and suppliers. However, the cooperation between buyers and suppliers hasn't always been actualized in practice yet. For example, around 40% of buyers would like to reduce CO2 emission in supplier's process collaboratively with suppliers, but only 6.5% of buyers can make a collaborative action with suppliers in practice. The reason why the cooperation between buyers and suppliers hasn't always been actualized in practice could be because the suppliers haven't understood such thinking of buyers. And 8.7% of buyers answered that they know the amount of CO2 emission in the supplier's process. If MFCA information is completed, buyers and suppliers could reach a common understanding of CO2 emission in the supply chain. MFCA information will be able to contribute an establishment of green supply chain in practice.

It is not essential significance for us to got MFCA as a useful sustainable management tool in production line, but as a tool of fundamental sustainable management information over the whole of business flow inside company and supply chain. To establish MFCA management system means to start corporate management of sustainability

REFERENCES

[1] Higashida, A., "Environmental Management Accounting in Support of Supply Chain Management; Applicability of MFCA" in *Final Report on Environmental Decision Making and Accounting System, Japan, Japan Accounting Association*, *Tokyo, 2010*, pp.135-151 (available only in Japanese).

[2] ISO, *ISO 14051 Environmental Management – Material Flow Cost Accounting – General Framework*, ISO, 2011.

[3] Kokubu, K., Itsubo, N., Nakajima, M., "Integration of Material Flow Cost Accounting and LIME", *the Kokumin-Keizai Zasshi (Journal of Economics & Business Administration)*, the Keizai-keiei Gakkai, Kobe University, 2006, Vol.194, No.3, pp.1-11 (available only in Japanese)

[4] Ministry of Economy, Trade and Industry, *Material Flow Cost Accounting: MFCA Case Examples*, METI Japan, 2010.

[5] Nakajima, M., "Significance of Supply Chain Management by Material Flow Cost Accounting: Possibilities of an Environment-Conscious 'KEIRETSU'", *Environmental Management (JMAI)*, 2009, Vol. 45, No. 4, pp. 60-65. (available only in Japanese)

[6] Nakajima, M., "Environmental Management Accounting for Sustainable Manufacturing: Establishing Management System of Material Flow Cost Accounting (MFCA)", *Kansai University Review of Business and Commerce*, 2010, No.12, pp.41-58.

[7] Nakajima, M., "Environmental Management Accounting for Cleaner Production: Systematization of Material Flow Cost Accounting (MFCA) into Corporate Management System," *Kansai University Review of Business and Commerce*, 2011, No. 13, pp. 17-39.

[8] Nakajima, M. and A. Kimura, "Promotion of Innovative Improvement integrated MFCA with Budgeting," *The Journal of Cost Accounting Research*, 2012a, Vol. 36, No. 2, pp.15-24. (in Japanese)

[9] Nakajima, M. and A. Kimura, "Development of Material Flow Cost Accounting (MFCA) to Asian Countries promoted by International Standardization of MFCA: for example, in Malaysia and Vietnam," *Environmental Management (JEMAI)*, 2012b, Vol. 48, No. 7, pp. 105-111. (in Japanese)

[10] Nakajima, M. and Kokubu, K., *Material Flow Cost Accounting*, 2nd. Tokyo: Nikkei Publishing Inc, 2008 (available only in Japanese).

[11] Nakajima, M., Kokubu, K., Kitada, H., "Supplement 1: Questionnaire Research on Cost Accounting and Environmental Management Accounting in Japanese Companies", Special Committee in Japan Accounting Association, *Research on Environmental Management Decision-making and Accounting System (Final Report)*, Sept. 2010, pp. 305-323, 2010. (available only in Japanese)

[12] Wagner, B., Enzler, S. (eds.), *Material Flow Management: Improving Cost Efficiency and Environmental Performance*, Phsica-Verlag, 2006.

[13] Wagner, B., Nakajima, M., Prox, M., "Materialflusskostenrechnung – die internationale Karriere einer Methode zu Identifikation von Ineffizienzen in Produktionssystemen", *UWF – UMWELTWIRTSCHAFTSFORUM*, 2010, Vol. 18, Numbers 3-4, SS.197-202, Springer.

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Material Flow Cost Accounting (MFCA) in Malaysia: An SME's Case for Cleaner Production

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***Abstract*: Material Flow Cost Accounting (MFCA) has the potential to address the profound impact that Small and Medium-Sized Enterprises (SMEs) in Malaysia may have on the natural environment. The main reason is that MFCA may attract the business community in Malaysia with its dual achievements of environmental and economic objectives simultaneously. The purpose of this paper is to highlight the facilitating factors and barriers experienced by one SME in Malaysia. The case study of an automotive SME showed that the main facilitating driver for the MFCA implementation was to reduce its financial burden, and not because of the increase in the level of environmental awareness. Despite that, the company was still able to achieve improved environmental performance through a reduction of its metal scrap (waste). In the Malaysian context, financial reasons driving environmental initiatives may be common among SMEs. Therefore one way to attract them to positively contribute to the natural environment is to encourage cleaner production using MFCA. The diffusion of innovations (DOI) theory was used to guide the study as it helped explain the factors that may influence the rate of MFCA implementation in the company. It was found that among the facilitating factors included MFCA's own attribute of being compatible with the existing systems in the company. Further, the concept of MFCA was easily understood by employees in the various units. Other facilitating factors included the communication channels used, the MFCA team composition and also the extent of the change agents' promotion efforts. Meanwhile the barriers included vendor constraints and the inability to link MFCA to the performance management system (PMS). Delayed supply of the new material by vendors had resulted in delayed cost savings, whereas acknowledgement of MFCA efforts in the PMS is needed to avoid future employee grievances. There are two pertinent contributions of the study. The facilitating factors and barriers of MFCA implementation in the case company may help other companies intending to adopt MFCA in future. Secondly, identifying a theoretical framework to explain the facilitating factors and barriers for MFCA implementation may enhance the "academic-practitioner" links.**

***Keywords*: Material Flow Cost Accounting (MFCA), SME, ISO 14051, Qualitative Research, Malaysia**

I. INTRODUCTION

The operations of small and medium-sized enterprises (SMEs) in Malaysia are likely to have a significant impact on the natural environment. This is highly likely because they comprise 97% of total business establishments in Malaysia [1], and in Europe itself SMEs contributed approximately 64% of the industrial pollution in Europe [2]. Furthermore, there has been an overall increase in air pollution, water pollution and scheduled waste levels in Malaysia [3].

Material flow cost accounting (MFCA) has the potential to address this problem because it supports organisations to achieve both environmental and economic objectives simultaneously. Most SMEs in Malaysia will value this. MFCA was introduced into Malaysia in 2010 under a project organised by Malaysia Productivity Corporation (MPC) in five SME companies.

The objective of this paper is to highlight the facilitating factors and barriers experienced by one of these companies in the hope to provide some insights that may be used by other companies who wish to adopt MFCA.

The remainder of this paper is organised as follows; Section II describes the research methodology adopted for the study which is an explanatory case study, Section III explains the theoretical framework employed being diffusion of innovations (DOI) theory, Section IV discusses the findings from the study while Section V concludes.

II. METHODOLOGY

This study was conducted using an explanatory case study. This type of case study is suitable to explain the details of a specific accounting practice being observed in great depth. It needs theory to help explain these details because theory will provide a basis or guide when developing the questions and during the analysis. However, being a qualitative study under an interpretive perspective, there may be a possibility that the theoretical framework initially used may be found to be inappropriate for the study due to emerging themes during data collection. Since a case study involves in-depth and detailed analysis, the flexibility it offers is deemed suitable.

The case company selected for the study was one of the five SME companies in the MPC MFCA project. This company, Alpha, manufactures metal parts for the automotive industry. This company was selected because the automotive industry is the top five contributors of scheduled waste in Malaysia [3].

The study was framed within the theoretical framework of diffusion of innovations (DOI) theory, of which will be discussed in the following section. Indeed the researcher is the one the data collection instrument. Nevertheless, other data collection methods such as in-depth interviews, document review and observations will also be employed. This is to further enrich the study with additional data and data that can be triangulated against another in order to perform a better quality research work.

The interviews were conducted with five MFCA team members of the case company and the MPC liaison officer. Additional clarification from the Japanese technical expert was also sought through e-mail. Documents reviewed mainly included background information on the MPC MFCA project, the company's costing sheets used during MFCA analysis, presentation slides, ISO 14051, MFCA guidebooks produced by MPC as well as other relevant documents. Observations were mainly made during the site visits to the company and during presentations by the company in MFCA training sessions.

III. Theoretical Framework

MFCA is a new tool in Malaysia and its adoption will involve change and will be an innovation to the company, so it is important for the management to at least take appropriate measures that the innovation is diffused to the company members in the best possible way. As such, the diffusion of innovations (DOI) theory advocated by Everett M. Rogers [4] was deemed to be most helpful as a guiding theory. This is because it provides a detailed framework for explaining the intricacies of diffusing an innovation throughout an organisation. Rogers [4] has defined '*diffusion* as a process by which (1) an *innovation* (2) is *communicated* through certain *channels* (3) *over time* (4) among members of a *social system*' [4, p. 11, emphasis in original]. As such the four main elements in the diffusion of innovations are innovation, communication channel, time and the social system.

Diffusion of innovation in simple terms may be defined as the spread of new ideas [4]. Innovation can be a practice, object or an idea that is perceived to be new by an individual, group of individuals or even the organisation itself [4]. Communication channel, on the other hand is the nature of the exchange of the information among individuals whether it is via mass media or interpersonal channels. In addition, there is also the issue of heterophily (differences) and homophily (similarities) which refers to the extent the individuals interacting share similar or different personal attributes. Typically homophilous communication is more likely to be more effective as compared to heterophilous communication due to the shared interests or 'language' in a homophilous interaction.

Time, the third element, is important in this theory because it places a boundary to measure the extent of the innovation decision process (i.e. knowledge, persuasion, decision, implementation or confirmation stages), the innovativeness and the rate of adoption of the innovation (i.e. adopter categories: innovators, early adopters, early majority, late majority and laggards). Finally, social system, as the fourth element refers to a set of interrelated units who are bound together by a common goal and are engaged in joint problem solving. The social system members can either be individuals, informal groups, organisations and/or subsystems.

The overall model for Rogers' DOI theory is depicted in Figure 1. There are five types of variables theorised to determine the rate of adoption; (1) perceived attributes of innovation, (2) type of innovation-decision, (3) communication channels, (4) nature of the social system, and (5) the extent of change agent's promotion efforts. Each type of variable has its own sub-variables and categories. The rate of adoption, as the dependent variable, has been categorised in terms of the time taken to adopt the innovations, also has five categories. The innovators are those who first adopt the innovation and at the other end, the laggards are the last ones to adopt. In between, there are the early adopters, early majority and late majority.

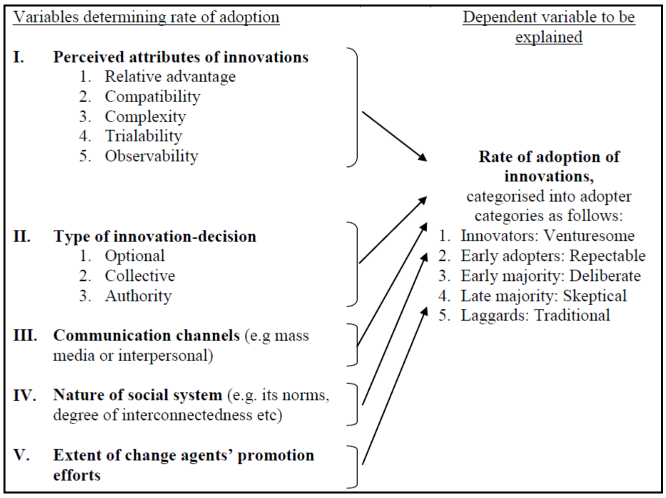

Figure 1: Diffusion of Innovations Model [4]

This study however is not testing the relationship between the rate of adoption and the influencing variables. Instead it is explaining the potential facilitating factors and barriers to the MFCA implementation for the company, guided by the influencing factors explained in DOI. One of the reasons that a relationship test is not conducted is due to the difficulty in measuring the rate of adoption for MFCA implementation. This is mainly because the MFCA boundary is at the discretion of the company. Therefore, the extent of an MFCA implementation in one company may be different from another. For example, both companies A and B had implemented MFCA. However, company A had only implemented for one product, whereas company B had implemented across its supply chain. Surely company B may take a longer time to implement MFCA compared to company A, but to say company B is a laggard may not be accurate nor is it appropriate.

Consequently this study had analysed the influencing factors that have helped or hindered the case company in the process of their implementation of MFCA, guided by the five types of variables in DOI along with its sub-variables. Further detail is in the following findings and discussion section.

IV. Findings and Discussion

1. Background of case company

Alpha, the case company is an SME established since March 1988. Its main business is manufacturing automotive metal stamping parts. Alpha serves two major customers in automotive assembly, Epsilon and Gamma. The MFCA team members for Alpha included those from the production, engineering, purchasing and costing departments. Alpha was mainly interested in MFCA due to its annual scrap volume of 1.8 tonnes which was equivalent to RM7.2 million. Alpha was keen to transform these into cost savings and can see that MFCA has great potential to assist Alpha in doing so. It is clear from here that Alpha's motivation to adopt MFCA into the company was financially driven. However, the additional attraction that MFCA has is its concurrent achievement of environmental objectives. In the Malaysian context, where financially driven motivations are common, having in place a tool which can help a company achieve both economic and environmental objectives together is an opportunity not to be missed. Consequently the experiences shared by Alpha can at least provide some insights to other companies in Malaysia who intend to embark on MFCA. In this paper, these experiences are discussed in terms of facilitating factors and barriers, framed within DOI.

2. *Facilitating factors*

The first group of facilitating factors relate to the attributes of MFCA itself. Firstly, MFCA is seen to have a relative advantage over the existing tools known to Alpha. By implementing MFCA they can visualise clearly where their hidden profits are, and they can strongly justify relevant improvement initiatives. This is because when the equivalent costs are attached to the material losses during the MFCA analysis, it immediately attracts management's attention. Prior to this it would have been hidden within overheads.

Secondly, MFCA is seen to be consistent with the existing business environment of Alpha. MFCA is compatible with Alpha's use of tools such as total quality management (TQM), lean production system (LPS) and Budomari. Alpha's certification of ISO 14000 Environmental Management System (EMS) also helps. The compatibility experienced helped Alpha's organisation members to adopt MFCA more readily.

Thirdly, MFCA's level of complexity is reasonable to the extent that employees from various units across the company were also able to understand the concepts in MFCA rather easily. It is designed in such a way that non-accountants need not be apprehensive about MFCA's 'cost accounting' terminology. This is apparent because for Alpha, there was not a full-fledged accountant as part of their team, and they were still able to implement MFCA and achieve their cost savings and scrap reduction. The nearest team member to accounting was their costing executive, who provided input regarding the costs of items analysed. The costing executive was not involved in financial reporting, hence was not able to shed light on how the costs of product output and non-product output are treated in the financial reports.

Trialability is the fourth sub-variable for the innovation attributes. Trialability is the extent that MFCA can be experimented [4], and this is proven by the successful trial runs which then turned out to be successful new cost-saving production runs.

Observability on the other hand is the extent that the results are visible to others [4] and this was achieved by Creanova 2012, which was the seminar where the five companies presented their final outcomes and summary of their MFCA experiences.

The second group is on communication channels. Effective communication channels were also important for MFCA in Alpha. Their effective communication included constant meetings for improvement efforts and ensuring all team members have agreed on the details of each MFCA Kaizen activity. Despite differences in terms of years of working experience and age among them, teamwork continued successfully. For example, the Engineering Executive talks about teamwork spirit:

> What helps us is the teamwork, the cooperation from all involved (Executive, Engineering Division).

The third group relates to the nature of the social system in the company. For Alpha, what was shining was the team composition for MFCA implementation. The team members comprise of multiple relevant units and that they comprise of various levels so that decision making can be done easier. In other words, multi-unit and multi-level team composition. Another important point for team composition is a dedicated team leader. As highlighted by the team leader during the MPC MFCA project,

> Before this, I was a team leader for MFCA but I was also in charge of Safety. So the progress had been rather slow. It was two months for one part. Now, there is a dedicated person […] it is two weeks for one part (Head of Operations Division).

The fourth group relates to the extent of the change agent's promotion efforts in the process of implementing MFCA in Alpha. For Alpha, it can be observed that there were several change agents. These include MPC, the technical expert from Japan, Alpha's own liaison officer (who in this case was the MFCA team leader) and also the local consultants. Each had their own role in promoting the implementation of MFCA in Alpha.

The fifth group relates to the type of innovation decision, whether it was optional, collective or authority. Unfortunately, the data collected did not reveal any emerging themes on this aspect.

3. *Barriers*

A process of change within an organisation has its own barriers. For Alpha, this primarily concerns the performance management system (PMS) which involves the issues of rewards, key performance indicators (KPI), performance evaluation and bonus distribution. Currently their PMS is only a potential barrier. Their current PMS does not include measures for MFCA activities either in terms of rewards, KPI targets or bonus distribution. PMS is an important issue to address especially if management wants to maintain the employees' motivation for excellent performance. Three out of the five team members interviewed highlighted that this issue was very important to them. Thus, firms wanting to implement MFCA should pay particular attention to such issues as these may become potential barriers to MFCA implementation. The Executive in the Stamping Section had this to say,

> If there is cost reduction involving material usage, there must be some rewards……for instance pay rise or bonus. However, this is not happening now. In my opinion, there must be a reward system because the cost reduction is high…yet there are no "returns" for the employees. The task is not easy. It involves thinking. Just saying thank you is not enough. It does not work because sometimes people may not be motivated to continue doing it.

Another critical barrier concerns vendor constraints. Before the new production run, Alpha needs to get their vendors to agree to supply the new pre-cut material size. An agreement between Alpha and the vendors must be achieved because this affects their mother coil supply, distribution and prior order stocks. Sometimes the delay in procuring the new pre-cut material can take as long as 3 months whereas the MFCA activity analysis and trial runs were completed within 2 weeks. This barrier was taken into account during Alpha's new production planning because the vendors themselves also have their own constraints and these are beyond Alpha's control.

> When we change to a new material size, it will affect their mother coil. This is the reason they cannot give us the new material immediately. They will perform their own analysis, and if they were to bring in a new coil, it will actually take them about 2 to 3 months (Assistant Manager, Purchasing Department).

These two barriers can be considered as part of the social system. As such when analysing the data within DOI, the five variable groups influencing the rate of adoption can be either facilitating or hindering the implementation processes of MFCA in a company.

V. Conclusion

Collectively, SMEs in Malaysia can cause a significant impact to environmental sustainability due to its major composition in the business community. Hence, encouraging SMEs to embark on environmental initiatives is crucial. However, the traditional view that investment in environmental initiatives will reduce financial performance may hinder these SMEs from doing so, especially since SMEs usually have limited financial resources.

The latest managerial innovation such as MFCA may help to solve this problem. As experienced by Alpha, an automotive company, the MFCA has helped them to generate significant cost savings and waste reduction. Alpha was primarily motivated to implement MFCA by its need to reduce cost. Ideally, environmental protection would have been a better motivator for environmental sustainability advocates but in the case of MFCA implementation, both outcomes are possible.

The MFCA had been smoothly implemented in Alpha due to its own beneficial attributes, team composition, communication channels used and the various Kaizen activities undertaken. However, one key factor that may hinder the successful implementation of MFCA is the vendor. Companies need to be wary of this. In addition, learning from Alpha's experience, companies wanting to embark on MFCA should also provide a link between the performance measurement system to the MFCA and Kaizen activities so as to reward employees accordingly. Finally, to be proactive on environmental issues companies must realize that there is a need to put in place a tool such as MFCA so that good environmental management can provide opportunities for reducing costs, enhances environmental performance and improves the bottom line.

References

[1] DOS, "Economic Census 2011: Profile of Small and Medium Enterprise," Department of Statistics, Malaysia, Prime Minister's Office, Putrajaya, Malaysia, 2011.
[2] C. Constantinos, S. Y. Sørensen, P. B. Larsen, S. Alexopoulou, K. Pedersen, K. R. Kristiansen, J. Mogensen, and M. Papageorgiou, "SMEs and the Environment in the European Union," European Commission, DG Enterprise and Industry, Greece, 2010.
[3] DOE, "Environmental Quality Report (EQR) 2010," Department of Environment, Ministry of Natural Resources and Environment, Malaysia, Putrajaya, Malaysia, 2010.
[4] E. M. Rogers, *Diffusion of Innovations*, Fifth. New York, USA: The Free Press, 2003.

Material Flow Cost Accounting: Turning Waste into Gold

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***Abstract*: Presently, there is increasing pressure for companies to take a more holistic approach to environmental management. Companies now are focusing less on the *recycle* and *reuse* concepts when addressing environmental issues. Proactive companies are presently concentrating on *reducing* their material input in order to manage its waste. An environmental management accounting tool that has now become an international standard (ISO 14051), material flow cost accounting (MFCA), can help companies address environmental issues as well as improve the bottom line. This paper discusses MFCA, its benefits, the steps to implement it and finally how 2 (out of the 5 pioneering SMEs) have turned their waste into "gold".**

***Keywords*: Material Flow Cost Accounting (MFCA), Malaysia, Small Medium Enterprise (SME), Material waste.**

I. INTRODUCTION

Companies are now developing systematic, proactive responses to environmental matters. More importantly, such companies now are focusing less on the *recycle* and *reuse* concepts when addressing environmental issues. Accordingly, proactive companies are now concentrating on *reducing* their material input in order to manage its waste. In particular, material flow cost accounting (MFCA), an EMA tool that has now become an international standard, ISO 14051 [1], can help companies address environmental issues as well as improve their bottom lines. MFCA is said to address the impact of a firm's activities on the environment by using less natural resources and simultaneously increase productivity and profits. What is MFCA and how can environmentally responsible companies adopt this tool? This is precisely what the paper attempts to address. The remainder of the paper is structured as follows. Section II elaborates on what MFCA is and compares it with conventional cost accounting. Section III describes the steps to embark on MFCA while section IV documents the "*gold"* that companies uncover from managing waste. Section V concludes.

II. MFCA AND CONVENTIONAL COST ACCOUNTING

A better understanding of environmental costs will help firms increase profits and induce efficient materials usage and wastage [2]. According to Schaltegger and Figge [3], the modern cost accounting system is an important tool which can help identify environmentally induced financial impact of a firm's activities. As indicated in Figure 2: Conventional Cost Accounting and MFCA [4]Figure 2, conventional cost accounting generally does not attach any costs to material loss. However, in MFCA, part of the conversion cost is also allocated to the non-product output. Thus, including the purchased cost of wasted materials of $2,800, the cost attached to material loss is actually $8,600. More importantly, this implies that, not including waste disposal costs, $8600 per product (25% of the total manufacturing cost) is wasted. MFCA provides such information to management and motivates them to reduce waste substantially. It is interesting to note here that in MFCA, the conversion cost is also allocated to material and this is done on the basis of its mass. Additionally, it must be remembered that this cost of $8,600 does not include the cost of additional storage, processing costs of wasted materials, administrative costs of processing waste, cost of machinery abrasion caused by wasted materials and labour costs of processing waste. Thus, companies should realize that cost of material waste does not merely refer to waste disposal cost.

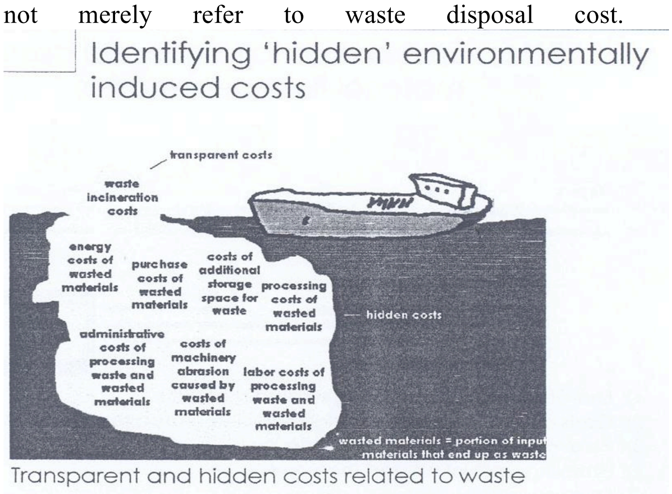

Figure 3 clarifies the various costs that are attached to waste. Ideally, a company should be able to determine all the "hidden costs" of material waste. However, in practice this may be difficult. Accordingly, at the initial stage of MFCA implementation, it would suffice if cost of material loss consists of purchased cost of wasted materials and the allocated conversion costs.

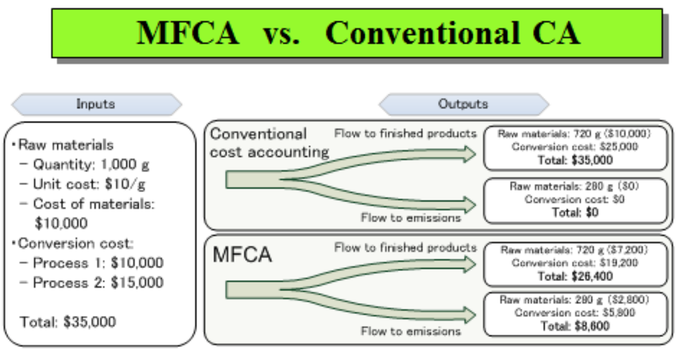

FIGURE 2: CONVENTIONAL COST ACCOUNTING AND MFCA [4].

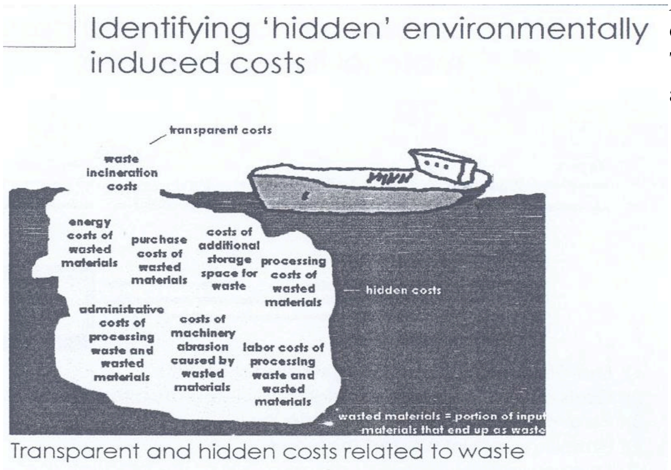

FIGURE 3: "HIDDEN" COSTS OF WASTE.

III. THEORETICAL FRAMEWORK

The theory that can best explain the adoption of MFCA in the 5 SMEs is institutional theory. Specifically, the theory posits that organizational structures and actions are shaped by pressures from the government, the profession and society. Organizations' participants will normally respond to these pressures by acting in accordance with the rules that have been set out by the institutions in their effort to ensure that the organization could survive [5], [6] and [7]. According to DiMaggio and Powell [6], three types of pressures, coercive, mimetic and normative, shape organizations in a common organizational field to have similar structures and practices. Coercive isomorphism occurs as a response to political influence or/and legitimacy problems. On the other hand, mimetic processes are a result of standard responses to uncertainty. Normative pressures stem from the "professionalization" factor. These three mechanisms tend to overlap and thus may not always be empirically distinct from each other [6]. Given that prior studies have linked institutional pressures (regulatory, ownership, market and societal) with environmental management, it can be argued that institutional pressures particularly governmental pressure may also explain MFCA implementation by companies. Companies are coerced by the government and society to adopt MFCA.

Specific to the Malaysian context, MFCA was introduced in the 5 SMEs by the government through the Malaysia Productivity Corporation (MPC) as part of its Green Productivity program. Accordingly, coercive isomorphism may help explain the adoption of MFCA. This is somewhat supported by Nakamura et. al's [8] study of Japanese companies. They argued that governmental pressure led large Japanese manufacturers to incorporate environmental goals in their decisions, obtain environmental certification (ISO 14001) and become early adopters of environmental certification.

IV. MFCA IMPLEMENTATION IN TWO SMES IN MALAYSIA

A brief discussion on the implementation of MFCA, as provided in ISO 14051, will be provided before discussing the adoption of MFCA in 2 SMEs in Malaysia. The standard lists 10 steps to implement MFCA. These are:

1. Involvement of management
2. Determination of necessary expertise
3. Specification of a boundary and a time period
4. Determination of quantity centres
5. Identification of inputs and outputs for each quantity centre
6. Quantification of the material flows in physical units
7. Quantification of the material flows in monetary units
8. MFCA data summary and interpretation
9. Communication of MFCA results
10. Identification and assessment of improvement opportunities

According to ISO 14051, implementing MFCA in organizations that have an EMS in place is relatively easier. However, this does not mean that MFCA cannot be implemented in organizations that do not have an EMS. What is pertinent is top management involvement. Top management should lead the implementation by providing resources, identifying relevant personnel, monitoring progress, reviewing results and decide on improvement measures on the basis of MFCA results achieved on the initial project. Additionally, implementing MFCA requires a multitude of expertise. For example operations personnel from the design, procurement, and production departments are needed to determine the flow of materials and energy use throughout the organization. Technical expertise for material balance implications is also important. Staff from quality control department is needed to handle issues on product reject frequency, causes, and rework activities while environmental experts are needed for a product's environmental aspects and impacts, waste types, and waste management activities. Last but not least, accounts people are important for cost accounting data and cost allocation. Another important dimension in MFCA implementation is the specification of a boundary and a time period. Boundaries are determined at the discretion of the organization. A boundary can be a single process, multiple processes, an entire facility, or the whole supply chain. However, it is always advisable to focus on an activity/process with significant environmental and economic impacts. Perhaps, when first implementing MFCA, it is important to focus on an activity that is manageable and does not involve external parties. Often, a company will start with a product that has a high volume and with future market potential. Once the boundary has been determined, the period for MFCA data collection should be determined. More often than not, the data collection period is generally aligned with the manufacturing of a production lot.

Fundamental in MFCA is the concept of quantity centre (QNC). After specifying the boundary, QNCs will be determined. A QNC serves as a data collection point where material flows, energy use, material costs, energy costs, system costs and waste management costs are quantified. A QNC may refer to one process or a group of processes. Subsequently, the inputs and outputs for each quantity centre are identified for a QNC within the boundary determined. Generally, the inputs focus on materials and energy while the outputs are products, material losses and energy losses. It is essential that a material flow analysis be conducted in order to determine the inputs and outputs of a chosen boundary. The inputs and outputs are then quantified in physical units such as mass, length, number of pieces, or volume. It is essential that all physical units be convertible to a single standardized unit (e.g. mass) so that material balances can be conducted for each QNC. Finally, the monetary value of the physical inputs and outputs are then determined. Such information are usually tabulated in a summarized format showing the "before" and "after".

Finally, it is important that the results of the initial MFCA project be communicated to all relevant personnel. The positive results would spur employees to identify other potential MFCA projects in the company. The standard suggests that potential MFCA projects may include the possibility of substituting materials which are cheaper and more environmentally friendly (without affecting the quality of the final product) as well as modifying the production process, production lines or products.

1. *Energy and system costs*

Another essential component in the costing of material wastes is energy costs. If a company has implemented ABC, energy cost of material wastes will be determined with greater accuracy. However, if energy costs for individual QNC are not known, then the energy costs should be allocated to the QNC using an appropriate basis. Next would be the system costs. The standard classifies system costs as all expenses *other than* material costs, energy costs, and waste management costs. Some schools of thought may regard system cost as overheads but in MFCA, system costs refer to all other costs besides energy costs.

As alluded to earlier, in Malaysia, the MPC has played an active role in the dissemination of MFCA information. Collaborating with the Japan Productivity Corporation (JPC) and the Asian Productivity Organization (APO), MPC has assisted with the implementation of MFCA in 5 SMEs in Malaysia. The five participating companies consist of 2 automotive parts manufacturers, a power cable company, a plastic magnet manufacturer, and a precision tool manufacturing company. In the interest of space and time, for the purpose of this conference, the following section will describe MFCA projects undertaken by only 2 (out of the 5) SMEs, an automotive parts manufacturer (Alif Enterprise) and a precision tool company (EM Enterprise).

2. *Alif Enterprise*

The core business of Alif Enterprise includes small to medium size metal stamping, die and jig making and the manufacturing and assembling of body and panel metal components for the automotive industry. The company has been certified with the ISO TS 16949:2009 since 2005 as well as the ISO 14001:2004 Environmental Management System (EMS).

Table 1 provides the physical and monetary values of the product and non-product output of "small press stamping" of Alif. What motivated Alif to embark on the pilot MFCA project was the RM 7.2 million (or in physical terms, 1800 tons) of material waste that they incur annually. The company's pioneer MFCA project focused on scrap metal waste for "small press stamping" (the boundary). To reduce scrap, the MFCA team focused on the pre-cut material input. The weight of materials for each unit of bracket, initially, was 300grams and the *good* product output was only 165 grams. Thus, for each unit of bracket there was a total loss of 135 grams of material waste. Realising that 45% of material input ended up in waste, they then reduced the size and weight of the pre-cut material to 267 grams. This involved the expertise from production, engineering, quality control and quality assurance, production and planning, purchasing and product costing. Shop floor and executives from these departments were involved in the discussion on the possible reduction of scrap. With the new pre-cut size material input, the company managed to save 33gm of material input per unit. With a production volume of 9,000 units per month, the total material wastes saved from small press stamping was 297kg per month resulting in a cost savings of approximately RM700 per month or an annual cost savings of RM 8,400 from the small press stamping alone. As indicated earlier, material waste includes cost of energy, waste disposal cost and system cost. At the time of writing, Alif has yet to assign such costs to material wastes. Should the company embark on this, they will realize that the costs saved would be much more than RM8,400.

Cost	BEFORE	AFTER	SAVINGS
Product	1485 kg	1485 kg	
	RM 3800	RM 3800	
Material Loss	1215 kg	918 kg	297 kg
	RM 3000	RM 2300	RM 700
Total	2700 kg	2403 kg	
	RM 6800	RM 6100	

TABLE 1: SUMMARY OF COSTS SAVED PER MONTH ON SMALL PRESS STAMPING (ALIF ENTERPRISE).

3. *EM Enterprise*

The company manufactures precision and semi precision metal parts and components for the oil and gas industry as well as the electronics, medical and precision machinery industries. MFCA was first introduced in

September 2010. The MFCA project focused on the "Bracket Control Panel". According to the company, this activity was chosen primarily because it is a high volume product with positive future prospect and possesses improvement potential. The Bracket Control Panel is machined by a CNC vertical milling machine. The materials loss (consisting of material cost, energy cost and system cost) of the relevant processes include excess metal chips, machine coolant and the machine slide way oil. More importantly, because of the long machining process, greater consumption of energy, coolant and slide way oil wastes were evident. The detailed material flows and the input and output of each process is presented in Figure 4.

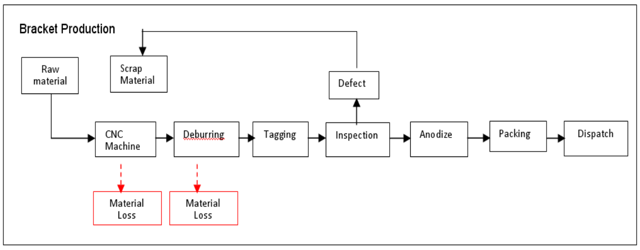

FIGURE 4: PROCESS FLOW OF BRACKET PRODUCTION (EM ENTERPRISE).

EM is unique in that although their material consumption increased, they were able to save production costs by 47.5%. Tables 2 and 3 tabulate the results. Specifically, by increasing the thickness of the input material by 6.35mm, their energy and systems costs were reduced. Offsetting the increased material cost, they managed to reduce their production costs. Encouraged by the success in using MFCA in the production of bracket control panel, the company has since used MFCA as a management tool to improve quality, efficiency and environmental performance of the company.

	BEFORE	AFTER
Material		
Dimension	50.8mm x 175mm x 195mm	57.15mm x 175mm x 195mm
Weight	4.68kg	5.38kg
Price	RM 99.00	RM 118.80

TABLE 2: MATERIAL INPUT BEFORE AND AFTER MFCA (EM ENTERPRISE)

	BEFORE	%	AFTER	%	Savings / (Cost Increase)
Material Cost	RM 16,000		RM20,000		(4,000)
Process cost	RM183,000		RM96,000		87,000
Total	RM199,000		RM116,000		83,000
Finished Product	RM 90,000	45%	RM46,000	40%	44,000
Scrap	RM 109,000	55%	RM70,000	60%	39,000
Total	RM 199,000		RM116,000		83,000

TABLE 3: PRODUCT COST BEFORE AND AFTER MFCA (EM ENTERPRISE)

V. CONCLUSION

To be proactive on environmental issues companies should measure its environmental performance and embark on a ***strategic*** approach to environment related management accounting and performance evaluation. Additionally, companies must understand and manage its environmental costs and introduce waste minimization schemes. It is pertinent that companies put in place a tool such as MFCA so that good environmental management can provide opportunities for reducing costs, enhances environmental performance and improves the bottom line. Most importantly, MFCA makes material loss "visible". All the 5 Malaysian SMEs are now staunch believers of MFCA. As at 31st December 2011, together these five companies have achieved a savings of RM 1.6 million. Indeed, these companies have actually found *gold* in their material waste.

REFERENCES

[1] ISO 14051, "ISO/FDIS 14051 Final Draft: Environmental Management-Material Flow Cost Accounting-General Framework," International Organization for Standardization, Geneva, 2011.

[2] J. Ranganathan and D. Ditz, "Environmental accounting: A tool for better management," *Management Accounting*, vol. February, pp. 38–40, 1996.

[3] S. Schaltegger and F. Figge, "Environmental shareholder value: Economic success with corporate environmental management," *Eco-Management and Auditing,*, vol. 7, pp. 29–42, 2000.

[4] METI, "Material Flow Cost Accounting MFCA Case Examples 2011," Ministry of Economy, Trade and Industry, Japan, Tokyo, Japan, 2011.

[5] J. W. Meyer and B. Rowan, "Institutionalized organizations: Formal structure as myth and ceremony," *American Journal of Sociology*, vol. 83, pp. 340–363, 1977.

[6] P. J. DiMaggio and W. W. Powell, "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields," American Sociological Review, vol. 48, no. 2, pp. 147–160, 1983.

[7] L. G. Zucker, "Institutional theories of organization," *Annual Review of Sociology*, vol. 13, pp. 443–464, 1987.

[8] M. Nakamura, T. Takahashi, and I. Vertinsky, "Why Japanese firms choose to certify: A study of managerial responses to environmental issues," *Journal of Environmental Economics and Management*, vol. 42, pp. 23–52, 2001.

Changing Public Forest Service accountability and reporting through Material Flow Cost Accounting

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Abstract*: Public sector's accountability is an important research topic among scholars. Public sector can lead as an example for the implementation of sustainability accounting regimes which are able to improve its social, environmental and economic performance, and influence private sector for applying similar regimes. Among public sector's services, Forest Service stands as an organization which has to manage not only its financial capital sustainably, but also its natural capital, mainly forests and forest land, in a sustainable way in order to produce high quality and environmentally friendly products and services. Among them are wood products, quarry species, carbon storage, protection from soil erosion and floods. In Greece, Forest Service possesses more than 70% of the total forest land and supervises the management of the rest 30% of private forest land. One of this organization's objectives is to provide its products and services to mountainous areas' people in low prices, or totally free. Such a policy shows that the managerial aspect is focused on serving people, no matter the cost of this objective. Part of this work is published annually in an "Activity Report" through which Forest Service informs stakeholders generally about its actions in whole Greece and the financial resources spent or invested for these actions. In the present research we argue that the implementation of an accountability regime, such as Material Flow Cost Accounting, is able to augment the responsibility of Forest Service to the public, but it can also improve its efficiency in material flows used for its objectives. For example, Forest Service produces annually millions of round and fuel wood products and sells it to the wood merchants. However, no research has been conducted for example on what the material flows of this production are, what are the costs of the non product outputs and how much cheaper or more expensive should these wood products be sold. Such a regime could, also, potentially change the annual report presented to the public through the construction of more modern environmental performance indicators compared to the existed in the traditional report. Therefore, the objective of the present research is to discuss the benefits arising from a potential use of the Material Flow Cost Accounting methodology by the Greek Public Forest Service. It is believed, that during the present recession years such a methodology is able to offer environmental protection and economic sustainability, issues of the highest importance for the current situation in Greece.

I. INTRODUCTION

Public sector's environmental accounting and reporting is an issue which has been discussed for a lot of years in the accounting literature [1], [9]. The need for improving the social and environmental performance of public agency has been highlighted throughout the years and, after 2005 when the Global Reporting Initiative (GRI) released a pilot version of reporting guidelines for public sector, the term used for this accountability was partially shifted into sustainability accounting and reporting [6].

Sustainability accounting for public sector has been mainly examined through the reporting dimension. Most researches have tested the drivers that push public sector to report on sustainability issues, and the aspects covered by public sector's sustainability reports [3], [5], [8].

One of public sector's important agencies is Forest Service. Forest service has some distinct characteristics compared to other public agencies. Forest service works for the provision of critically important environmental products and services such as oxygen, wood, quarry species, CO_2 sequestration, and protection from floods among others. It manages a big share of natural capital, such as forests and forest land. Therefore it does not only need to provide its environmental products, which sometimes other sectors' organizations may use as procurement to improve their environmental performance (for example wood from sustainably managed forests), but it should produce these products and services in a sustainable way.

Material Flow Cost Accounting (MFCA) is a methodology which arises from the industry sector [22] and its main focus is to help environmental managers track inefficiencies in the production process and financial resources losses due to materials becoming wastes and not part of a final product [12]. These characteristics show that it is a methodology that could be used in public forest service for the sustainable production of forest products and services and the improvement of the sector's sustainability reporting.

Thus, the objective of this research is to examine if and the way that Material Flow Cost Accounting could be used by public forest service for improving its accountability and conforming to the calls for public sector's accountability for sustainable development.

II. MATERIALS AND METHODS

For fulfilling the objective of this research, the annual report of public forest service in Greece (PFSG) was used as case study [13]. PFSG issues an annual "Activity Report" since 2003 informing stakeholders generally about its actions for forests in whole Greece and the financial resources spent or invested for these actions. The 2010 report was checked in terms of the sustainability information included. Then, Material Flow Cost Accounting theory was analysed with the objective of finding out if and to what extent this theory could be applied to the production process of Public Forest Service in Greece and its annual report. For this, two examples of production processes were taken into account; the process of wood production and the process of quarry species rearing in public farms for releasing purposes.

III. THEORY

In this section three issues are discussed: public sector's sustainability accounting theory, material flow cost accounting theory and public forest service operation in Greece.

1. *Public sector's sustainability accounting*

The term of sustainability accounting has been introduced in the literature for more than ten years now [12]. It is a term which gradually replaced and put under its "umbrella" the terms of social and environmental accounting, triple-bottom line accounting and other relevant terms [17]. Researchers have tried to find out what this term includes in general and specifically, and define it [12], [17]. However, corporate practice has shown that it can be used with different meanings, from a "buzzword" to a "pragmatic goal driven set of tools" [17]. The goal driven interpretation of sustainability accounting is the integrated approach to sustainable issues, which not only is relevant to legislative and stakeholder pressure, but it is also driven by ethical reasons [17].

This approach seems to be the one that best fits the public sector. Public sector does not need to use the term for "greenwashing" reasons, but to really inform stakeholders about the use and best utilization of public money through sustainably produced goods. Public sector is concerned with promoting values such as public good, social justice and sustainable communities, so it can lead by example in promoting sustainability accounting [2]. Some of the reasons why GRI produced the pilot version of public sector's guidelines were the fact it could promote transparency and accountability in the sector, and that it has a major impact on national and global progress towards sustainable development [9].

2. *Material Flow Cost Accounting*

Material Flow Cost Accounting is one of the approaches for performing an Environmental Cost Accounting analysis and it is included in the more general Environmental Management Accounting framework [4]. It origins from the manufacturing sector and it has been used mainly in Germany and Japan [15] . It can be used also in the service sector [10] and it has been proved that it can be a useful tool to partially augment the accountability of the non profit sector [16]. It is based on the input-output analysis aspect of sustainability accounting and the principle "what goes in must come out" [12].

An organization should track all the material inputs and all the outputs of its production process in physical units. Material inputs are the a) raw and auxiliary materials, b) the merchandise and packaging, c) the operating materials, d) energy and e) water that enter an organization. Outputs are a) the finished goods, b) services, c) by-products, d) emissions or e) waste. Non-product output is any output which does not leave the organization as a manufactured physical product [10], [16].

Two groups of environmental costs are recognized under the MFCA framework: i) those related to the environmental protection expenditure and ii) those related to the material flow costs, that is the purchase cost of materials that become non-product output. These two groups are distinguished into six cost categories [10], [16]:

a) Materials costs of product outputs, including the purchase costs of materials that become physical products

b) Materials costs of non-product outputs, including the purchase costs of materials that become waste and emissions

c) Waste and emission control costs, including the costs for treating the non-product output, costs for restoration of environmental damages, and regulatory compliance costs

d) Prevention and other environmental management costs, including the costs for proactive environmental behavior

e) Research and development costs, including costs for research in environmental issues, and

f) Less tangible costs, including internal and external costs related to future regulations externalities, or stakeholder relations [10], [16].

All these costs are derived from the annual expenditure accounts, refer to the same fiscal year, and under a usual cost accounting method (like activity based costing) can be assigned to cost categories, cost centers and cost carriers. These costs are afterwards distributed to the environmental domains which they affect, such as: i) air and climate, ii) wastewater, iii) waste, iv) biodiversity, and v) soil and ground [10], [16].

3. *Public Forest Service*

Public Forest Service's main mission is the provision of forest commodities and services to society [23]. This objective may differ among countries, among states in the same country and throughout the years [11]. For example, Federal Forest Service in United States has gradually changed its view about appropriate forest management from the principle of multiple-use forestry with a focus on timber production, to the provision of ecological services and recreational amenities which are now preferred compared to other commodities [11]. However, this is a general trend when income is increased in society and people look for other services in forests than primary produced products [21]. In Greece, though forestry produces low quality roundwood and mainly fuelwood, forest management is focused on timber production, taking into account the principles of multiple-use forestry and sustainable production. However, neither US nor Greek public forest service seem to report on the environmental impacts of timber production or other products. Several studies have shown that these impacts are significant and only for the logging operations of timber from plantations it may vary from 115 to 155 MJ/m^3 solid under bark [7]. This is clearly a waste of timber production and by taking it into account and performing a material flow cost accounting analysis forest management and timber prices may differ.

IV. Results

The following results are limited to Greek Public Forest Service. The findings, however, could be easily applied to the work of other forest services in the world, if there are similarities in forest management.

1. *Contents of "Activity Report"*

Sustainability information is practically non-existent in PFSG's "2010 Activity Report" or older than this. The report presents 27 Tables with information about expenses for forestry works such as timber production, forest roads, seedlings production, hunting-fishing, reforestation and afforestation, National Parks, grasslands, forest conservation, and supervision of private forestry. Information is also given about quantities of seedlings produced, hunting licenses sold, grassland improvement, CITES convention licenses sold, area in hectares of reforested or afforested land, forest fires and hectares of burned forest land. The information given is mostly in numbers. There is no target set, no benchmarks, and no explanation why, for example, seedlings production has been reduced from 5.5 in 2009 to 4.9 in 2010 million trees. Although sustainable forest management is described as one of the main principles of Greek forestry, no hectare of Greek forests is certified by a certification scheme (for example Forest Stewardship Council or Sustainable Forest Initiative) for its sustainability. No information is given about negative environmental impacts of timber production (for example CO_2 emissions from loggers transportation or wood transportation), or positive environmental impacts of reforestation (for example CO_2 sequestration).

2. *MFCA for PFSG*

Seeing Forest Service in a broader sense, MFCA could be used in several segments of organization's operation. Since, for example, carbon neutrality issues have already emerged for public sector, MFCA could possibly help Forest Service find out if the overall carbon sequestration from forest management practices annually is greater than carbon emissions from its overall operation. The present research focuses on timber production and the quarry species to discuss possible analogues of MFCA framework with PFSG operation

(i) The non-product outputs of timber production

As mentioned earlier, several researches have estimated the negative environmental impact of forest management practices. Clearly, the energy used for timber production is a non-product output according to MFCA theory. During the logging of a natural tree stand energy is used for the final felling of timber, its extraction and for the workers transportation [7]. If a plantation is cut, it should be taken into account that energy has been also used for silviculture operations such as soil scarification, cleaning and fertilizers production among others [7]. In the boundaries of PFSG operation timber is produced mainly from natural stands. Thus, energy used for logging operations does not become a manufactured physical product, so, according to MFCA theory it is a non product output [10].

Additionally, two other non-product outputs can be distinguished in the production process of timber in PFSG. Due to the low quality of roundwood of several Greek forest stands, or the fact that Greek Wood Industry is in decay, there used to be significant quantities of roundwood or fuelwood that remained unsold to the roadside. These significant quantities used to become rotten wood and can be considered as a non product output. Although it is a product output, it remains unsold in the "warehouse" (roadside) of the organization and according to the theory of MFCA, it should be considered as a non product output [10]. It has to be mentioned, however, that after 2010, when recession in Greece became a major problem, with millions of households in cities and villages demanding fuelwood as the main fuel for thermal energy, the quantities of this non-product output may be minimal.

Finally, illegal logging and its output could be considered as a non product output. Illegal logging is an action that increases gradually due to the aforementioned economic crises. Local people and wood merchants log without a license from the local forest service significant quantities of wood. This is an inefficiency of the Forest Service production process. PFSG employs thousands of forest rangers for controlling logging works and discouraging illegal logging practices. In 2012 forest rangers pressed charges to illegal loggers who had logged 13 thousand tones of wood [14]. But this quantity is clearly a non product output of Forest Service's production process. It can be a reason for unsustainable forest management and economic loss for the organization.

(ii) The non-product output of quarry species rearing

PFSG operates a number of public farms for releasing reasons. Mainly galliforms are artificially and hares are intensively reared [19], [20]. The objectives of the releases are the augmentation of hunted populations, 'put and take' in public shooting preserves and population establishment or augmentation [20]. Several studies, however, have proved that this technique is inadequate for the objectives that it tries to serve. For example, it has been estimated that more than 50% of artificially reared galliforms die within few weeks after release [18]. This is clearly a non-product output of the production process. Birds which were reared to serve the above three objectives, die from predation as soon as they are released in nature. It has been estimated that although the price per reared bird is 6.7 € in Greece, until this bird had been hunted, the cost raised to 36 € [18]. This is almost a 30 € non product output. The same situation occurs with reared hares. Researchers have found that 60-90% of the intensively reared hares died in thirty days after release due to predation [19].

V. Discussion

By accounting for these non-product outputs, PFSG can understand the inefficiencies of timber production and quarry species rearing. For energy, which is allocated to general overhead costs of the timber production process, assigning it to the cost category "materials costs of non-product outputs" and then to the responsible wood product, it could help the cost accounting process and the better pricing of production.

Accounting for the non product output of unsold round- or fuelwood would give a chance to the foresters to consider it as a by-product and try to sell it for other uses in wood industries, or construct indicators for better monitoring the relationship between product output and non product output. It could also help to locate where these quantities mostly occur, the reasons behind this situation, and the ways to avoid it.

Accounting for the non product output of illegal logging would give the chance for the estimation of the cost of not protecting the sustainability of forest management. Pressing charges after wood has been cut illegally it is an "end of pipe" environmental protection action. Forest rangers should act proactive and try to discourage such practices. The cost of this non-product output, of course, can be estimated and the illegally logged timber can be sold back to local people and merchants. However, the scheduled legal loggings of the following years should be reduced up to the quantity of the illegally logged wood. The cost of not logging this wood could be assigned to the "waste and emission control costs" and then to the legally produced wood products. Such an action, of course, would have increased the wood prices for interested buyers, who were not responsible for the inability of PFSG to protect the forests.

Accounting for the non product output of quarry species rearing would give insight into the controversial in the literature technique of artificial rearing and releasing in nature. Better techniques with less cost could be used, such as natural rearing, or the translocation of wild quarries to the area of interest.

Reporting on all these non product outputs would augment the accountability about environmental impacts of PFSG production process. As a public agency, PFSG has many stakeholders who are interested in its operation. The organization should form a number of suitable indicators for monitoring these outputs, should set some targets, and explain each year why these targets have been met or not. Examples of possible indicators could be the fraction of illegally logged wood against legally logged wood, the energy spent for 1 m^3 of wood product, the percentage of hunted species which come from releases to the total number of released species. Of course, PFSG could also report on positive environmental impacts, which were not discussed in this research, that occur from the CO_2 sequestration as a result of the forest management practices and the reforestations or afforestations.

VI. CONCLUSION

The present research is an introductory research on the issue of applying material flow cost accounting to the operation of public forest service. It is limited to the Greece paradigm; however, if there are any similarities with other forest agencies in the world, it could also be applied to them. Material flow cost accounting gives the opportunity for discovering inefficiencies of the production process and the better assignation of environmental costs to the responsible products. It is believed that MFCA gives insight into PFSG production process by revealing non-product outputs which put a cost on the production and result in negative environmental impacts. By including such a piece of information into management systems, foresters will be able to find the suitable techniques to reduce it. On the other hand, constructing a list of environmental performance indicators and reporting on them annually, would augment PFSG's sustainability reporting and respond to the need for public sector's accountability for sustainable development.

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REFERENCES

[1] Ball, A., & Bebbington, J. 2008. Editorial: Accounting and Reporting for Sustainable Development in Public Service Organizations. Public Money and Management, 28(6), 323-326.

[2] Ball, A., Mason, I., Grubnic, S., Hughes, P., 2009. The carbon neutral public sector. Public Management Review 11(5), 575-600.

[3] Burritt, R. L., & Welch, S. 1997. Accountability for environmental performance of the Australian Commonwealth public sector. Accounting, Auditing & Accountability Journal, 10(4), 532-561.

[4] Burritt, R.L., Hahn, T., Schaltegger, S., 2002. Towards a comprehensive framework for environmental management accounting. Links between business actors and environmental management accounting tools. Australian Accounting Review, 12 (2), 39-50.

[5] Farneti, F., & Guthrie, J. 2009. Sustainability reporting by Australian public sector organisations: why they report. Accounting Forum, 33(2), 89-98.

[6] Global Reporting Initiative (GRI) 2005. Sector supplement for public agencies. With an abridged version of the GRI 2002 Sustainability Reporting Guidelines.

[7] González-García, S., Berg, S., Feijoo, G., & Moreira, M. T. 2009. Environmental impacts of forest production and supply of pulpwood: Spanish and Swedish case studies. The International Journal of Life Cycle Assessment, 14(4), 340-353.

[8] Guthrie, J., & Farneti, F. 2008. GRI sustainability reporting by Australian public sector organizations. Public Money and Management, 28(6), 361-366.

[9] Guthrie, J., Ball, A., & Farneti, F. 2010. Advancing sustainable management of public and not for profit organizations. Public Management Review, 12(4), 449-459.

[10] Jasch, Ch, 2009. Environmental and Material Flow Cost Accounting: Principles and Procedures. Springer, Berlin.

[11] Koontz, T. M. 2007. Federal and state public forest administration in the new millennium: revisiting Herbert Kaufman's the forest ranger. Public Administration Review, 67(1), 152-164.

[12] Lamberton, G., 2005. Sustainability accounting: a brief history and conceptual framework. Account. Forum 29 (1), 7-26.

[13] Ministry of Environment, Energy and Climate Change, 2012. Activity Report of Forest Services for 2010 (in Greek).

[14] Ministry of Environment, Energy and Climate Change, 2013. Illegal logging events 2012. Available at (http://www.ypeka.gr/Default.aspx?tabid=390&sni[524]=2225&language=el-GR) (in Greek) (accessed on Feb 28th, 2013) (in Greek).

[15] Nakajima, M., 2006. The new management accounting field established by Material Flow Cost Accounting (MFCA). Kansai Univ. Rev. Bus. Com. 8, 1-22.
[16] Papaspyropoulos, K.G., Blioumis, V., Christodoulou, A.S., Birtsas, P.K., & Skordas, K.E., 2012. Challenges in implementing environmental management accounting tools: the case of a nonprofit forestry organization. Journal of Cleaner Production, 29-30, 132-143.
[17] Schaltegger, S., Burritt, R.L., 2011. Sustainability accounting for companies: catchphrase or decision support for business leaders? Journal of World Business 45 (4), 375-384.
[18] Sokos C., Birtsas P., Papaspyropoulos K., Kelesidou S., Billinis C. 2011. Galliforms releases in North, Central and Island Hellas. Proceedings of 15th Pan-hellenic Forestry Congress. Hellenic Forestry Society, 16–19/10/2011, Karditsa, Hellas.
[19] Sokos C., Birtsas P., Spyrou V., Iakovakis C.,Billinis C. 2013. Evaluation of hare rearing and release: obligations and techniques. Proceedings of 4th Hellenic Congress on Animal Production Technology, Thessaloniki, Greece, 8/2/2013, in press.
[20] Sokos, C. K., Birtsas, P. K., & Tsachalidis, E. P. 2008. The aims of galliforms release and choice of techniques. Wildlife Biology, 14(4), 412-422.
[21] Stamou, N.I., 2006. Economics of Natural Resources and Environment. Aristotle University of Thessaloniki (in Greek).
[22] Strobel, M., & Redmann, C. 2004. Flow cost accounting, an accounting approach based on the actual flows of materials. Environmental Management Accounting: Informational and Institutional Developments, 67-82.
[23] United States Department of Agriculture, 2007. USDA Forest Service Strategic Plan FY 2007-2012.

The role of accountants in controlling sustainability information

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Abstract: **Accountants' involvement in environmental and sustainability management has merely been investigated to date. With the continuous take-up of sustainability issues by companies and with the growing experience companies gain in dealing with this topic, this paper raises the question whether accountants have started to get more involved than previously reported and if yes, what their role is in sustainability accounting practice.**

Based on 58 interviews with corporate practitioners this paper firstly explores the roles in the sustainability accounting practice in companies which are considered to be leading in sustainability reporting in the UK and Germany. Secondly the role of professional accountants is analysed from a power theory perspective.

The main findings suggest that professional accountants are partially involved in sustainability accounting practice but mainly exert a gatekeeping role between sustainability managers and higher management.

Investigating the observed behaviour empirically can help improve sustainability accounting. Should it turn out that the accountants have no other option but to act like gatekeepers, accounting education will play a major role in overcoming this deficiency in the pursuit of improved sustainability knowledge and performance. If, on the other hand, it is the defensive stance of accounting professionals and the fear of losing power in corporate structures which motivates them to act as gatekeepers, mechanisms to motivate them to cooperate should be researched.

Although the large (or excessive) power of accountants has not been considered problematical, the empirical findings suggest that this statement might need rethinking if corporate sustainability is strived for.

I. INTRODUCTION

For the last two decades sustainability accounting and reporting and related management accounting and control approaches have been developed to create transparency about the unsustainability of corporate impacts [1] and to provide decision support for managing sustainability challenges [2]. Whereas the understanding of what sustainability accounting encompasses differs [3], [4] and its contribution in practice to tackling sustainability challenges is disputed [5], [6], most of the extant literature agrees that accountants should be involved in environmental and sustainability management [7], [8].

The role and involvement of accountants in conventional accounting have been well researched for several decades. Much less research examines with the role of accountants in sustainability accounting and reporting. The few publications in the area reveal that accountants are not or not sufficiently involved in managing environmental and sustainability information [7]-[12]. By highlighting the capabilities of accountants and the potential benefits of their involvement as well as the drawbacks and problems associated with the identified ignorance the extant literature has called for more involvement of accountants in sustainability accounting. Although the topic has regained interest more recently [9] newer empirical research on what role accountants actually play in corporate sustainability accounting practice is missing.

For the last decades sustainability accounting research has dealt with a large range of issues such as transparency [1], accountability [1], [13], stakeholder engagement [14], [15], the role of accounting for organizational change [16], [17], the development of accounting and management control methods [2] or the increasing number of companies dealing with sustainability reporting [18].

With the increasing number of academic, professional and practitioner-oriented literature on sustainability accounting and reporting [19] and the continuous take-up of sustainability issues by companies it can be expected that many organisations have gained more experience in dealing with sustainability accounting. Given these developments since the early empirical publications on the role of accountants in sustainability accounting, this paper raises the question whether accountants have now (finally) started to get more involved than previously reported and if yes, what their role is in sustainability accounting.

This paper explores the involvement of accounting professionals in corporate sustainability accounting practice and distinguishes three kinds of engagement – adaptive, constructive and defensive involvement – depending on the observed pattern of activities and the potential rationale behind these observations. The analysis is based on 58 interviews with employees who are specifically managing social and environmental information in companies which are considered to be among the leaders in sustainability reporting in the UK and Germany. The analysis draws on the literature of power in management [20]-[22] and the classification of promoter roles for innovations in organizations [23]-[28] and is used to develop an analytical framework for exploring the roles of accountants in sustainability accounting practice.

Researching the accountants' involvement may help to understand drivers and problems of engagement and contribute to improving sustainability accounting and its application in corporate practice. Depending on the kind of current involvement of accountants and the reasons that lead to it, conclusions may be drawn for accounting education or the communication to motivate accountants to get more involved.

The paper is structured as follows: Section 2 draws on the extant literature and highlights the demand for investigating the role of accountants in environmental and sustainability management. Section 3 frames the analysis in extant literature. The results are presented and discussed and discussed in Section 4.

II. Accountants' contribution to sustainability management

An ignorant approach to sustainability has inflicted serious financial damage upon numerous companies globally, including large ones. Sustainability issues have sometimes even threatened the existence of companies as for example illustrated for in the well-documented case of BP and its oil platform accident in the Gulf of Mexico [29]. The relevance of social and environmental performance for business cannot be denied any longer. Whilst managers are aware of the importance of informed decision making, accounting as a central information system of the company is recognized as an approach for tackling sustainability challenges [3], [6]. The generation of information provides a means by which organisations try to reduce uncertainty about their environment [30]. The accountants, being the professionals dealing with corporate accounting, are thus expected to potentially play an important role, firstly, in improving the information stakeholders receive about the social and environmental impacts of a company and, secondly, in improving how well managers are informed about sustainability issues.

Social and environmental accounting has enjoyed a growing popularity since the beginning of the 1990s [4] and the potential contribution of accountants to improve information management practices for sustainability management has been a research subject for well over a decade. The contributions range from what needs to be and what can be measured [1], to identifying what areas of business need to be revised [17] and to establishing corporate-wide sustainability accounting systems. The case for engaging accounting professionals in environmental and sustainability management has been made both implicitly [9]-[12] and explicitly [7], [31], [32]. The latter group can be cited as exceptions who expressed a less enthusiastic view about accountants' and auditors' involvement in sustainability accounting practice. The understanding of what comprises sustainability accounting and what the role of accountant could or should be, have however varied, as have the interpretations of potential benefits to organisations and society [1], [3].

Given the large impact companies exert on nature and society with their production processes and products, sustainability accounting and reporting should aim at creating transparency and accountability to stakeholders to enable and motivate an informed debate about how sustainable development could be achieved [6], [14], [15]. Accountants, in this view, should primarily collect sustainability information to serve societal interests and create transparency and accountability to external stakeholders.

Also the relevance of social and environmental accounting for company-internal decision making has been addressed in literature. An improved information basis to make more sustainable decisions, the recognition of important business aspects, higher efficiency and lower costs of production, and a potential legitimacy gain are some of the most commonly cited benefits [33]-[35]. Consequently, various sustainability accounting tools and methods have been developed and adaptations of conventional accounting tools to fit the needs of sustainability managers have been made [34]. From such a decision oriented perspective, the role of accountants is to design sustainability management accounting systems, collect sustainability information, and inform management to make more sustainable decisions.

Taken together prior sustainability accounting research provides societal as well as business reasons to involve accounts in sustainability accounting. Whether for accountability and transparency reasons or for internal decision making reasons, accountants are called for involvement in collecting social and environmental information.

Earlier empirical research has observed a discrepancy between the professionals engaged in environmental and sustainability management and those dealing with accounting; and it concludes that accountants are not or merely involved in dealing with sustainability. Newer empirical research on the involvement and role(s) of accountants in sustainability accounting is however missing. In spite of recognising the potential benefits of adopting and applying sustainability accounting, the role of accountants in today's corporate practice remains empirically under-researched.

III. Promotors, champions, gatekeepers…

The power and expertise functions identified with regard to the adoption and implementation of sustainability accounting have not been subject to an extensive discussion so far. Practitioners have been observed to not see accounting as a purely technical activity which is objective, factual and neutral. Instead, they see it as a social activity and draw on the differentiation of objective, subjective, inter-subjective, and positional meanings in explaining how accountants construct practice within specific social contexts. By interpreting sustainability information into a language understood by senior management, the uptake of sustainability issues and the importance of sustainability performance are brought to the immediate attention of senior management, whose commitment is essential for the success of activities.

The following analysis of the accountants' roles in sustainability accounting is informed by the literature on power in management and research on the role of champions [23]-[28] for organizational and innovation development in organizations.

As discussed above, in their supportive function, accountants can be seen as experts and methodological promoters who create awareness in an organization that sustainability information should and can be collected. Champions of organizational innovations unveil problems in the organization, i.e. in the case of sustainability accounting the problems related to missing sustainability information, and they support the introduction of innovations [27], [28], in our case sustainability accounting processes and methods. As juxtaposition to these promotion roles, accountants can also act as gatekeepers.

"It is my thesis that problems of implementation are, in many instances, problems in developing political will and expertise – the desire to accomplish something, even against opposition, and the knowledge and skills that make it possible to do so" [21].

Particularly Jeffrey Pfeffer's notable research on power in organisations has been a source of motivation for extended research in the field. His work summarises various organisational phenomena related to power. Against this background, accounting departments have been identified as loci of enhanced control and power because of the potential 'uncertainty-reducing' information which they are able to define, possess or generate [42]. The establishment of information management systems in other departments such as marketing or production could therefore be read as an instance of decentralisation and a shift in relative power away from accounting as a centre of organisational power. Accountants, being a part of the system of professions, have strived to defend and expand their area of jurisdiction and power in competition with rival professions.

Challenges to the accountancy profession do not, however, come only from those who seek to occupy its territory. Challenges also come from journalists, academics, politicians and others who have no desire to occupy the territory of accountants but can nevertheless advance some competing discourses that may disrupt and weaken the profession's capacity to secure and expand its domain. In the process of defining, defending and extending its jurisdiction, the accountancy profession attaches considerable importance to its image of 'independence'. Thus accountants need to develop mechanisms to retain their power in organisations. One such possibility is by acting as gatekeepers.

Perceived as a small group of organisational actors whose structural position suggests that they share an interest in coordination and community organisation, gatekeepers and the phenomenon of gatekeeping have been subject to extensive research in both managerial and social science. In both cases, gatekeeping is considered a form of brokerage, i.e. a process by which intermediary actors facilitate transactions between other actors lacking access to or trust in one another.

Any brokered exchange can thereby be thought of as a relation involving three actors, two who are the actual parties of the transaction and one who is the intermediary or broker. Brokerage as the act of facilitating exchange is usually rewarded with a 'commission' but can also be used to obtain or exert power. There are numerous examples of intermediaries whose reward for brokerage services is diffuse or even non-existent. Since accountants clearly facilitate transactions or information and resource flows, they can be viewed as brokers regardless of whether or not they attempt to extract a commission as direct reward. Furthermore, the existence of empirical evidence that brokerage potential is actually an accurate predictor of influence and thus power, makes the investigation of the accountant's role in the context of sustainability accounting even more relevant.

With very few exceptions [34] the gatekeeping function of the accountant has hardly been subject to research. On the contrary, a few studies implicitly identify the necessity to involve management accountants in various emerging areas (such as sustainability management and accounting) precisely for their potential as gatekeepers [7], [37]. When analysing the accountants' roles in sustainability accounting it thus seems necessary to also consider the role of being a gatekeeper of sustainability information in the organisation.

This raises the essential question whether the accountants' involvement in sustainability accounting may reflect more a gatekeeping power role than a promotion role as often emphasized with regard to their technical abilities, acquired during studies, training, etc.

IV. DISCUSSION AND CONCLUSION

The empirically observed activities of accountants in sustainability accounting practice reveals an interesting trait. The accountant's involvement in directing data generation and communicating information to higher management shows that accountants are in fact involved in sustainability accounting, although less compared to other professionals such as sustainability or general managers. The results suggest that accountants are involved in sustainability accounting in a way that has not been investigated in literature to date: accountants act as gatekeepers and as methods and organizational experts.

From a gatekeeper viewpoint, the definition of indicators and the provision of this information to decision makers on higher hierarchy levels can be seen as exercising power. Applying technical capabilities in the process of information management, on the other hand, can be mainly attributed to general and sustainability managers. Whereas various studies [38], [39] reveal that other functions such as sustainability or middle managers are largely in charge of sustainability accounting, these studies do not analyse the gatekeeping function of accounting professionals.

With the sustainability discussion gaining relevance for corporate activities, a change in accounting is observed to be taking place. A change in accounting systems and methods, however, results in a shift in power [40]. Thus, sustainability information and information handled by sustainability accounting has not only the potential to affect the performance of a company but also to change its power order. Although sustainability management is designed and should be carried out in the best interest of the company – i.e. to improve its overall performance – separate individuals or groups of individuals may not perceive the involved necessary changes as desirable. Hence, certain actors, such as accountants, may focus on gatekeeping [41]-[43] of sustainability information in an attempt to influence the practice and relevance of sustainability accounting – e.g. the information collected, the type of information certain recipients get, the ways in which the information is generated, etc.

Investigating the observed behaviour empirically can help improve sustainability accounting. Should it turn out that the accountants have no other option but to act like gatekeepers, accounting education will play a major role in overcoming this deficiency in the pursuit of improved sustainability knowledge and performance. If, on the other hand, it is the defensive stance of accounting professionals and the fear of losing power in corporate structures which motivates them to act as gatekeepers, mechanisms to motivate them to cooperate should be researched. An example of the latter could be the motivation to improve overall sustainability performance rather than focusing on purely financial measures.

A hesitant involvement of accountants in sustainability accounting may not be seen as problem. If accounting is a set of skills taught in accounting education, the sustainability accounting skills can also be learnt and applied by other functions with sufficient interest in sustainability issues. This view, however, neglects both the role and the power of accountants in the organizational networks, information management and management decision making. It is not necessarily accountants who develop the sustainability equivalent to the complex ROI model, as accountants lack expertise in what constitutes good sustainability performance [44]. Mathews [8] goes as far as to criticise management for authorising "the accounting function to produce social and environmental information, even when the accounting profession does not show any interest" - and we might add, the accountants may neither be willing nor sufficiently trained to understand sustainability issues.

An important consideration may thus be the large (or excessive) power of accountants who play a major role in providing sustainability information to decision makers on higher hierarchy levels. Although this has not been considered problematical [45], our empirical findings suggest that this statement might need rethinking.

References

[1] Gray, R.H., Owen, D. & Adams, C. (1996). Accounting & Accountability. Prentice Hall.

[2] Henry, J. & Journeault, M. (2010). Eco-control. The influence of management control systems on environmental and economic performance. Accounting, Organizations and Society, 35, 63–80.

[3] Burritt, R.L. & Schaltegger, S. (2010). Sustainability accounting and reporting: fad or trend? Accounting, Auditing & Accountability Journal, 23(7), 829–46.

[4] Parker, L.D. (2011). Twenty-one years of social and environmental accountability research: A coming of age. Accounting Forum, 35, 1–10.

[5] Medley, P. (1997). Environmental accounting. What does it mean to professional accountants? Accounting, Auditing and Accountability Journal, 10(4), 594–600.

[6] Bebbington, J. & Gray, R. (2001). An Account of Sustainability: Failure, Success and a Reconceptualization. Critical Perspectives on Accounting, 12(5), 557–588.

[7] Davey, H. & Coombes, R. (1996). A review of accountant and corporate involvement in environmental accounting in New Zealand. Asian Review of Accounting, 4(2), 100–124.

[8] Mathews, M.R. (1997). Twenty-five years of social and environmental accounting research: Is there a silver jubilee to celebrate? Accounting, Auditing & Accountability Journal, 10(4), 481–531.

[9] Christian, J. (2001). Wherefore the missing management accountant? Mapping Metaphysical Worlds.

[10] Benston, G.J. (1982). Accounting and corporate accountability. Accounting, Organizations and Society, 7(2), 87–105.

[11] Schreuder, H. & Ramanathan, K. (1984). Accounting and corporate accountability: A postscript. Accounting, Organizations and Society, 9(3–4), 421–423.

[12] Gray R.H., Bebbington, K.J. & Walters, D. (1993). Accounting for the Environment: The greening of accountancy. Part II. London: Paul Chapman.

[13] Burritt, R. (2012). Environmental performance accountability: planet, people, profits. Accounting, Auditing, and Accountability Journal, 25(2), 370–405.

[14] Bebbington, J., Brown, J., Frame, B. & Thomson, I. (2007). Theorizing engagement: the potential of a critical dialogic approach. Accounting, Auditing & Accountability Journal, 20(3), 356–381.

[15] Gray, R., Bebbington, J. & Collison, D. (2006). NGOs, civil society and accountability: making the people accountable to capital. Accounting, Auditing & Accountability Journal, 19(3), 319–348.

[16] Larrinaga-González, C., Carrasco-Fenech, F., Caro-González, F., Correa-Ruíz, C. & Páez-Sandubete, J. (2001), The role of environmental accounting in organizational change. An exploration of Spanish companies. Accounting, Auditing & Accountability Journal, 14(2), 213–239.

[17] Burritt R. (2004). Environmental management accounting: roadblocks on the way to the green and pleasant land. Business Strategy and the Environment, 13, 13–32.

[18] Bebbington, J., Larrinaga, C. & Moneva, J. (2008). Corporate social reporting and reputation risk management. Accounting, Auditing & Accountability Journal, 21(3), 337–361.

[19] Parker, L.D. (2005). Social and environmental accountability research: A view from the commentary box. Accounting, Auditing & Accountability Journal, 18(6), 842–860.

[20] Mintzberg, H. (1983). Power In and Around Organizations. Englewood Cliffs, NJ: Prentice-Hall.

[21] Pfeffer, J. (1992). Managing with power: Politics and influence in organizations. Harvard Business School Press, Boston.

[22] Pfeffer, J. (2010). Power: Why Some People Have It - and Others Don't, HarperBusiness.

[23] Chakrabarti, A.K. (1974). The role of champions in product innovation. California Management Review, 17, 58–62.

[24] Witte, E. (1977). Power and innovation: a two center theory. International Studies of Management and Organization, 7, 47–70.

[25] Hauschildt, J. & Kirchmann, E. (2001). Teamwork for innovation. The 'troika' of promotors. R&D Management, 31(1), 41–49.

[26] Hauschildt, J. & Schewe, G. (2000). Gatekeeper and process promotor: key persons in agile and innovative organizations. International Journal of Agile Management Systems, 2(2), 96–103.

[27] Hauschildt, J. (2003). Promotors and champions in innovation. Development of a research paradigm, in: Shavinina, L. (Ed.): The international handbook on innovation, Oxford: Elsevier, 804–814.

[28] Fichter, K. (2009). Innovation communities. The role of networks of promotors in open innovation. R&D Management, 39(4), 357–371.

[29] Lüdeke-Freund, F., & Zvezdov, D. (2013). The Manager's Job at BP: Decision Making and Responsibilities on the High Seas. International Journal of Case Studies in Management.

[30] Daft, R.L. & Lengel, R.H. (1986). Organizational Information Requirements, Media Richness and Structural Design. Management Science, 32(5), 554–571.

[31] Zvezdov, D., Schaltegger, S. & Bennett, M. (2010). The Increasing Involvement of Accountants in Corporate Sustainability Management. Journal of the Asia-Pacific Centre for Environmental Accountability, 16(4), 20–31.

[32] O'Dwyer, B. & Owen, D. (2007). Assurance statement practice in environmental, social and sustainability reporting: a critical evaluation. The British Accounting Review, 37, 205–229.

[33] Bennett, M. & James, P. (2000). The Green Bottom Line: Environmental Accounting for Management: Current Practice and Future Trends. Greenleaf Publishing, Sheffield, UK.

[34] Burritt, R., Hahn, T., & Schaltegger, S. (2002). Towards a Comprehensive Framework for Environmental Management Accounting. Links Between Business Actors and Environmental Management Accounting Tools. Australian Accounting Review, 12(2), 39–50.
[35] Schaltegger, S. & Burritt, R. (2010). Sustainability Accounting for Companies. Catchphrase or Decision Support for Business Leaders? Journal of World Business, 45(4), 375–384.
[36] Coffee, J.C. (2006). Gatekeepers: The Role of the Professions in Corporate Governance: The Professions and Corporate Governance, Oxford University Press.
[37] Flesher, D.L. & Zanzig, J.S. (2000). Management accountants express a desire for change in the functioning of internal auditing. Managerial Auditing Journal, 15(7), 331–337.
[38] Bennett, M., Schaltegger, S. & Zvezdov, D. (2012). Exploring the Corporate Reality of Sustainability Accounting Practice, in: Sustainable Economy. Helsinki Metropolia University of Applied Sciences, Helsinki.
[39] Burritt, R., Schaltegger, S. & Zvezdov, D. (2011). Carbon Management Accounting. Australian Accounting Review, 21(1), 80–98.
[40] Bariff, M.L. & Galbraith, J.R. (1978). Intraorganizational power considerations for designing information systems. Accounting, Organizations and Society, 3, 15–27.
[41] Pettigrew, A.M. (1972). Information Control as a Power Resource. Sociology, 6, 187–204.
[42] Bloomfield, B.P. & Coombs, R. (1992). Information technology, control and power: the centralization and decentralization debate revisited. Journal of Management Studies, 29, 459–484.
[43] Mechanic, D. (1982). Sources of power of lower participants in complex organization. Administrative Science Quarterly, 7, 349–364.
[44] Schaltegger, S. & Burritt, R.L. (2000). Contemporary Environmental Accounting: Issues, Concept and Practice. Sheffield: Greenleaf.
[45] Hopper, T.M. (1980). Role conflicts of management accountants and their position within organisation structures. Accounting, Organizations and Society, 5(4), 401–411.

The role of consultants in disseminating environmental management accounting in a developing country context

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Abstract: **Previous research on the diffusion of environmental accounting within developing countries has focused on the role of accountants and accountancy bodies as well as governments. This exploratory study investigates the external consultant's role in disseminating environmental management accounting (EMA) within a developing country context. We develop a framework consisting of eight different roles assumed by consultants from a review of the consultancy literature. We use this framework to explore how consultants in the Philippines contribute to disseminating EMA. Our study is based on interviews with highly experienced environmental consultants from the Philippines. To inform our understanding why certain roles may be more apparent than other roles, we rely on institutional and economic perspectives of EMA development and implementation within companies.**

Keywords: **Environmental management accounting, consultants, dissemination, developing country, Philippines**

I. INTRODUCTION

Previous research on the diffusion of environmental accounting within developing countries has focused on the role of accountants and accountancy bodies (e.g. [1], [2]) as well as governments (e.g. [3]). This exploratory study investigates the external consultant's role in disseminating environmental management accounting (EMA) within a developing country context. We develop a framework consisting of eight different roles assumed by consultants from a review of the consultancy literature. We use this framework to explore how consultants in the Philippines contribute to disseminating EMA. We analyse the data obtained by interviews with five highly experienced environmental consultants from the Philippines. To inform our understanding why certain roles may be more apparent than other roles, we rely on institutional and economic perspectives of EMA development and implementation within companies.

II. PERSPECTIVES IN THE DISSEMINATION OF EMA

Qian and Burritt [4] point out to two main fields of literature addressing the causes for the rise of EMA. While studies undertaken by Klassen and McLaughlin [5] and Bennett et al. [6] explore the implementation and dissemination from the economic rationality perspective, researchers including Boons and Strannegard [7], Ball [8], Qian and Burritt [4] and Bouma and Van Der Veen [9] focus on social theories to reconnoitre the relationship between organisations' adoption of EMA and the pressure and norms prevailing within the social boundary in which the organisations operate.

The economic rationality perspective focuses on the application of EMA tools and techniques with the objective of augmenting the financial bottom-line achievable by reducing costs and risks resulting in lower likelihood of financial outlay through fines and penalties and providing means of earning additional revenue (such as selling carbon credits) (e.g. [10]-[12]). Herzig et al. [12] note EMA's usefulness in allowing organisations attain operational efficiency, make strategic investment decisions, and undertake eco-efficiency measures facilitating cleaner production practices. For instance, the material flow cost accounting (MFCA) technique is applied to study the costs (i.e. the monetary aspects) associated with the production processes including the material input cost, product and non-product cost and waste/wastewater disposal cost. This is seen to be beneficial from the corporate decision-making perspective as it brings to the forefront the major cost drivers associated with the production processes and the impact on the bottom-line thereby encouraging a review of the steps to allow for potential newer efficient technologies or introduction of new practices to improve both environmental and financial performance.

The development and dissemination of EMA through the institutional lens can be discussed in accordance with the regulatory, normative and cognitive institutional pillars [13] and in relation to the mechanisms through which information of acceptable behaviour or practice is transmitted (coercive, normative, mimetic pressures; [14], [15]).

Qian and Burritt contend that regulatory pressure and enforcement provide the "strongest incentive for environmental actions" undertaken by organisations [4, p. 238]. Studies have indicated that environmental regulations enacted by governments have provided extensive stimulus for organisations to improve practices in environmental management [16] and EMA [17]. In a similar study, Milstein et al. [18] pointed out to the direct relationship among coercive pressure (weak) and environmental strategy implementation (fewer) (see also [19]).

In the Philippines, up until the late 1980s, the regulatory approaches were mainly directed towards controlling pollution rather than preventing it [20]. In the 1990s and 2000s, the government introduced policies and regulatory approaches which were framed by considering the principles of sustainable development and aimed at achieving socio-economic development as well as environmental improvement and protection through self-regulation [10]. The environmental agency has also introduced several innovative policy measures and programmes (market-based mechanisms, public private partnership models); however, as Pascual [20] notes, such programmes may not be legally enforced but are introduced to encourage proactive environmental practices by the private sector. These more recent developments include EMA based information strategies such as pilot projects on innovative cleaner production methods [3] and a guidebook on environmental management and environmental cost accounting published by the Environmental Management Bureau of the Philippines [21]. To summarise, while the earlier approaches emphasised industrial compliance with environmental standards imposed by the government, more recent approaches to promoting environmentally friendly business practices signify a shift from the emphasis on compliance for pollution control to proactive environmental management practices founded on the principles of pollution prevention and sustainable development.

Diffusion of EMA tools and techniques within and across organisations can also happen through collective shared beliefs and values. As emphasised by Scott [13], organisations might be compelled to follow the will imposed by the society and organisations feel obligated to conform to social expectations to earn the right to operate or in other words gain social legitimacy. As pointed out by Qian and Burritt [4, p. 239] it is 'appropriateness' that drives organisations to conform to social norms or values. They refer to DiMaggio and Powell [15] conviction that social changes and expectations shape the social norms and that professional development and training contributes to the norms and values getting embedded into activities undertaken by different professionals.

Emphasising the relationship between environmental pressures emanating from the society and the organisation's commitment to environmental stewardship, Boons et al. [7] in their study that incorporated the notion of institutionalisation argued that social pressure has the potential to contribute to organisational 'greening' [4, p., 239]. Ball's [8] study confirms that when society places high expectations for protecting the environment, evident from the Canadian case, EMA has been adopted by organisations to ensure conformity with social expectations.

Several scholars have pointed out to the role of accountants, auditors and accounting-related professionals in promoting environmental accounting through education and practice in various developing countries [1], [2], [22]. In the Philippines, some aspects of EMA have been integrated into undergraduate accountancy education and continuing professional development; mainly driven by the country's organisation of accountants, the Philippines Institute of Certified Public Accountants [22]. Still, whilst there seems to be a slightly advanced status of EMA dissemination in the Philippines relative to other developing countries of South East Asia [22], the institutionalisation of EMA within and through professional accountancy bodies appear to have taken place slowly and research in this area can be seen as being underdeveloped [2].

Whilst research on the dissemination of EMA through the diffusion of norms, values and acceptable organisational practice have been studied with regard to the role of accountants and accountancy bodies, the consultant's roles in disseminating EMA has not achieved much attention so far. Research undertaken by Young et al. [23] on the corporate social responsibility (CSR) consultancy industry in the UK however has provided ground for assuming that consultants can play an important role in the diffusion and adoption of socially-responsible business practices. As pointed out by Young et al. [23], apart from diverse channels or modes of exchanges through which socially-responsible business practices can be disseminated (e.g. business networks, membership organisations), consultants can provide a crucial mean through which recipient organisations can obtain ideas or services for enhanced responsible business practice. One may argue that this role might even more be more critical in a developing country context where institutional developments in the area of CSR and the environment are a more recent phenomenon and less advanced (e.g. CSR ASEAN) and where the majority of companies (apart from very large and multinational companies) might not have their own CSR/environmental management department or a strategically embedded approach to socially responsibility (which could be mobilised by organisations for enhanced integration of these new and emerging practices, see e.g. Boiral [24]). It is the role consultants tend to perform in improving management practices, which we now turn to.

III. Conceptual Framework: The Roles of Consultants

Consultants have been identified as professionals providing "advisory service to client managers and organisations in achieving organisational purposes and objectives by solving management and business problems, identifying and seeing new opportunities, enhancing learning and implementing changes" ([25], p. 8) "on a fee for service basis" [26, p. 22]. They assume diverse roles which include their functions as *problem solver* ("by solving management and business problems"), *facilitators of organisational learning* ("enhancing learning and implementing changes") and as *standard setters* ("identifying and seeing new opportunities") [27]-[29]. Furthermore, from our literature review we can identify five other roles. These include their roles as *knowledge transferer* (by disseminating business knowledge through ideas, tools, etc.), *knowledge broker* (by sharing experiences across industries), *technology transferer* (by transferring technological know-how), *facilitators of organisational capacity building* (by strengthening client's internal competences) and as the *'legitimator' of decision makers* (by implementing or legitimising certain managerial actions or plans otherwise unpopular) [30]-[34]. Hence, our framework consists of eight different roles through which consultants can contribute to the dissemination of novel business practices or management concepts.

Based on this framework, we explore the diffusion of EMA ideas and techniques in a developing country context, namely the Philippines, and discuss how external consultants spread EMA ideas and concepts within and across companies. To inform our understanding why certain roles may be more apparent than other roles given the Filipino socio-economic context, we will rely on the institutional theoretical and economic rationality perspectives on EMA development and implementation within companies. The methodology is outlined next.

IV. Methodology

To explore how consultants might contribute to the dissemination of EMA within the Philippines we analyse the data obtained by interviewing five environmental consultants. The qualitative approach with an interpretive stance is ideal assumed in this context as it permits the researcher to obtain a deeper understanding of the issue or topic under study that otherwise is not possible through quantitative methods [35]. In order to "enhance the appropriateness of sampling and adequacy of information gathered", a combination of sampling strategies has been adopted in this study [36, p. 726]. These include purposeful or judgemental sampling in addition to snowball sampling strategy [37]. Out of 36 consultants invited to participate in the study, five environmental consultants who are highly experienced and on average have sixteen years of environmental consultancy experience across different industrial sectors in the Philippines took part in the study. Semi-structured interviews closely resembling the Focussed Interview type, ranging between 36 minutes to 75 minutes, were undertaken [38, p. 75]. All interviews were audio recorded and transcribed for subsequent analysis. To systematically analyse interview data, a codebook was developed whereby relevant pieces of information were segregated and categorized into pre-determined and emerging code groups.

V. Results

Our findings indicate that consultants appear to play an important role in *transferring knowledge* in the form of ideas and tools which allow companies to learn about EMA practices such as emissions measurement as well as waste and related cost control. Closely related to this are the roles as *problem solver* and *technology transferer* where the consultants provide solutions to their clients mostly in response to external codes and standards. For example, interviewees referred to waste water treatment and waste treatment facilities, the generation of electricity from waste which resulted in cost savings and pollution prevention, and carbon footprinting. The following quote also illustrate some of these points.

> We advise them what are the right mitigating measures for them to address the impacts of their businesses and other than that we also give them an idea by improving their monitoring systems on how they could account for the emissions [...]. (EC1)

As this quote shows, during the course of a project, consultants might adopt different, successive roles (such as knowledge transferer and problem solver; see [39]). This can also include the role of technology transferer, as one interviewee stated,

> [...] so aside from measuring the emissions that they have we have also given them some workable solution in order to comply. Not on only in principles but also in actual constructions of waste control devices. (EC3)

Depending on the organisational dimensions of the consulting companies, a team of consultants can be involved or the consultant collaborates with other external parties to implement EMA in practice. However, it appears that it is often the 'business knowledge' of how to comply with environmental regulations through EMA application that is transferred. The majority of the interviewees emphasised that knowledge transfer as well as problem solving is mostly confined to making recommendations and implementing such endorsements upon approval from clients with regard to complying with the environmental regulations and standards. Therefore, on the one hand, legal compliance is viewed to positively influence organisations in the Philippines to adopt EMA tools and techniques such as environmental impact assessment and material flow accounting. On the other hand however, the interviewees pointed out to restrained possibilities to promote EMA particularly to small and medium sized enterprises due to ineffective enforcement of environmental regulations.

> It is not unusual for them not to comply. Especially if no one is looking. (EC5)

It was further argued that complying with standards is seen to be dependent on the cost factor and if the cost of compliance is higher than the penalties imposed by government, client organisations would consider the latter approach rather than complying with standards.

> [...] sometimes it is very frustrating because even though that you know that you are transferring the information to the client, most of the clients totally ignore it because it will cost money in order to bring the gap together and comply with the emission controls. (EC3)

Apart from regulatory pressure, MNCs and large companies are seen to put pressure on their supply chain to adopt sound environmental management practices which leads to an enhanced take-up of EMA tools and techniques. MNCs themselves are often seen possessing the necessary capability and culture to comply and adopt environmentally friendly practices which is also framed as a response to "internal" pressure, as interviewee EC2 explained,

> So this [multinational] company is known to be very sensitive to environmental movement all over the world so they wanted to make sure that their plant is not giving out environmental pollutants which will definitely be considered a violation against the clean air act. (EC2)

Although there was the view that,

> The role of the consultant there is that once the company starts to comply with the environmental laws, the regulations, then you have your information ready with you. It's the start of it. Meaning they want to comply and maybe they want to move further ahead with their operations. […] it's the start for them to move into efficiency accounting system […] that's the route of the development of our assistance. (EC5)

the overall picture painted by the findings is that of Filipino organizations being at an early stage of environmental development, focussing specifically on the compliance aspect (reactive mode, [40]) and portraying features of a strong defender client [41]. As one would expect in the context of such strategic stances not all roles described in the framework have found their significance. For example, the consultant's role of *knowledge broker*, providing a diverse set of solutions based on experiences of solving different problems from different industries was hardly evident in the data. As Canato and Giangreco [40] state, knowledge brokers support the generation of original ideas and help customers (e.g. prospector clients) to innovate and differentiate themselves from competitors.

Closer analysis of the consultants' strategies to influence the adoption of EMA within a context characterized by clients' reactive and defensive stances to environmental management shows that collaboration with governmental bodies is sought by the consultants. Most of the consultants seem to hope that this might provide a source of legitimacy and way to build up a discourse to progress standardization of EMA tools and techniques used in industry, for which they can offer assistance. While the interviewees seem to be interested in convincing clients of the indispensible nature of EMA tools they propose and for example receive support in organizing joint training workshops, there is also a broader interest in this relationship. The consultant's role in the relationship between the government and the corporate sector could be described as one of an *intermediary* that will benefit both corporations as well as the government [17]. As pointed out by one participant, there is a need to inform the regulators about the problems faced by companies to comply with the standards and apply EMA tools and techniques. The regulators could learn about the difficulties faced by corporations and accordingly bring appropriate changes to the environmental policies, suggesting the consultant's role as a contributor to policy making. One interviewee said:

> "It's really important for the consultant to be part of [...] at least to guide the local government or the government into how to regulate the industry [...] that can serve as the bridge.

VI. Discussion and conclusion

Client organisations' reliance on obtaining knowledge from external sources such as consultancies has been highlighted in previous studies [42], [43]. Our findings echo this general observation in that the consultant's roles as the knowledge and technology transferer as well as problem solver appear to be significant for advancing new perspectives in and approaches to accounting and managing for the environment to the client organisations.

However, based on the perspectives of the interviewees, the reasons why clients approach consultants, is often to find out ways to comply with the standards and not to enquire about more advanced and proactive sustainable environmental practices. The interviewees indicated that this is due to the tendency of higher management not to appreciate EMA and the associated tools beyond the compliance aspects. It was apparent from the interviews that EMA is not recognised as an integrated management decision making tool by corporate managers. Arguably, this is because client organisations are still at early stages (reactive modes) of environmental development and focussing specifically on the compliance aspect.

The study also explores and discusses further roles adopted by consultants when advancing EMA application within and across companies. It shows that consultants assist companies to obtain higher quality information for use in environmental management and control process; facilitate companies to learn about the environmental impacts of organisational activities as well as provide assistance to organisational capacity building, albeit to a limited extent; and shows how consultants aim to increase their legitimacy and reputation as a standard setter through highly visible relationships with governmental institutions. A new type of role referred to as the intermediary has been identified in the context of the study. We argue that the 'bridging' function between the government and the private sector has not featured prominently in previous literature on consultancy because of institutional reasons, i.e. the prevailing focus on developed and industrialised countries within research on consultancy. Moreover, this role might be of substantive use for policy makers and the shift in environmental regulation towards a more proactive stance of the corporate sector in alleviating environmental problems and undertaking a broader range of environmental management initiatives. Further interviews are planned to be carried out in order to advance the study.

References

[1] S.K. Lodhia, "Accountants' responses to the environmental agenda in a developing nation: an initial and exploratory study on fiji," *Critical Perspectives on Accounting,* vol. 14, pp. 715-737, 2003.

[2] N. Kuasirikun, "Attitudes to the development and implementation of social and environmental accounting in Thailand", *Critical Perspectives on Accounting* 16(8), 1035-1057, 2005.

[3] R.L. Burritt, C. Herzig, and B.D. Tadeo, "Environmental management accounting for cleaner production: The case of a Philippine rice mill", *Journal of Cleaner Production* 17(4), 431-439, 2009.

[4] W. Qian, and R.L. Burritt, "The Development of Environmental Management Accounting: An Institutional View", in *Environmental Management Accounting for Cleaner Production*, Schaltegger S., Bennett M., Burritt R.L., and Jasch C., Eds. *Environmental Management Accounting for Cleaner Production*, Dordrecht, Springer, 2008.

[5] R. Klassen, and C. McLaughlin, "The Impact of Environmental Management on Firm Performance", *Management Science* 42, 1199-1214, 2006.

[6] M. Bennett, P. James, and L. Klinkers, *Sustainable Measures: Evaluation and Reporting of Environmental and Social Performance*, Greenleaf Publishing, Sheffield, 1999.

[7] F. Boons, L. Baas, J. Bouma, A. Groene, and K. Le Blanch, *The Changing Nature of Business: Institutionalisation of Green Organisational Routines in the Netherlands 1986–1995*, International Books, Utrecht, 2000.

[8] A. Ball, "Environmental Accounting and Change in UK Local Government", *Accounting, Auditing & Accountability Journal* 18, 346-373, 2005.

[9] J. Bouma, and M. Van Der Veen, "Wanted a Theory for Environmental Management Accounting", in *Environmental*

Management Accounting: Informational and Institutional Developments, Bennett M., Bouma J., and Wolters T., Eds., Kluwer, Dordrecht, 2002.

[10] C. Herzig, T. Viere, S. Schaltegger, and R.L. Burritt, *Environmental Management Accounting Case Studies of South-East Asian Companies*, Routledge, Oxon, 2012.

[11] S.L. Berman, A.C. Wicks, S. Kotha, and T.M. Jones, "Does Stakeholder Orientation Matter? The Relationship between Stakeholder Management Models and Firm Financial Performance", *Academy of Management Journal* 42, 486-506, 1999.

[12] S. Hart, "A Natural-resource-based View of the Firm", *Academy of Management Review* 20, 986-1014, 1995.

[13] W. Scott, *Institutions and Organisations,* 2nd ed., Sage Publications, Thousand Oaks, 2001.

[14] J.W. Meyer, and B. Rowan, "Institutional Organizations: Formal Structure as Myth and Ceremony", *American Journal of Sociology* 80, 340-363, 1977.

[15] P.J. DiMaggio, and W.W. Powell, "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields", *American Sociological Review* 48, 147-160, 1983.

[16] J. Newman, and K. Breeden, "Managing in the Environmental Era: Lessons from Environmental Leaders", *Journal of World Business* 27, 210-221, 1992.

[17] A. Mia, "Implementing Environmental Management Accounting: Status and Challenges", Eco-Efficiency in Industry and Science 18, 297-320, 2005.

[18] M. Milstein, S. Hart, and A. York, "Coercion Breeds Variation: The Differential Impact of Isomorphic Pressures on Environmental Strategies", in *Organisations, Policy and the Natural Environment: Institutional and Strategic Perspectives*, Hoffman A., and Ventresca M., Eds., Stanford University Press, Stanford, 2002

[19] S. Dasgupta, H. Hettige, D. and Wheeler, "What Improves Environmental Performance? Evidence from Mexican Industry", *The World Bank Development Research Group, Policy Research Working Paper*, Issue 1877, 1-25, 1998.

[20] R.V.J. Pascual, "Impacts of Philippine Environmental Regulatory Policies on PNOC-EDC's Corporate Environmental Management Initiatives", *Proceedings World Geothermal Congress, Antalaya, Turkey*, 1-7, 2005.

[21] Environmental Management Bureau (EMB), *Guidebook on Environmental Management System, Pollution Prevention/Cleaner Production and Environmental Cost Accounting*, EMB, 2003.

[22] M.F. Reyes, "Environmental Management Accounting Education in the Philippines: The Accountancy Profession as a Medium for Change", *Journal of the Asia Pacific Centre for Environmental Accountability* 7, 7-11, 2001.

[23] A.F. Young, J. Moon, J., and R. Young, "The UK Corporate Social Responsibility Consultancy Industry: A Phenomenological Approach", ICCSR Research Paper Series, 2003.

[24] O. Boiral, "Tacit Knowledge and Environmental Management", *Long Range Planning* 35, 291-317, 2002.

[25] M. Kubr, *Management Consulting: A Guide to the Profession,* 3rd ed., Geneva: International Labour Office, 1996.

[26] J.G. March, "Organisational consultants and organisational research", *Journal of Applied Communication Research*, June, 20-31, 1991.

[27] G.P. Huber, "Organizational learning: the contributing processes and the literatures," *Organization Science* 2, 88-115, 1991.

[28] A.B. Antal, and C. Krebsbach-Gnath, "Consultants as agents of organizational learning: The importance of marginality," in *Handbook of Organizational Learning,* M. Dierkes , A.B. Antal A, J. Child and I. Nonaka, Eds., Oxford, Oxford University Press, 2003.

[29] E. Abrahamson, "Management fashion", *Academy of Management Review* 21, 254–285, 1996.

[30] A. Kieser, "On communication barriers between management science, consultancies and business organizations," in *Critical Consulting*, T. Clark and R Fincham, Eds. Oxford, Blackwell, 2003.

[31] W.H. Starbuck, "Learning by knowledge intensive firms", *Journal of Management Studies* 6, 713-740, 1992.

[32] J. Bessant, and H. Rush, "Building bridges for innovation: the role of consultants in technology transfer," *Research Policy* 24, 97-114, 1995.

[33] J. Kitay, and C. Wright, "Take the money and run? Organisational boundaries and consultants' roles," *The Service Industries Journal* 24, 1-18, 2004.

[34] R. Jackall, *Moral Mazes: The World of Corporate Managers*, , New York: Oxford University Press, 1988.

[35] T. Greenhalgh, and R. Taylor, "How to read a paper: papers that go beyond numbers (qualitative research)", *British Journal of Management* 315, 740-743, 2009.

[36] E. Fossey, C. Harvey, F. McDermott, and L. Davidson, "Understanding and evaluating qualitative research", *Australian and New Zealand Journal of Psychiatry* 36, 717-732, 2002.

[37] M.N. Marshall, "Sampling for qualitative research," *Family Practice* 13, 522-525, 1996.

[38] U. Flick, *An Introduction to Qualitative Research*, 2nd ed., London, Sage, 2002.

[39] A. Canato, and A. Giangreco, "Gurus or Wizards? A Review of the Role of Management Consultants", *European Management Review* 8, 231-244, 2011.

[40] M.A. Berry, and D.A. Rondinelli, "Proactive Corporate Environmental Management: A New Industrial Revolution" *Academy of Management Executive* 12, 38-50, 1998.

[41] R.E. Miles, and Snow, C.C. "Organizational strategy, structure, and process, New York, McGraw-Hill, 1978.

[42] L. Argote, B. McEvily, and R. Reagans, "Managing knowledge in organizations: an integrative framework and review of emerging themes", *Management Science* 49, 571-582, 2003.

[43] L. Engwall, and M. Kipping, "Introduction – Management Consulting as a Knowledge Industry," in *Management Consulting – Emergence and Dynamics of a Knowledge Industry*, M. Kipping, and L. Engwall, Eds., Oxford, Oxford University Press, 2002.

MFCA in Practice – A Longitudinal Case Study of Company A

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***Abstract*: This paper attempts to clarify the process of implementing material flow cost accounting (MFCA) in a company. It examines the practices of MFCA in Company A from 2003 to 2012. We descriptively analyse the relationship between MFCA as calculation and the people who were involved in it. The continued use of MFCA can be attributed to not only the people who supported its introduction but also its inherent features. Because various company operations affect the features of MFCA, companies can apply the basic principle of MFCA even if the actual method of MFCA is different.**

I. INTRODUCTION

Japanese companies have been adopting material flow cost accounting (MFCA) during these past ten years. Researchers have focused mainly on the technical aspects of its adoption, such as expanding its application to the supply chain, the possibility of coordinating with environmental assessments, and the differences from and coordination with existing management accounting and production management methods [1]. The current research interest focuses on how to apply MFCA continuously, rather than temporarily, as a management method for the promotion of environmental management [2].

This paper attempts to clarify the process of MFCA implementation in a company that has been using MFCA for about ten years. We do not aim to explain how to use MFCA continuously. Instead, we descriptively analyse the relationship between MFCA as calculation and the people who, for ten years, were involved in it. Our contribution is distinguished from the existing studies that focus on the development of the technological aspects of MFCA.

II. MATERIAL AND METHOD

1. Methods

We conducted unstructured interviews with Company A's employees and top managers, including the president, during 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 center (Names of company, interviewees, and division are anonymous.). The interviews, which lasted 1–1.5 hours, were digitally recorded and transcribed. All the interviews were conducted in Japanese. Therefore, all the quotations in this paper have been translated into English with care taken not to change the meaning.

Additionally, we used several different types of data: annual reports, environmental reports, in-house magazines, scripts of managers' speeches, and interviews.

2. Overview: Company A

Company A belongs to the chemical industry and has about 20,000 employees. Its headquarters are located in Japan. It has a long tradition of demonstrating sensitivity to environmental issues because it is a chemical company. It established an environmental management division as early as the 1970s and began pursuing an ISO 14001 environmental management system in 1996. It also started to work toward zero emissions at the end of the 1990s and achieved it in a few years.

MFCA was introduced first in one factory production line in 2003. After that, attempts have been made to introduce MFCA company-wide and to use it continuously. Accordingly, Company A is the most suitable company to analyse the introduction and transformation of MFCA in a company over a long period.

III. THEORY

Many studies on MFCA focus mainly on the technological aspects such as its differences from and coordination with existing management accounting and production management methods, the connection with performance evaluation, expanding its application to the supply chain, and the possibility of coordinating with environmental impact assessments [1]. The current research interest focuses on how to apply MFCA continuously, rather than temporarily, as a method for the promotion of environmental management.

Recently, four aspects of this current research interest have been analysed: an expansion of the scope of the responsibility to eliminate the conflicts that appear during continuous application [2], the importance of setting a target that improves resource efficiency [3], the existence of a manager responsible for the entire product life cycle to reduce material loss [4], and the coordination of MFCA with existing management control mechanisms such as a medium-term plan and budget control [5].

These studies also focus on the technological aspect involved in the continuous application of MFCA. Few studies have analysed the introduction and transformation of MFCA in a company over a long period. We will be able to clarify this dynamic process, especially the interaction between MFCA as calculation and the organization employing it, by analysing a longitudinal case study. This has not been clarified by existing studies that focus on its technological aspects.

IV. Results

1. Prior to the introduction of MFCA

Company A experienced a great financial turning point starting at the end of the 1990s to the beginning of the 2000s when it recorded an operating loss. During this period, 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. While still vice-president, he used the phrase 'environmentally creative organization' for the first time in a business plan. This slogan means pursing both ecological and economic goals.

At this point, however, the company lacked a specific direction towards becoming an environmentally creative organization, and many employees shared the feeling that it would cost too much to address environmental conservation. Then, the company established an environmental management project to discuss environmental strategies and their execution. This project reported the results of the discussion to the president after 6 months.

2. The introduction of MFCA

Mr. P, who was a member of the environment management project and became the manager of the environmental management division, was looking for ways to connect environmental conservation activities to company profit and sought methods and strategies for the company to use. In the spring of 2003, he learned of MFCA at a symposium and believed that he found an ideal environmental management method.

Mr. P immediately tried to introduce MFCA into Company A on a trial basis. He asked the manager of Plant M to implement MFCA, and together they decided to try it at one of the production lines of Manufacturing Division T.

Despite the president's affirmative opinion of MFCA, the manufacturing floor refused to introduce it. The staff of Manufacturing Division T was very proud of the division's high yield rate. Thus, Mr. P tried to persuade the plant staff, saying, 'Let's try this. MFCA is not for checking results but for analysing the production process'. As a result, MFCA was then introduced on a trial basis.

In 2003, a few Japanese companies were introducing MFCA, and there were scarcely any cases to use as a 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'.

Before MFCA was introduced, material losses at Plant M were not considered a major problem, because it was commonly recognized that many of these losses occur naturally in the production process. Consequently, MFCA was put back into the production line. Workers at Plant M were very surprised by the amount of loss.

Reflecting on that time, President X said the following: 'Because the result of MFCA was very shocking to me, I decided to incorporate production innovation in the next midterm plan. I think MFCA led to the innovation of production in my mind. Additionally, I thought that if we could reduce material loss, this would improve the economic aspect of Company A'.

This remark shows that the president recognized the viability of MFCA as a new business tool.

3. Company-wide deployment of MFCA

Having confirmed that MFCA could simultaneously reduce environmental impacts and cost through its trial at Plant M, Mr. P selected model plants from three of in-house companies for the company-wide deployment of MFCA.

Although Mr. P had the support of President X, he encountered opposition at each of the model plants similar to that at Plant M. Responding to this resistance, Mr. P told the workers, 'MFCA is a tool to see the entire material flow process, not part of the process'. Additionally, he would persuade the workers by saying, 'If we succeed in reducing the material loss, this result would, in turn, reduce the environmental impact of our production activities'. In introducing MFCA, he paid more attention to how to visualize the material loss rather than how to perform accurate calculations.

To advance MFCA projects, a structure was put in place consisting of an organizational system and a plan-do-check-act (PDCA) cycle, which considers the feasibility and priorities of a plan to reduce material loss. The managers of in-house companies, plant managers, staff members from the plant's manufacturing division, and managers of environmental management attended to this system.

Managers or staff in each in-house company endorsed the usefulness of MFCA. One manager said, 'Without MFCA, we all knew where waste was produced. However, we were surprised to see how effective MFCA was because it allowed us to specify the points producing waste and to know the amount of material loss in each monetary unit. Listing material losses motivated us to take action to reduce them'.

Analysis based on MFCA was completed in every plant by the second half of 2005, and the results, which proved to be surprising to President O, were presented at a management meeting. Later, a production innovation plan was built into the midterm business plan of 2006 that incorporated MFCA into it.

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

4. Coordination between MFCA and production innovation

Although a management system to reduce material losses was organized, a big issue arose. The environmental management division that had been promoting MFCA lacked the knowledge to reduce material losses. The production workers involved in MFCA would have experienced a great sense of futility if MFCA did not help them reduce material losses. Mr. P, therefore, submitted a direct request to his superior in charge of environmental management, Executive Managing Director Z, to establish a department focusing on improvement activities.

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 was that Company A lacked an underlying production philosophy on the elimination of defective products and the increase of productivity.

Another issue was that Company A lacked uniform performance indicators to clarify the contribution of production activities for management. The introduction of the in-house company system strengthened the autonomy of each in-house company, which resulted in individual approaches to how each company addressed production improvement activities. Furthermore, these in-house companies reported their results to managers using their own separate indices. Consequently, Managing Director Y considered setting up a new department for production activities that would resolve these issues.

Under these circumstances, Managing Director Y, Executive Managing Director Z, and Mr. P collaborated in the decision to staff the Production Innovation Center with specialists in production technology, thus leading to the introduction of MFCA there instead of the environmental management division. Additionally, it was decided that Mr. P, who took the initiative to introduce MFCA, would be transferred to the Production Innovation Center in 2006.

Therefore, MFCA resulted in the Production Innovation Center obtaining specialists. The Production Innovation Center set production innovation indices in 2006 to clarify the contribution of production activities for management. These indices comprised five items: external loss cost (the amount to settle product complaints), internal loss cost (the amount involved in the disposal of defective products), productivity improvement (the amount of cost reduction to improve raw material and labour costs), safety loss cost (the amount incurred from equipment-related disasters and labour accidents), and environmental cost (the amount to dispose of waste produced inside the plant and the energy necessary for its disposal). The target reduction value was set for each of the five items and assigned to each subsidiary company. Staff from the Production Innovation Center joined the each in-house company and addressed cost reduction together. The cost reduction value represented how much it affected the operating profit of the company as a contribution by management.

When transferred to the Production Innovation Center, MFCA was positioned as a method to help achieve the target values of the production innovation indices. Company A identified the costs involved in material loss that were clarified by MFCA as 'loss cost'. It includes raw material cost, energy cost, system cost, and waste disposal cost. That is, reducing these loss costs achieves the production innovation index targets and contributes directly to company profit as a form of cost reduction. MFCA became important because it was associated directly with production innovation indices.

Mr. Q, who headed the Production Innovation Center, said, 'The Production Innovation Center faced adverse conditions in the initial stages. However, we achieved great results in the long run. The Production Innovation Center would not have achieved results without MFCA'.

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. The new business plan assumed the task of halving energy costs and doubling productivity as the major issues for production innovation. The company initially intended to promote these two new issues by coordinating them with MFCA.

In 2011, however, two great changes regarding MFCA occurred in the network. One was the departure of Mr. P, who had taken the initiative to introduce and promote MFCA, from Company A. The other change was that Managing Director Y, who had taken on implementing MFCA in this division, left his office.

Before these two changes, however, the network promoting MFCA had been changing gradually as well. The system for executing MFCA had evolved as described above. Each in-house company started to take the initiative in performing the PDCA cycle involved in the measurement of material loss and improvement activities, and the Production Innovation Center mainly played a supporting role in reducing loss cost. Therefore, each in-house company became strongly aware of the cost involved in collecting MFCA information.

Additionally, because the new business plan emphasized halving energy costs and doubling productivity, these new targets attracted more attention than MFCA. As a result, the use of MFCA gradually declined.

In the midst of these network changes 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 to only the loss cost of the materials-to-waste ratio. However, the calculation of the material loss cost included not only the volume of material-to-waste but also the volume of material-to-use. This is presumably because the strategy to increase resource efficiency by considering input material was different from the 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 to improving resource efficiency, 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.

V. Discussion

In this section, we analyse 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 at the end of the 1990s. The tool with the potential to advance environmental management was MFCA, and it was introduced first on the production line. The results of this trial affected the factory manager, and President X endorsed the use of MFCA in environmental management.

As a result, MFCA had been introduced in all factories. At this time, however, another problem appeared. This problem was that the environmental management division lacked knowledge to reduce material losses. This problem was related to the problems in production management that Company A lacked production philosophy and uniform performance indicators to clarify the contribution of production activities to the company. In order to solve these problems, the new division, the Production Innovation Center, supported the introduction of MFCA and the practice of material loss reduction activities there instead of at the environmental management division. MFCA became the main tool of this new division, and material loss reduction was built into the midterm business plan that started in 2006.

In order to understand the transformation of the MFCA network, it is not sufficient to analyse the actors surrounding MFCA. We need also to consider why these actors were able to affect MFCA. We focus on the active role of its calculation as it integrated the needs of actors through a visualization of material losses. After important actors abandoned the promotion of MFCA and the model of MFCA was changed, the spirit of MFCA was maintained.

In order to clarify this, we focus on the features of MFCA: 1) input: it facilitates the collection of information that is subject to material flow that is shared among all departments involved, 2) output: it identifies the unified performance indicators.

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 loss from the same point of view.

On the other hand, the output aspect relates to 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. Looking back to the activities during the three years starting in 2006, Managing Director Y said, ‘Staff at the worksite improved their awareness greatly because they were engaged in activities to create a philosophy for each production line’. Additionally, the performance of each in-house company’s production management was measured by material loss or loss costs. Thus, Company A obtained uniform performance indicators.

The network surrounding MFCA greatly changed and the loss reduction activities 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.

VI. Conclusion

In this paper, we analysed the introduction and transformation process of MFCA within a company and clarified that MFCA integrated the needs of actors through a visualization of material losses. Therefore, after the staff that promoted the introduction and spread of MFCA left and the model of MFCA was changed, MFCA’s basic concept remained in the company through production management.

References

[1] M. Nakajima, “Environmental Management Accounting for Sustainable Manufacturing: Establishing Management System of Material Flow Cost Accounting,” *Kansai University Review of Business and Commerce*, No.12, pp. 41-58, Mar. 2010.

[2] K. Kokubu, “Continuous Implementation of Material Flow Cost Accounting”, *Journal of Economics and Business Administration*, Vol.196, No.5, pp.47-61, 2007 (in Japanese).

[3] M. Nakajima, “Environmental Management Accounting for Cleaner Production: Systematization of Material Flow Cost Accounting into Corporate Management System”, *Kansai University Review of Business and Commerce*, No.13, pp. 17-39, Mar. 2011.

[4] A. Higashida, “Material Loss Improvement by Using Material Flow Cost Accounting Analysis: Focusing on Sanden”, *Research in Corporate Social Accounting and Reporting*, Vol.23, pp.71-83, 2011 (in Japanese).

[5] M. Nakajima and A. Kimura, “Promotion of Innovative Improvement Integrated MFCA with Budgeting”, *The Journal of Cost Accounting Research*, Vol.36, No.2, pp.5-24, 2012 (in Japanese).

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Does Better Environmental Performance Lead To Improved Bottom Lines? A Theoretical Framework

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Abstract: **Over 40 years of study, researchers have not been able to identify a clear cut relationship between a company's environmental performance (FP) and its financial performance (EP). For that reason, this paper provides the theoretical framework on the relationship between the two. This framework considers a dual perspective from traditional economic research and strategic management field in an attempt to justify the paradoxical results. Specifically the study posits whether companies do well financially under shareholder theory or do good environmentally under resource-based-view (RBV). Further, in attempt to address the methodological shortcomings, especially as it relates to the lack of a robust measure of EP, the current paper proposes four indicators from two broad dimensions. The indicators based on strategic dimension include: top management commitment (TMC) and EMS-ISO14001 certifications, while the operational dimension indicators are both environmental strategy (ES) and programs to reduce environmental impact (PREI).**

Keywords: **Environmental Performance (EP), Financial Performance (FP), Shareholder theory, Resource-Based View (RBV), Strategic Environmental Performance (SEP), Operational Environmental Performance (OEP).**

I. INTRODUCTION

Change in climate, fast depletion of natural resources and the threat of global warming have made environmental concerns one of the leading global agenda. The concerted efforts of the nation governments in combating the negative effect of climate change and the awareness campaign of the non-governmental organizations on the need to be environmentally conscious have made environmental performance (EP) a concern for all businesses. With the advent of ISO 14000, environmental sustainability has been one of the over arching goals of companies in their corporate responsibility. Environmental Management System (EMS) implementation is gaining popularity as a result of its perceived link to profitability. A fundamental question that begs for answer is whether good EP can be associated with good FP. However, over 40 years of study has not been able to identify a clear cut relationship between company's EP and its FP [1], [2], [3].

Two main reasons have been adduced to the inconclusiveness of the findings. The absence of sound theoretical foundation to explain the link between the two performances has contributed to the conflicting results. The extant literature have studied the relationship between EP and FP using several hypotheses that have been developed from different theories, but the prevailing ones are stakeholder theory and shareholder theory as two opponent fundamental theories. The outcome of the studies has always been determined by the theories used. Accordingly, the present study provides a theoretical framework which comprises both the shareholder theory and RBV. Consistent with prior research, the present study will adopt RBV [4],[5]**.** This is because the EP of the company, under RBV perspective, is considered as one of strategic intangible resources that lead to sustainable competitive advantage. To achieve this, the company must work on developing EP by using encouraging resources that are difficult for competitors to copy or substitute. Moreover, RBV is linked to shareholder theory because the shareholders are the primary source of financing. These resources are then invested in improvements of EP in order to create value for shareholder.

Although the two perspectives have been used independently of each other because they are considered as competing views relating to environmental responsibility, this paper seeks to improve the understanding of the contribution of EP to FP in building upon the complementarity between the two perspectives. To do so, the framework provides an insight on why companies engage in environmental activities, and do shareholders gain when managers devote the corporate resources to environmental activities. As well, given that shareholder is the main external source of financial resources (which is considered under RBV as one of organizational resources) the present study uses both theories in order to explain the EP-FP link from different perspectives.

The second reason has contributed to uncertainty and ambiguity about the relationship between EP and FP is the methodological difficulties [6],[7], especially as it relates to the lack of a robust measure of EP. With the environmental issues being complex, multi-dimensional, and often difficult to quantify, thus far there is no consensus on one approach to address theoretically the common dimensions of EP [8], [9],[10]. In much of the accounting literature, the researchers used one or two indicators to measure EP. Given that prior studies have failed to come up with concrete measures for EP, this study proposes four indicators from two different dimensions. The significance of these indicators will be investigated as proxies for EP. The indicators based on strategic dimension include: top management commitment (TMC) and EMS-ISO14001 certifications, while the operational dimension indicators are both environmental strategy (ES) and programs to reduce environmental impact (PREI).

Similarly, the current study utilize the two dimensions of strategic and operational FP indictors reflecting various market evaluations, in attempt to clarify how each FP responds to a company's effort in dealing with different environmental issues. While the operational indicators of FP (corporate success and liquidity) are reflected in the accounting based measures, strategic (strategic success potential) indicators are indicated in stock market based measures [11]. This approach avoids the problems of accounting and stock-market-based studies, and is able to examine isolated impacts on environmental profit.

The aim of this paper is to examine the significance of the relationship between EP and FP in order to help managers justify choice of doing well or doing good.

The rest of the paper is structured as follow: section II describes the methodology of the research while section III presents the theoretical framework. Shareholder theory and RBV are also discussed in this section. Section IV concludes.

II. METHODOLOGY

As a consequence of the shortage of EP data and the absence of verified performance information, most studies are based on data generated through companies' self-assessment and focused on a very small number of companies [10]. The comparison among companies regarding EP is challenging even for companies that operate in the same sector because their activities are performed under different economic, technological and regulatory conditions.

In accordance with aforementioned, there is always risk of a vicious circle in the existing measurements and ratings that thwart stakeholders to interpret such data and reduce the credibility of these measures and ratings which might be attributable to measurement error [8,12]. As a response to these challenges, most studies use postal or telephone surveys as methods obtain data to measure EP [10]. In tandem with these studies, the current study will use survey to measure EP in attempting to reduce the measurement error.

Regarding FP measures, many prior research have used perceptual method to operationalize it [13,17,26,48]. A number of reasons have been used to justify this. Some researchers identified managers' openness to provide their perception instead of giving accurate quantitative data as the main reason [14]. Donna and Raymond [17] indicated that perceptual method prevents the problem of data mismatch which has resulted in non-significant results. As a result, profitability, liquidity (operational indicators) and shareholder value (strategic indicators) are based on perception method. Consistent with prior studies, the current research will also employ the perceptual method in determining FP measures. Additionally and more importantly, semi-structured interviews will also be conducted with environmental managers and accountants to obtain a richer understanding of the survey findings.

Data so obtained will be subjected to statistical analysis using Partial Least Square (PLS). PLS is a variant of the structural equation modeling often used in similar researches to investigate hypothesized relationship between the latent construct of EP and FP.

III. THEORETICAL FRAMEWORK

The causal relationship between EP and FP will be assessed based on the theoretical framework, as illustrated in Figure 1. The framework considers a dual perspective from the economists and revisionists view points. Both theories examine whether improvement in EP contributes to FP. In other words, the arrow in both theories runs from EP to FP. In terms of the measurement of EP, TMC has been chosen because it is considered a very crucial strategic indicator in the degree to which a company exhibited environmental awareness. EMS-ISO14001 is also critical strategic indicator to EP because it indicates that the companies in possession of certified EMS have a greater impact on EP than do companies that have not certified their EMS [18],[19],[20]. ISO-14001 is an internationally acceptable standard against which a company's EP can be gauged. Drawing on the RBV, in order to improve the performance that leads to obtaining sustained competitive advantage, the ES must be adopted [5],[21],[22]. Further, some scholars asserted that ES is important operational indicators of EP because of the leading role it plays in improving the productivity of their resources and attain considerable and lasting improvements of their EP [23],[24]. In view of that, ES is considered as important operational indicators of EP Finally, PREI has been taken into account as the second operational indicators of EP. This indicator is very important because it is used to alleviate the harmful effect caused by the activities of the company towards the environment.

The trade-off hypothesis is based on the shareholder theory [25] and deals with neoclassical economists' position which holds that environmental protection imposed a heavy burden on companies that cause a competitive disadvantage [26]. In view of this conventional wisdom, the liberal economists suggest that the requirements of environmental improvements distract managers from an executive's primary mandate to maximize shareholders' wealth [27]. In other words, the tightening of environmental regulations compel companies to spend large amount on environmentally protective technology and environmentally-friendly products and thus lead to increase production costs as well as decrease marginal net benefits [28],[29]. Thus, the fines and penalties for non-compliance are seen as threats which in turn will stifle innovation and give rise to competitive disadvantage [30]. Thus, the idea is that companies can voluntarily invest their money in environmental improvements, if they find that the improvements are money-making [29]. This means that if companies do not find this improvement profitable, they will not undertake it.

Consequently, for proponents of shareholder theory, a negative relationship between EP and FP is expected when EP causally precede FP [25],[31]. According to this theory, a company will not be able to take advantage of any economic opportunities that come with environmental abatement activities due to its primary task of making profit in the short-term [32].

RBV has since assumed a very important position in the discourse related to the theories of strategic management [33]. According to previous research [34], the development of the RBV can be traced to the pioneering works of scholars like Penrose. Succinctly, Penrose described a company as "a collection of productive resources the disposal of which varies between different uses and over time is determined by administrative decision" [35]. Following this seminal work of Penrose, subsequent researchers came up with the RBV. A prominent work in this regard is that of Birger [36] who coined and introduced the term, "RBV". He posits that a company that exploits its resources to the maximum would have a first mover advantage and may easily diversify to enhance its performance.

On the other hand, a rebuttal of the stance of the proponents of the industrial organization (IO) economics was offered. Michael Porter [37] presented an approach whose focus is on the company's position in the industry (external environment)as a determinant of its performance. Porter termed approach is the Competitive Forces Approach (CFA). This approach is in stark contrast to the RBV whose focus is skewed strategist's orientation towards inside of the company [21],[38]. Another contrasting standpoint is the degree of homogeneity of the resource and capabilities across companies. While the IO proponents hold that such resources and capabilities are homogenous across companies [37], the RBV proponents argue for its heterogeneity towards achieving competitive advantage. In this regard, the latter argue further that a company's performance would ideally differ from its cohorts based on the resources and capabilities that are valuable, rare, inimitable, and non-substitutable [21],[39]. These attributes are termed the "VRIN"-conditions [40]. According to Barney [21], conceptually, resources considered in the RBV framework ideally should include all assets and capabilities, as well as organizational processes, that are controlled by a company to achieve its strategic goals. Such resources enable the company in their formulation and implementation of strategies needed for operational and financial efficiency [21].

However, a high point in the RBV proponents' view for instance, Andy and Steve [41], is that focusing on the company's resources rather than its production function would help to isolate the effect of the resources on companies' performance. As such, if two companies have similar resources at their disposal, it is unlikely that their performances would also be identical. This is because the utilization of such resources would differ across companies. In this case, in the long run, differential in their performance will not only be easily linked to the resources but also its utilization [42].

Accordingly, the rationale for the RBV stemmed from the perceived deficiency in the industrial organization economics explanation of some issues. For instance, RBV proponents argued that the IO economics could not offer tenable explanations of a company's competitive edge beyond the cost and price discourse. Moreover, the proliferation of companies, each with its own distinct identity and procedure for doing things further advertised the limitations of the IO model because it was not able to capture the relative difference in companies' performance due to resource and capability differentials. Consequently, it is not surprising that renewed attention is being placed on the RBV in the extant strategic management literature as a possible platform to explain the apparent heterogeneity of resources and performance among companies.

Sequel to the forgoing, a number of studies have attempted to unravel the facts behind the success of achieving sustainable competitive advantage via the adoption of RBV mechanisms.

Moreover, a comprehensive detail of the positive implication of EP for a company's enhancement of its competitive advantage is well captured in the RBV of the company. This very influential study has since become indispensable in the discussion of the relationship between the two divides of environmental and financial performances regardless of how the latter is measured. Notable studies in this regard includes but not limited to, James [43], Michael and Paul, [44], and Sanjay and Harrie [45]. These studies have provided empirical evidences for the positive impact of EP on FP from both the market value based measures and accounting measures. The convergence of the results regardless of the measurement basis, therefore, indicates a clear directional path between environmental and financial performances especially when situated within the framework of the arguments of proponents of the RBV.

The importance of the RBV is also emphasised in the concept of environmental technology introduced by Paul Shrivastava [46]. It is noted that the evolution of environmental technologies are manifest both as a set of techniques (technologies, equipment, operating procedures) and as a management orientation [46]. Furthermore, Paul Shrivastava stated that there is a need for ensuring that production is environment-friendly. As such, production activities should ideally involve a process that conserves energy, reduce degradation, regulate emission, and protect the natural environment. In this regard, the author suggested that environmental technology should take cognizance of both the hardware and operating mechanism. While the former includes availability of pollution control equipment for instance, the latter focuses on how waste products are recycled to minify environmental degradation.

Drawing from above arguments, it can be deduced that the implication of environmental technologies for company performance is positive. This is because the likely production cost reduction, economic of large scale production in an environmentally friendly manner, expanded market potentials, and good community relations as consequences of environmental technology all combine to give a company a competitive edge. In this regard, a company that views its environmental technology as a strategic resource and thus channels it properly has got the capability to take advantage of efficient performances that arises from the uniqueness and inimitability of such resources.

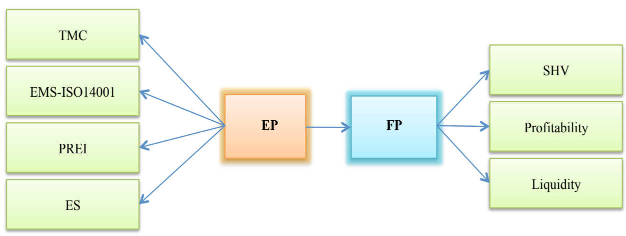

FIGURE 1: THE THEORETICAL FRAMEWORK

Sequels to the foregoing explanation of the theories, the following hypothesized relationships are proposed:
H1: There is a negative relationship between EP and FP
H2: There is a positive relationship between EP and FP

IV. CONCLUSION

This study is presently at the theoretical stage. Subsequent data obtained will be used to empirically test the hypothesised relationship. Meaningful conclusion can then be drawn and located within the extant literature.

REFERENCES

[1] J. D. Margolis and J. P. Walsh, "Misery Loves Companies: Rethinking Social Initiatives by Business," *Administrative Science Quarterly*, vol. 48, no. 2, pp. 268–305, 2003.
[2] M. Orlitzky, F. L. Schmidt, and S. L. Rynes, "Corporate Social and Financial Performance: A Meta-Analysis," *Organization Studies*, vol. 24, no. 3, pp. 403–441, 2003.
[3] E. Günther, H. Hoppe, and J. Endrikat, "Corporate financial performance and corporate environmental performance: A perfect match?," *Journal of Environmental Law and Policy*, vol. 34, pp. 279–296, 2011.
[4] P. Christmann, "Effects of 'Best Practices' of Environmental Management on Cost Advantage: The Role of Complementary Assets," *Academy of Management Journal*, vol. 43, no. 4, pp. 663–680, 2000.
[5] S. L. Hart, "A Natural-Resource-Based View of the Firm," *Academy of Management Review*, vol. 20, no. 4, pp. 986–1014, 1995.
[6] O. Salzmann, A. Ionescu-somers, and U. Steger, "The Business Case for Corporate Sustainability : Literature Review and Research Options," *European Management Journal*, vol. 23, no. 1, pp. 27–36, 2005.
[7] A. Mcwilliams, D. S. Siegel, and P. M. Wright, "Guest Editors ' Introduction Corporate Social Responsibility : Strategic Implications," *Journal of Management Studies*, vol. 43, no. 1, pp. 1–18, 2006.
[8] A. Y. Ilinitch, N. S. Soderstrom, and T. E. Thomas, "Measuring corporate environmental performance," *Journal of Accounting and Public Policy*, vol. 17, no. 4–5, pp. 383–408, 1998.
[9] M. Wagner, N. Van Phu, T. Azomahou, and W. Wehrmeyer, "The relationship between the environmental and economic performance of firms: an empirical analysis of the European paper industry," *Corporate Social Responsibility and Environmental Management*, vol. 9, no. 3, pp. 133–146, Sep. 2002.
[10] J. Hertin, F. Berkhout, and M. Wagner, "Are 'soft' policy instruments effective? The link between environmental management systems and the environmental performance of companies," vol. 44, no. 124, pp. 0–22, 2004.
[11] E. Günther, T. Günther, and H. Hoppe, "Are environmental aspects value drivers for companies? A review of empirical studies. empirical studies .," *Dresdner Beiträge zur Betriebswirtschaftslehre*, vol. 81, no. 4, pp. 1–70, 2004.
[12] S. Xie and K. Hayase, "Corporte environmental performance evaluation : a measurement model and a new concept," *Business Strategy and the Environment*, vol. 16, no. 2, pp. 148–168, 2007.
[13] W. Judge and T. Douglas, "Performance implications of incorporating natural environmental issues into the strategic planning process: an empirical assessment," *Journal of Management Studies*, vol. 35, no. 2, pp. 241–262, 1998.
[14] J. A. Aragon-Correa, N. Hurtado-Torres, S. Sharma, and V. Garcia-Morales, "Environmental strategy and performance in small firms : A resource-based perspective," *Journal of Environmental Management*, vol. 86, no. 1, pp. 88–103, 2008.
[15] M. D. López-Gamero, J. F. Molina-Azorín, and E. Claver-Cortés, "The whole relationship between environmental variables and firm performance : Competitive advantage and firm resources as mediator variables," *Journal of Environmental Management*, vol. 90, no. 9, pp. 3110–3121, 2009.
[16] J.-F. Henri and M. Journeault, "Eco-control : The influence of management control systems on environmental and economic performance," *Accounting, Organizations and Society*, vol. 35, no. 1, pp. 63–80, 2010.
[17] D. J. Wood and R. E. Jones, "Stakeholder mismatching: A theoretical problem in empirical research on corporate social performance," *International Journal of Organizational Analysis*, vol. 3, no. 3, pp. 229–267, 1995.
[18] S. A. Melnyk, R. P. Sroufe, and R. Calantone, "Assessing the impact of environmental management systems on corporate and environmental performance," *Journal of Operations Management*, vol. 21, no. 3, pp. 329–351, 2003.
[19] J.-F. Henri and M. Journeault, "Environmental performance indicators: an empirical study of Canadian manufacturing firms.," *Journal of Environmental Management*, vol. 87, no. 1, pp. 165–176, 2008.
[20] J. A. Massoud, B. F. Daily, and J. W. Bishop, "Perceptions of environmental management systems: An examination of the Mexican manufacturing sector," *Industrial Management Data Systems*, vol. 111, no. 1, pp. 5–19, 2011.
[21] J. B. Barney, "Firm resources and sustained competitive advantage," *Journal of management*, vol. 17, no. 1, pp. 99–120, 1991.
[22] K. Buysse and A. Verbeke, "Proactive environmental strategies: a stakeholder management perspective," *Strategic Management Journal*, vol. 24, no. 5, pp. 453–470, 2003.
[23] M. E. Porter and C. Van Der Linde, "Green and Competitive : Ending the Stalemate Green and Competitive," *Harvard Business Review*, vol. 73, no. 5, pp. 120–134, 1995_a.
[24] M. E. Porter and C. Van Der Linde, "Toward a new conception of the environment -competitiveness relationship," *The Journal of Economic Perspective*, vol. 9, no. 4, pp. 97–118, 1995_b.
[25] M. Orlitzky, "Institutional Logics in the Study of Organizations : The Social Construction of the Relationship between Corporate Social and Financial Performance," *Business Ethics Quarterly*, vol. 21, no. 3, pp. 409–444, 2011.
[26] M. Friedman, "The Social Responsibility of Business is to Increase its Profits," *The New York Times Magazine*, pp. 32–33, 122, 124, 126, 1970.
[27] K. Davis, "The Case for and against Business Assumption of Social Responsibilities," *Academy of Management Journal*, vol. 16, no. 2, pp. 312–322, 1973.
[28] N. Walley and B. Whitehead, "It's not easy being green," *Harvard Business Review*, vol. 72, no. 3, pp. 46–52, 1994.
[29] K. Palmer, W. Oates, and P. Portney, "Tightening environmental standards: the benefit-cost or the no-cost paradigm?," *Journal of Economic Perspectives*, vol. 9, no. 4, pp. 119–132, 1995.
[30] S. E. Jackson and J. E. Dutton, "Discerning Threats and Opportunities," *Administrative Science Quarterly*, vol. 33, no. 3, pp. 370–387, 1988.
[31] L. E. Preston and D. P. O'Bannon, "The corporate social-financial performance relationship: a typology and analysis," *Business & Society*, vol. 36, no. 4, pp. 419–429, 1997.
[32] S. Schaltegger and T. Synnestvedt, "The link between 'green' and economic success: environmental management as the crucial trigger between environmental and economic performance.," *Journal of Environmental Management*, vol. 65, no. 4, pp. 339–346, 2002.
[33] J. B. Barney, "Strategic Factor Markets: Expectations, Luck, and Business Strategy," *Management Science*, vol. 32, no. 10, pp. 1231–1241, 1986.
[34] J. T. Mahoney and J. R. Pandian, "The resource-based view within the conversation of strategic management," *Strategic Management Journal*, vol. 13, no. 5, pp. 363–380, 1992.
[35] A. Zubac, G. Hubbard, and L. W. Johnson, "The RBV and value creation: a managerial perspective," *European Business Review*, vol. 22, no. 5, pp. 515–538, 2010.
[36] B. Wernerfelt, "A Resource-Based View of the Firm," *Strategic Management Journal*, vol. 5, no. 2, pp. 171–180, 1984.
[37] M. E. Porter, *Competitive Strategy*, vol. 1, no. 2. Free Press, 1980, p. 396.
[38] R. M. Grant, "The resource based theory of competitive advantage: implications for strategy formulation," *California Management Review*, vol. 33, no. 3, pp. 114–135, 1991.
[39] R. Amit and P. J. H. Schoemaker, "Strategic assets and organizational rent," *Strategic Management Journal*, vol. 14, no. 1, pp. 33–46, 1993.

[40] K. M. Eisenhardt and J. A. Martin, "Dynamic capabilities: what are they?," *Strategic Management Journal*, vol. 21, no. 10–11, pp. 1105–1121, 2000.

[41] A. Lockett and S. Thompson, "The resource-based view and economics," *Journal of Management*, vol. 27, no. 6, pp. 723–754, 2001.

[42] R. E. Hoskisson, M. A. Hitt, W. P. Wan, and D. Yiu, "Theory and research in strategic management: Swings of a pendulum," *Journal of Management*, vol. 25, no. 3, pp. 417–456, 1999.

[43] J. T. Hamilton, "Pollution as News: Media and Stock Market Reactions to the Toxics Release Inventory Data," *Journal of Environmental Economics and Management*, vol. 28, no. 1, pp. 98–113, 1995.

[44] M. V. Russo and P. A. Fouts, "A resource-based perspective on corporate environmental performance and profitability," *The Academy of Management Journal*, vol. 40, no. 3, pp. 534–559, 1997.

[45] S. Sharma and H. Vredenburg, "Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities," *Strategic Management Journal*, vol. 19, no. 8, pp. 729–753, 1998.

[46] P. Shrivastava, "Environmental Technologies and Competltlve Advantage," *Strategic Management Journal*, vol. 16, no. S1, pp. 183–200, 1995.

An Investigation into Material and Energy Use in a Paper Recycling Plant In Malaysia Using Material Flow Cost Accounting Approach

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Paper recycling has many environmental benefits other than contributing to sustainability through the conservation of earth's natural resources. Among others, it helps reduce greenhouse gas emissions, saves landfill space and reduces energy and water consumption. Environmental management tools like Material Flow Cost Accounting (MFCA) can further help not only in terms of identifying and reducing waste, but also through increasing resource efficiency.

This paper describes an MFCA project conducted at a paper recycling plant in Malaysia which uses secondary fibres (e.g. newspapers and corrugated boxes) as input materials. The recycling process involves pulping, screening, refining, drying and rewinding. The process flow shows that besides the secondary fibre, the main inputs are energy (in the form of electricity and steam) and water. Chemicals are added after the refining stage. Material losses mainly consist of fibre, foreign materials, chemicals, other than the energy and water. However, at the final quantity centre (paper rewinder), the material losses may also come from the reject paper and packaging materials.

In monetary terms, for the recycling plant studied, the secondary fibre accounted for about 61 percent, while the energy about 25 percent of the cost of input materials. Other costs included chemical, waste treatment and system costs. In terms of losses, the highest was attributed to foreign materials, followed by reject product and fibre loss.

MFCA analysis has given new insights into the financial performance of the company, where it shows that profit can be increased if the material loss (which can amount to more than US$1 million) can be minimised. The analysis also reveals that the company could save more money by improving its current productivity management activity to focus on losses from fibre attached to the foreign materials, leaking of fibre from tanks, reject paper from the pope-reel (dryer) and edged material. Although waste from the dryer is returned to the process, it does not have the same original cost, so MFCA can be used to determine its true cost.

The company should also improve its current input-output data collection and verification, as the study reveals a gap of more than 60 percent between the amount of material loss in the form of foreign materials and fibre, and the amount collected at the waste disposal section. Lastly, considering that a very large amount of foreign materials were wasted, the company should consider using best available technologies (BAT) to recover them including using waste to energy option.

Gaining Competitive Advantage in an SME using Integration of Material Flow Cost Accounting and Design of Experiments: The Case of a Wood Products Manufacturing Company in Northern Thailand

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Abstract: **The garbage problem facing many provinces in Northern Thailand is one of the major factors for environmental problems such as air pollution problem caused by burning garbage. Haze and smoke from the open burning of waste is making many provinces in Northern Thailand remain covered by haze pollution. The best simpler solution to the garbage problem is to reduce waste production (zero waste). Furthermore, facing with the increase in the daily minimum wage (approximately 40-90% above previous levels) in Thailand, small and medium sized enterprises (SMEs) have to cut production costs and improve productivity to be able to compete and gain competitive advantage. The objective of this research is to apply Material Flow Cost Accounting (MFCA) and Design of Experiments (DOE) concepts in SMEs, in order to reduce material consumption and minimize waste. The case study company is a wood products manufacturer. The research methodology was divided into two main parts. The first part employed the MFCA concept to analyze the inefficiency of resources used in the production process, as well as the causes of these inefficiencies. In the second part, opportunities to reduce those inefficiencies could then be recommended. The study on the case study company production process reveals that more than 50% of the wooden raw material being wasted in terms of chippings of wood, sawdust, offcuts, and cutting defects. These wood wastes are stored in the company, disposed, or given away at no cost. The ineffective use of wooden raw material adversely affects production costs, costs of wasted raw materials, disposal costs, and associated costs of waste. DOE was used to increase the efficiency of the wooden raw material used. Full factorial experiment 2^k, with two replicates was used to find the optimal cutting settings that yield less tear-out length. Three factors (i.e. types of wood, blade angles, and number of saw teeth) were studied. The Analysis of Variance (ANOVA) was then conducted. Furthermore, the optimal wood cutting pattern was also proposed to reduce wood waste. Other practice recommended for wood waste reduction was to order wood at specified sizes. The results of the experiment have subsequently been put into practice. In conclusion, applying MFCA and DOE can help to increase product quality and reduce environmental impact simultaneously and ultimately save cost and improve competitiveness.**

I. INTRODUCTION

The case study company is a small and medium sized enterprise (SME) in the upper northern region of Thailand which manufactures wood products such as wooden music boxes. The company offers a made-to-order service or a customer-based handicraft. Like any other industries, music boxes and other souvenirs are now being made almost exclusively in countries with low labour costs. Facing with the increase in the daily minimum wage (approximately 40-90% above previous levels) in Thailand, the case study company has to cut production costs and improve productivity to be able to compete and gain competitive advantage.

In this case study company, the wooden music box model A has the highest quantity produced. As a result, there is an urgent need to conduct a study to determine improvements in the manufacturing process of wooden music box model A. The preliminary study on the case study company production process reveals that more than 50% of the wooden raw material being wasted in terms of chippings of wood, sawdust, offcuts, and cutting defects, as shown in Figure 1. These wood wastes are stored in the company, disposed, or given away at no cost. The ineffective use of wood adversely affects production costs, costs of wasted raw materials, disposal costs, and associated costs of waste.

FIGURE 1: WOOD OFFCUTS

Material Flow Cost Accounting (MFCA) is a framework that can help the company to enhance both environmental and financial performance through improved material and energy use practices [1]. MFCA focuses on both costs of products and costs associated with material losses [1]. The ultimate purposes of MFCA are to find opportunities to reduce material use and material losses, to improve efficient uses of material and energy, and to reduce environmental impacts [1].

Based on previous research, Design of Experiments (DOE) and Factorial Experimental Design methods are widely employed to facilitate production process improvements across several industries [2]. However, there have been only few studies into the applications of DOE in SMEs. Most of the research that has taken place has focused on the applications of DOE in larger-scale industries, such as in the electronics industry. In larger-scale industries, Factorial Experimental Design is commonly applied to identify relevant factors prior to determination of a suitable value for each step in the process. This method can help to reduce experiment times and the quantities of raw materials and other resources used [2].

This research; therefore, was conducted in order to apply MFCA and DOE concepts, in order to reduce material consumption and minimize waste.

II. RESEARCH METHODOLOGY AND RESULTS

As previously described, the research methodology was divided into two main parts. The first part employed the MFCA concept to analyze the inefficiency of resources used in the production process, as well as the causes of these inefficiencies. In the second part, opportunities to reduce those inefficiencies could then be recommended. This research paper explains in details how DOE was used to increase the efficiency of the wooden raw material used. The research steps plus the results are as follows:

1. Material Flow Cost Accounting

This research study focused on the wooden music box model A process. The data collection period was defined as the manufacturing of a production lot of 148 boxes.

The research study began with the determination of the quantity centers which were cutting, assembling, panting, decorating, and packing. For each quantity center, inputs and outputs were identified and the amounts of inputs and outputs were quantified in physical units (i.e. mass) and monetary units (i.e. Thai Baht). Inputs were classified as materials and energy, and outputs were classified as products, material losses and energy losses [1]. The material balance table for each quantity center was conducted. Table 1 depicts material balance table for quantity center 1 (cutting).

TABLE 1: EXAMPLE OF MATERIAL BALANCE TABLE FOR QUANTITY CENTRE 1 (CUTTING)

Material Balance Table (Cutting)					
Input: Material Used		Output: Waste		Output: Company Products	
Major Material	Quantity (g)	Waste (Negative Product)	Quantity (g)	Company Products	Quantity (g)
Wood X	139,608	chippings of wood, sawdust, offcuts	98,333	Music box (body)	41,275
Plywood	3,948	Plywood chippings	950	Music box (Plywood)	2,998
Total	143,556	Total	99,283	Total	44,273
%	100	%	69.16	%	30.84
Cost of Input Materials		Cost of Wasted Materials (negative product)		Cost of Materials Used (positive product)	
Total (THB)	13,600	Total (THB)	9,300	Total (THB)	4,300

In addition, for each quantity center, the costs of energy use, system costs, and waste management costs were quantified. System costs included labor costs, maintenance costs, etc. Table 2 depicts material flow cost matrix for quantity center 1 (cutting).

TABLE 2: EXAMPLE OF MATERIAL FLOW COST MATRIX FOR QUANTITY CENTRE 1 (CUTTING)

Material Flow Cost Matrix (Cutting)					
	Material Costs (THB)	System Costs (THB)	Energy Costs (THB)	Waste Mgmt. Costs (THB)	Total (THB)
Total	13,600	2,772	120	0	16,492
Product	4,300	855	37	0	5,192
Material Loss	9,300	1,917	83	0	11,300

Material loss data in terms of material costs, system costs, energy costs, and waste management costs, of each of the five quantity centers obtained during the MFCA analysis were then summarized using Pareto diagram, as shown in Figure 2. This Pareto diagram ranks data classifications in descending order from left to right and in this case, the data classifications are types of loss in each quantity center. It can be seen that the material loss in term of material costs in the quantity center 1 (cutting) is the "vital few" problem.

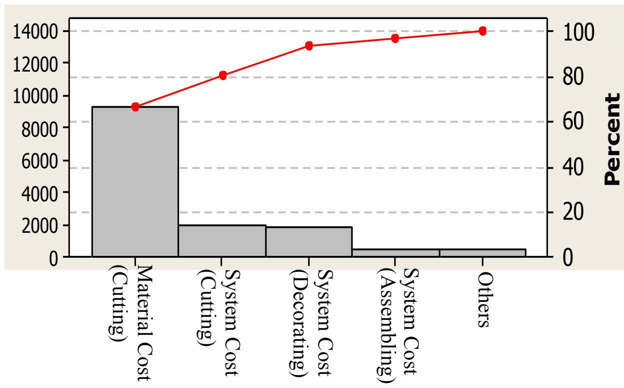

FIGURE 2: PARETO DIAGRAM OF LOSS IN EACH QUANTITY CENTER

After the MFCA data were summarized and interpreted, the improvement opportunities were identified. Fish bone diagram was used to investigate the causes of the material loss in the cutting process.

2. Design of the Experiments

According to the data collection and analysis carried out using a fish bone diagram technique, it was found that, in the 45 degree angle cutting process, one of the problems facing is the tear-out problem, as shown in Figure 3.

FIGURE 3: WOOD TEAR-OUT

Full factorial experiment 2^k, with two replicates was used to find the optimal cutting settings that yield less tear-out length. Three factors (i.e. types of wood, blade angles, and number of saw teeth) were studied. The response obtained was the tear-out length. Throughout the experiments in this study, the same tool and equipment as well as worker were employed, in order to minimize the impact of uncontrollable factors. Randomization principle was applied. A total of 16 experiments were carried out. The research design plus the results are as follows:

1) Factors (Independent Variables)

The researchers determined the levels of each factor by studying the previous research, brainstorming with the workers, and assessing the limitations of the case study company. The details are as follows:

Factor A – wood type: There are many different kinds of woods with wide ranging mechanical, physical, and thermal properties. Some types of wood are more prone to tear-out than others. Wood type X is currently used in the case study company process. Wood type Y has similar properties to Wood type X, but available in a variety of sizes.

Factor B: blade angles: In the brainstorming session with the workers, some workers proposed using higher blade angles to solve tear-out problem. However, some workers argued that in many cases, a very sharp blade set at the traditional 45 degree could out perform a high angle alternative. Therefore, the two levels of blade angel (i.e. 45 degree and 90 degree), with the same blade used, were studied.

Factor C – number of saw teeth: In the brainstorming session with the workers, some workers proposed using high tooth count blade to smoother the cut and control the tear-out problem. Therefore, the two levels of number of saw teeth (i.e. 48 and 100) were studied.

A summary of the factors and levels is shown in Table 3.

TABLE 3: FACTORS AND LEVELS

Symbol	Factors	Levels	
		Low (-1)	High (+1)
A	Wood Type	X	Y
B	Blade Angle (degree)	45	90
C	Number of Saw Teeth	48	100

2) Residual Analysis

There are preliminary assumptions made when carrying out an Analysis of Variance (ANOVA), these being that the errors are normally and independently distributed with a mean of zero and a constant but unknown variance [3]. Residual analysis was then carried out to check the model's adequacy.

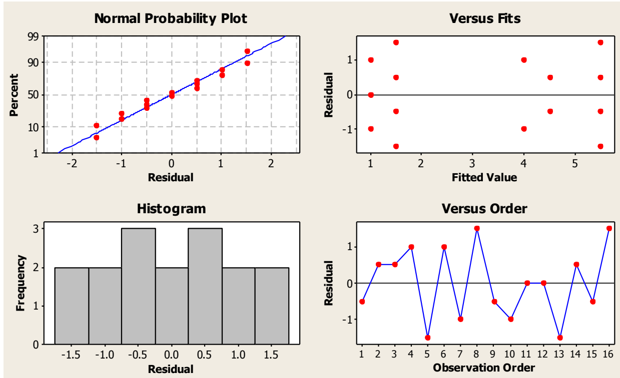

FIGURE 4: RESIDUAL PLOTS

From Figure 4, it can be seen that the Normal Probability Plot graph for the Residual Test shows a straight line, the Histogram of the Residuals is in a symmetrical form and that the graph showing the Residuals versus the Fitted Values presents a constant variance. The residual values observed against the order in the data graph revealed no abnormal tendencies. Thus, it can be concluded that the data measured were in line with the assumptions made for the design of the experiment.

3) Analysis of the Results

After data collection and data adequacy testing, an ANOVA and Main Effect Analysis were then carried out.

From the Normal Probability Plot of the Standardized Effects, as shown in Figure 5 , it can be seen that only blade angle factor (B) significantly affected the responses, to a confidence level of α = 0.05. Since all of the effects that lie along the line are negligible, whereas the large effects are far from the line [3].

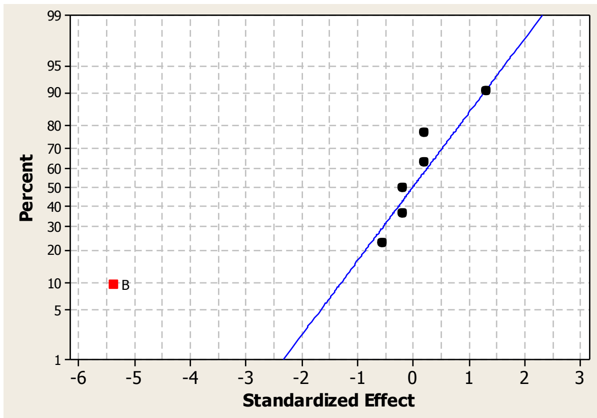

FIGURE 5: NORMAL PROBABILITY PLOT OF THE STANDARDIZED EFFECTS

An ANOVA was used to test the significance of the impact of the factors, and the results are shown in Table 4.

TABLE 4: ANALYSIS OF VARIANCE

Source	df	Sum of Squares	Mean Square	F Value	P Value
A	1	0.063	0.063	0.03	0.857
B	1	52.562	52.562	29.00	***0.001****
C	1	3.062	3.062	1.69	0.230
A*B	1	0.062	0.062	0.03	0.857
A*C	1	0.063	0.063	0.03	0.857
B*C	1	0.562	0.562	0.31	0.593
A*B*C	1	0.062	0.062	0.03	0.857
Error	8	14.500	1.813		
Total	15	70.937			

S = 1.34629   R-Sq = 79.56%   R-Sq(adj) = 61.67%

From Table 4 it can be seen that the factor significantly affecting the tear-out length was blade angle factor (B) only. The interaction between factors had no impact on the responses, as the P-value was higher than $\alpha = 0.05$. In addition, it can be seen that R-Sq, representing the accuracy of the analysis, is 79.56%, and that R-Sq(adj) - representing the accuracy of only those factor affecting the response - is 61.67%. These results mean that the accuracy of the analysis was satisfied.

The main effects of A, B, and C are plotted in Figure 6. It can be seen that 90 degree blade angle causes the least tear-out length.

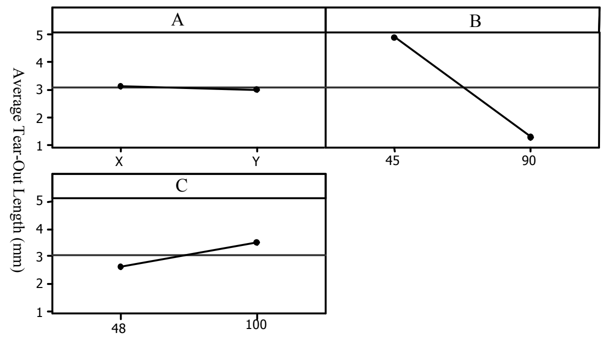

FIGURE 6: MAIN EFFECT PLOTS

TABLE 5: RESULTS OF CONFIRMATION TEST

Sample Number	Tear-out Length (mm)
1	2
2	0
3	3
4	1
5	2
6	0
7	2
8	3
9	2
10	1
Average	**1.6**

In this final step, after the optimum factor was obtained, an experiment to validate the experimental results was conducted, with ten samples. The results from the experiment, as shown in Table 5, showed that the mean of the tear-out length was 1.6 mm, whereas, the mean of the tear-out length obtained from the company previous procedure was 8 mm.

However, to set 90 degree blade angle in the 45 degree angle cutting process, if the table saw is used, support is needed on the surface of the table and along the trailing edge of the board. Figure 7 shows a picture of a piece of scrap wood used as a support in the 45 degree angle cut process.

FIGURE 7: SUPPORT IN THE 45 DEGREE ANGLE CUTTING PROCESS

In addition, other recommendations made by the workers to prevent the tear-out problems are, for example, using a sharp blade, and putting the good side down during the cut.

III. DISCUSSION AND CONCLUSION

The results of this research identified the inefficiency of resources used in the production process, the causes of these inefficiencies, as well as the opportunities to reduce those inefficiencies. Later, this research paper explains in details how DOE was used to reduce the tear-out problem in the 45 degree angle cutting process.

In addition, the optimal wood cutting pattern was also proposed to reduce wood waste. Other practice recommended for wood waste reduction was to order wood at specified sizes.

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REFERENCES

[1] ISO. *Environmental Management – Material Flow Cost Accounting- General Framework*, Switzerland, 2011.
[2] R. Chompu-inwai and A.Charoenkasemsuk, "Parametric Analysis in the Electronic Sensor Frequency Adjustment Process," *International Journal of Mechanical and Industrial Engineering*, vol. 6, pp.1-6, 2012.
[3] D.C. Montgomery. *Design and Analysis of Experiment*, USA: John Wiley Sons Inc, 2009.

Material Flow Cost Accounting as the tie for integrating LCC and LCA

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Abstract: **In the context of an economic and ecological sustainable decision making, in particular life cycle costing (LCC) and life cycle assessment (LCA) are quite useful approaches for the evaluation of long term effects of products. However, the corresponding analyses are often done separated from each other and on basis of differing presumptions, scenarios and/or life cycle models. So, the analyses do not necessarily refer to the same 'object'. The paper will show how the approach of material flow cost accounting (MFCA) can be used to bridge the methodical gaps between LCC and LCA models and it will present the MFCA-based LCC-LCA analysis in more detail.**

I. INTRODUCTION

The undisputed need for an increased attention to environmental aspects in managerial decision making provides a chance for an integration of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). The main challenge for integration is the generation of a shared data basis describing a product's life cycle. For this, material flow cost accounting (MFCA) has been identified as promising integration approach. Based on this finding, the article's focus is on modifications and enhancements of MFCA's methodology required for supporting a LCC-LCA integration.

After the current state of integration of LCA and LCC (section II) and of MFCA including an enhancement regarding the integration of energy (section III) are presented, it will be described how a LCA-LCC integration on the basis of MFCA can be realized.

II. LIFE CYCLE-ORIENTED EVALUATION

Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) are the two general concepts for the analysis and evaluation of the monetary and ecological consequences a product causes in its life cycle. LCA is a general procedure for identifying and quantifying the environmental impacts of a product life cycle from cradle-to-grave or from gate-to-gate [1]. It aims at revealing ecological improvement possibilities and facilitates the design of eco-friendly products. In addition, LCA studies' results are used for sustainability reporting and eco-labeling. LCC is a cost management method aiming at detecting and appraising all monetary impacts (e. g., cost, revenue, cash flows) related to a product and its life cycle [2]. A coordinated – or rather integrated – application of both concepts would be essential for the planning of products, the related processes, and improvement measures by identifying trade-offs between the achievement of ecological and economic goals and appraising measures with respect to both goal dimensions in a consistent way. This will, e. g., justify the ecological measures competing for capital resources by appropriately assessing their economic consequences throughout a product's life cycle [3]. Though an integrated LCC-LCA study would be preferable for ecological-economic decision support – and there are already examples of such studies – in most of the cases the surveys are made separately from each other. However, first approaches for an integrated view do already exist, but up to now, only selected integration aspects are covered by them. Especially, cost aspects are included in LCA surveys [1], [4], [5], and cost effects of environmental impacts in LCC [6], [7].

In a literature research, the main barriers for an integrated use have been identified in the definition of the goal(s) and scope of the study, the functional unit, the underlying life cycle concept and the corresponding life cycle phases, a lacking time dependence in LCA surveys (a reasonable LCC study is based on dynamic models) and the data base. However, the analysis of both concepts has shown that the barriers are not insuperable [8]. The main challenge of a LCA-LCC integration is a shared data basis which, additionally demands for a concerted goal and scope definition including the life cycle concept, life cycle phases, and functional unit definition. This shared basis is the description of the particular product life cycle and supports an integrated forecast of economic and ecological impacts.

To build up a common information or data base for integrated LCC-LCA studies, flow models as known from flow cost accounting (MFCA) can be used to bridge the current gap between LCC and LCA models. Originally developed for monetary appraisals of resource inefficiencies, MFCA bases on the evaluation of material and energy flows. Therefore, the data compiled in MFCA are similar to those required in LCA [9] and (to some degree) in LCC. Consequently, on the one hand, MFCA is introduced as a joint basis for LCC-LCA studies. On the other hand, since MFCA is more an as-is analysis, its applicability for future-oriented and multi-period assessments and forecasts has to be enhanced on a methodical and a data level, e. g., by integrating life cycle-relevant as-is and forecast data (see [10]).

III. MATERIAL FLOW COST ACCOUNTING

1. Basic approach

MFCA is a specialized accounting method which aims at the identification and monetary valuation of inefficiencies in material use (for an overview see [9], [11]). Generally, it can be applied to a wide range of systems (e. g., products, production processes, companies, value chains). It considers the production of goods as a system of movements of materials (material flows) which are assessed quantitatively and monetarily. The flows are distinguished into desired material flows (movements of raw materials, operating supplies, intermediates, products) and undesired material flows (e. g., clippings, rejects, and used lubricants). This distinction allows it to report all quantities and costs incurred by the 'production' of goods and of material losses, separately.

In order to identify and analyze inefficiencies, the basic procedure of MFCA comprises three steps. In the initial task of flow structure modeling, the system to be analyzed (e. g., company, process chain, process) is described with its elements quantity centers, boundaries, and flows. The quantity centers are those elements for which material in- and outputs can be physically quantified. In the second step, the flown quantities and the changes of quantity center stocks within a certain period of time are collected and visualized in a flow quantity model. Finally, the flows and stocks – that are perceived as cost collectors – are monetarily appraised. The costs incurred are assigned to them and displayed via a flow cost model. These costs include the direct material cost (material quantity multiplied by material price), and the indirect energy cost (expenses of energy used to enable operation), waste management cost (handling material losses), and system cost (other types of cost like depreciation, maintenance, labor). For details about the methods of cost assignment used in MFCA see [9] and [11].

2. Material and energy flow cost accounting

Unfortunately, the basic MFCA methodology does not explicitly include the energy. But, the growing relevance of the resource energy (rising prices, climate change, scarcity of primary energy sources, etc.) as well as the close link between companies' material and energy demand call for an in-depth analysis of energy use and energy-related inefficiencies (which is relevant for both, the economic and the ecological evaluation). However, due to the differing physical characteristics of energy, its flows have to be modeled separated from those of material [12]. So, the explicit consideration of energy in MFCA requires an extension of the flow structure. First, at the quantity center level it has to be analyzed, what energy (sources) are input and output of the respective quantity center. Since for physical and technical reasons the energy input to a production process is always higher than the theoretical amount of energy needed for the desired operation, the exceeding energy demand is considered as an energy loss.

The resulting flow structure is visualized in figure 1. Beyond that, in a company quantity centers generating and supplying energy for other quantity centers (compressed air station, transformer station) exist. In these supply centers energy is desired as well as undesired output. The intended energy output is in turn input to the other quantity centers. After the energy flows are integrated in the flow structure, the flown quantities of materials and energies are identified and visualized in the flow quantity model. Finally, besides the costs of the material flows, the costs of desired and undesired energy flows – consisting of the direct energy cost and the system cost of the energy supplying quantity centers – are calculated and displayed in the flow cost model.

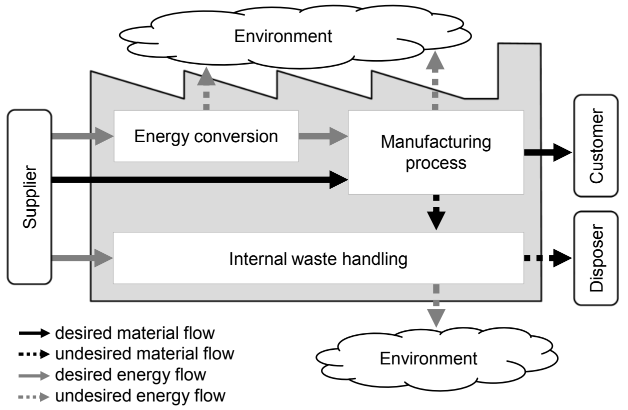

FIGURE 1: EXTENDED FLOW STRUCTURE MODEL (cf. [12]).

IV. TOWARDS AN INTEGRATED APPROACH

1. MFCA-based LCC-LCA analysis

To form a shared basis for a life cycle wide economic and ecological evaluation, MFCA's methodology has to be adapted according to the needs of LCC and LCA analyses. Here, the presented general three step procedure of MFCA will be kept – it also represents the framework of the MFCA-based LCC-LCA analysis:

- identification of the life cycle-wide flow structure,
- quantification of flows in physical units, and
- economic/ecological evaluation of the flow system.

As described in section III, MFCA's flow models refer to a single time period of the analyzed product. But, a product life cycle consists of different life cycle phases which, in turn may include several time periods. So, the flow models have to be enhanced in order to map life cycle phases with their time periods. Therefore, in the first step of the analysis, the identification of the flow structure, an appropriate life cycle model and the phases relevant for evaluation (cradle-to-grave vs. gate-to-gate) have to be chosen. Besides, due to the more complex models, it proves to be useful to build up separated submodels for the life cycle phases. In the following, for demonstration, the system life cycle is used. It consists of the production, the use and the disposal phase. Closely connected to the selection of a life cycle model and the relevant phases is the required definition of the system boundaries. Here, the relevant needs of the later economic and ecological evaluation have to be regarded. Notably, this refers to the estimation of impacts caused by the (flow) systems in- and output energies and materials in up- and downstream processes. In this context, the requirements of LCA are expected to be more challenging. For LCC, the monetary 'impacts' of these system in- and output flows can be simply calculated on basis of the particular factor or sales prices which are usually already known or can be estimated with little effort. Regarding the ecological evaluation, there are several LCA databases available which cover a wide range of basic materials and energies including the processes of their creation, supply and disposal (see e. g., [13] and [14]). But for instance, complex pre-products or new materials are not contained. So, in such cases, the system boundaries have to be enlarged to include the relevant processes whose ecological impacts cannot be derived from existing databases. However, a meaningful ratio of the analysis effort and benefit has to be regarded as well.

When the general life cycle model, the relevant phases and the system boundaries are defined, the quantity centers and the flows of the abovementioned phase-specific sub-models have to be identified, see figure 2. Here, the phase of production – which is commonly focused in the 'original' approach of MFCA – as well as the phase of disposal can be modeled as a sequence of consecutively passed technical processes which form the quantity centers of these sub-models. In contrast, the use phase is usually characterized by the repetition of a single (or a few) process(es). For instance, if the product is a machine tool, the use phase processes may be a defined machining task and planned maintenance activities. Here, traditional LCC and LCA studies usually presume a more or less detailed use phase scenario containing the relevant processes and material and energy demands. For transferring it to the flow structure model, the scenario's processes are considered as quantity centers of the use phase sub-model – in the simplest case it could be a single quantity center.

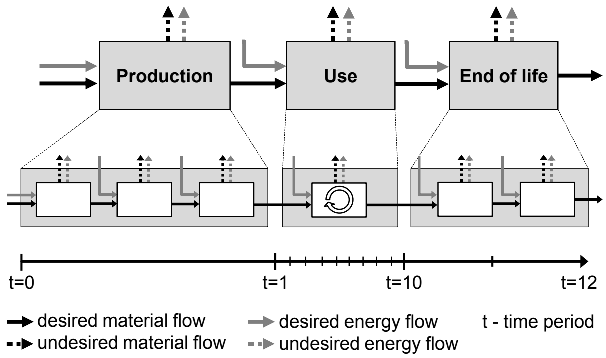

FIGURE 2: PHASE-SPECIFIC SUB-MODELS.

The second step of the LCC-LCA analysis is the quantification of the flows in physical units. The general procedure was already described in section III. But, the analysis now includes several time periods (and life cycle phases). Since the later monetary evaluation requires an attribution of flow data to single time periods, the flow quantity model should respect this fact and be build up period-wise or at least clearly attribute the flow quantities to the time periods they occur in. This is in particular true for the use phase of various products which usually comprises several time periods. Here, it has to be noted, that the structure of the use phase sub-model is identical for the relevant time periods. But, due to the fact that the underlying processes are performed several times and the corresponding conditions may differ, the flow quantities (the flow quantity models) of the particular time periods can vary accordingly.

The final flow quantity model is the joint basis of the economic and the ecological evaluation and, therewith, the starting point of the third step of the LCC-LCA analysis. As mentioned in section II, LCC is commonly based on dynamic methods of investment appraisal which regard the 'time-related value' of money. These methods are based on cash flows instead of costs and revenues which would be another challenge for modeling. While cash outflows may be derived from 'traditional' MFCA's cost data, cash inflow data would have to be collected from other sources (e. g., from accounting) and integrated into the model. Since cash inflows could be modeled as negative cash outflows, a separate methodical discussion is not necessary in here. (For details about models of investment appraisal see [15]). At this point, it has to be noted that the presented principles of cost assignment can be used for cash in- and outflows, too. The general advantage of using period-specific cash in- and outflows instead of revenues and costs is the possibility of regarding time-dependent effects – e. g., arising from learning curves, varying prices for raw materials, or a chosen maintenance strategy.

In order to achieve an increased consistency of LCC and LCA results, MFCA's basic 'idea of cost accounting' (the definitions of direct and indirect costs and the principles of assigning them to desired and undesired output flows) is transferred to the ecological evaluation. Accordingly, it is distinguished between the direct ecological impacts of the flown materials and energies and the 'indirect impacts' caused by the infrastructure of the quantity centers (or superior structures), e. g., of machine tools or transportation devices. The amount of the direct impacts can be determined using the above mentioned LCA databases. Analogous to the treatment of direct costs in MFCA, the impacts of an input flow are allocated to the desired and undesired output flows using their mass ratio. The infrastructure's total (life cycle-wide) ecological impacts can be derived from existing data or corresponding LCA studies. The allocation follows the MFCA methodology for system cost assignment. Firstly, an appropriate allocation criteria is defined, e. g., a machine hour rate. Secondly, the relevant share of the infrastructure's impact is calculated (e. g., impact per machine hour). Finally, this share is allocated to the outgoing flows by using their quantity ratio. In this regard, the infrastructure's impacts should only be determined if the effort of data collection does not exceed its benefit. As demanded for LCC, in LCA impacts should be assessed with respect to the point of time they occurred. However, such dynamic approaches are still an open question in LCA research (see e. g., [16]).

Beside the advantage of providing a joint basis for the economic and the ecologic evaluation, the use of MFCA's flow models enables an additional dimension of analysis. Since the differentiation of desired and undesired output is an inherent characteristic of MFCA, the derived LCC and LCA evaluation now includes this assessment of resource efficiency. In 'traditional' LCC and LCA studies the processes causing the highest share of monetary or ecological impacts where identified as starting points for improvements. Now the attention can be directed to the most inefficient processes, additionally. However, in multi-product cases the differentiation of desired and undesired outputs may hinder a product-specific evaluation. Here, appropriate conceptual approaches have to be found for retracing undesired outputs to single products.

2. Evaluation of design alternatives

The MFCA-based LCC-LCA analysis presented in the previous subsection enables users to clearly identify the most significant inefficiencies in terms of economic and ecological life cycle wide impacts. On basis of this criticism of an as-is state, engineers may examine the underlying technical processes and the related product design aspects in order to develop appropriate measures improving the resource efficiency and, therewith decrease the life cycle cost and the negative ecological impact of the product. However, these technical measures represent process-level changes which often affect other processes – even those in other life cycle phases – as well (see, e. g., [17]-[19]). So, the evaluation of a measure's benefit demands an appropriate adaption of the whole existing flow model. In this context, it has to be noted that several technical alternatives may be available for improving a single weakness and that all valid combinations of measures regarding different processes and/or product design aspects have to be evaluated. In conclusion, users face the challenge of building up a plenty of alternative flow models which may become quite laborious.

The same problem was already identified for 'traditional' MFCA and in the context of designing industrial process chains an extension of MFCA's methodology was proposed. The so called 'plan-MFCA' enhances the existing approach by technical models of the particular processes which allow to forecast the 'reaction' of the processes on varied internal parameters and external conditions. The technical models are necessarily very process specific, but follow a given structure: The specification of the processes' in- and output refers to the technical demands on input material and energy flows and the characteristics of the corresponding output flows. Within the element of throughput, the drivers of the transformation of input to output are identified and mathematically described. Furthermore, the throughput description includes the usage of the processes' infrastructure (which is identically with the quantity center's infrastructure). Finally, on basis of functional relationships between the technical drivers and the costs incurred by the process, cost forecasts for multiple alternative process chains could be performed with comparatively less effort [12], [21], [20]. (For an example see [22]). These functional relations may reach from simple correlations of quantities or time and costs up to complex cost functions.

Regarding a transfer of the plan-MCA methodology to the presented LCC-LCA analysis (subsection IV-1), firstly, it can be stated that the methodical enhancement is an additional modeling level (the technical process models) which does not affect the original 'basic' procedure of flow system modeling (see, e. g., [22]). So, the remaining question is whether this additional technical description is sufficient for forecasting purposes in the context of LCC and LCA. Since the plan-MFCA aims at forecasting costs, it can be adapted for life cycle costs quite obviously. Here, the use of period-specific cash in- and outflows has been mentioned already (see subsection IV-1). In the context of forecasting ecological impacts of technical alternatives, plan-MFCA's technical models are used for identifying the impacts of changed input, output or process parameters on the flow quantities and the usage of the processes infrastructure. Afterwards, on basis of this changed quantity model a monetary evaluation is performed. So, analogous to the procedure described in section IV-1, the quantity model may serve as a basis for appraising the impacts of the alternatives in ecological measures as well.

V. Conclusions

An informed decision making in the context of an economic and ecological sustainable product design requires a corresponding detailed and consistent basis of information. However, so far, LCC and LCA analyses were commonly performed separated from each other including a separated description of the examined system. Particularly the partly significant discrepancies in this basic description (differing presumptions/scenarios, life cycle models, etc.) hinder a consistent view on the system and, therewith an integrated decision making.

To overcome this problem, the approach of an MFCA-based LCC-LCA analysis is proposed. Here, MFCA's flow structure and flow quantity models are adapted to the needs of the later economic and ecological evaluation (integration of the flows relevant for both dimensions, separation of life cycle phases, period-specific quantification of flows). Therewith these models form a joint basis describing the relevant material and energy flows within the examined product's life cycle. Afterwards, MFCA's flow cost models can be adapted for use in the LCC context. For LCA analyses at least the corresponding methods of cost assignment can be used for assigning direct and indirect ecological impacts to the material and energy flows. Concluding, the use of the proposed approach entails several advantages:

- The LCC and the LCA study refer to exact the same structural and quantitative description of a product's life cycle. Firstly, this will lower the overall effort compared to separated economic and ecological analyses. Secondly, the consistency of the results in the context of an integrated economic-ecological decision making will be increased.
- MFCA's separated treatment of desired and undesired outputs reveals an additional dimension of the result's interpretation. Besides the reporting of the total and the life cycle phase-specific amounts of life cycle costs and ecological impacts, now the

corresponding shares of desired and undesired outcomes can be specified. This view on resource efficiency may provide meaningful starting points for technical and/or organizational improving measures.

- The integration of technical process models (plan-MFCA) enables users to compare available alternatives at a high level of detail (the complex interrelations of all life cycle processes are regarded) and with less effort at the same time.

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REFERENCES

[1] DIN EN ISO 14040:2009 *Environmental management – Life cycle assessment – Principles and framework*

[2] B. S. Dhillon, *Life Cycle Costing: Techniques, Models and Applications*, New York: Gordon and Breach, 1989.

[3] K. G. Shapiro, "Incorporating Costs in LCA," in *Int. J. LCA*, vol. 6, no. 2, 2001, pp. 121-123.

[4] G. A. Norris, "Integrating Life Cycle Cost Analysis and LCA," in *Int. J. LCA*, vol. 6, no. 2, 2001, pp. 118-120.

[5] G. Huppes, M. van Rooijen, R. Kleijn, R. Heijungs, A. de Koning, L. van Oers, *Life Cycle Costing and the Environment*, Report of a project commissioned by the Ministry of VROM-DGM for the RIVM Expertice Centre LCA.

[6] U. Steeger, *Umweltmanagement: Erfahrungen und Instrumente einer umweltorientierten Unternehmensstrategie*, 2nd ed., Wiesbaden: Gabler, 1993. [German]

[7] E. Günther, *Ökologieorientiertes Management: Um-(weltorientiert) Denken in der BWL*, Stuttgard: Lucius & Lucius, 2008. [German]

[8] A. Bierer, L. Meynerts, and U. Götze, „Life Cycle Assessment and Life Cycle Costing – Methodical Relationships, Challenges and Benefits of an integrated Use," in *Proceedings of the 20th CIRP International Conference on Life Cycle Engineering*, April 17-19, 2013, Singapore, submitted for publication.

[9] DIN EN ISO 14051:2011 *Environmental management – Material flow cost accounting – General framework*

[10] U. Götze, A. Bierer, and R. Sygulla, "Die Flusskostenrechnung und ihre Integration in die traditionelle Kostenrechnung," in *Jahrbuch Rechnungswesen und Controlling* 2013, G. Seicht, Ed. Vienna: LexisNexis, 2013, pp. 49-71. [German]

[11] R. Sygulla, U. Götze, and A. Bierer, "Material flow cost accounting: A tool for designing economically and ecologically sustainable production processes," in *Technology and Manufacturing Process Selection: the Product Life Cycle Perspective,* E. Henriques, P. Peças, and A. Silva, Eds., submitted for publication.

[12] R. Sygulla, A. Bierer, and U. Götze, "Material Flow Cost Accounting, Proposals for Improving the Evaluation of Monetary Effects of Resource Saving Process Designs," in *Proceedings of the 44th CIRP Conference on Manufacturing Systems*, May 31 - June 03, 2011, Madison, Wis., USA, URL: http://msep.engr.wisc.edu/ index.php/resources/cirp/category/1-sustainable-manufacturing (accessed February 06, 2013).

[13] ecoinvent LCI database, URL: www.ecoinvent.ch (accessed February 06, 2013).

[14] ELCD LCI database, URL: http://lca.jrc.ec.europa.eu/lcainfohub/ datasetArea.vm (accessed February 06, 2013).

[15] U. Götze, D. Northcott, P. Schuster, *Investment appraisal: Methods and Models*, Berlin: Springer, 2008.

[16] J. Reap, F. Roman, S. Duncan, B. Bras, "A survey of unsolved problems in life cycle assessment: Part 2," in *Int. J. LCA*, vol. 13, no. 5, 2008, pp. 374-388.

[17] M. Helua, A. Vijayaraghavan, D. Dornfeld, "Evaluating the relationship between use phase environmental impacts and manufacturing process precision," *CIRP Ann. – Manuf. Technol.*, vol. 60, 2011, pp. 49-52.

[18] D. Glew, L. C. Stringer, A. A. Acquaye, S. McQueen-Mason, "How do end of life scenarios influence the environmental impact of product supply chains? comparing biomaterial and petrochemical products," *J. Clean. Prod.*, vol. 29/30, 2012, pp. 122-131.

[19] U. Götze, H.-J. Koriath, A. Kolesnikov, R. Lindner, J. Paetzold, "Integrated methodology for the evaluation of the energy- and cost-effectiveness of machine tools," in: *CIRP J. Manuf. Sci. Technol.*, vol. 5, no. 3, 2012, pp. 151-163.

[20] U. Götze, C. Helmberg, G. Rünger, A. Schubert, S. Goller, B. Krellner, A. Lau, R. Sygulla, "Integrating Energy Flows in Modeling Manufacturing Processes and Process Chains of Powertrain Components," in *Proceedings of the 1st International Colloquium of the Cluster of Excellence eniPROD*, R. Neugebauer, Ed., Auerbach: Wissenschaftliche Scripten, 2010, pp. 409-437.

[21] A. Schubert, S. Goller, D. Sonntag, A. Nestler, "Implementation of Energy-Related Aspects into Model-Based Design of Processes and Process Chains," in *Proceedings of the 2011 International Symposium on Assembly and Manufacturing*, 2011, DOI: 10.1109/ISAM.2011.5942344

[22] U. Götze, A. Schubert, A. Bierer, S. Goller, R. Sygulla, „Material- und Energieflussanalyse – Methodik zur Optimierung von Prozessen und Prozessketten," in *Proceedings of the International Chemnitz Manufacturing Colloquium ICMC 2012/2nd International Colloquium of the Cluster of Excellence eniPROD*, R. Neugebauer, Ed., Auerbach: Wissenschaftliche Scripten, 2012, pp. 99-128. [German]

Integration of external costs and environmental impacts in Material Flow Cost Accounting – A life cycle oriented approach

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***Abstract*: This paper presents three approaches which integrate external costs or environmental impacts into Material Flow Cost Accounting (MFCA). It argues that the main criticism of MFCA is that the method only takes corporate internal costs into account, maintaining that this is sufficient for all companies that aim to improve internal efficiency from an economic perspective, but fails to consider the ecological perspective. For a more effective pursuit of environmental improvements, external environmental costs should also be included into MFCA. One possibility to consider external environmental effects or costs is the consolidation of MFCA and Life Cycle Assessment (LCA). Based on a comparison of MFCA and LCA, similarities and differences between the two methods are identified. Regarding the inclusion of external costs, the first approach integrates the process-based externals costs for emissions into the MFCA, whereas the second approach, which already includes a life cycle perspective, assesses material and energy flows by means of environmental impacts. The third and most elaborate approach combines both concepts and integrates the life cycle oriented external costs for emissions into MFCA. In the course of depicting these approaches, potential advantages and limitations are discussed.**

I. INTRODUCTION

Material Flow Cost Accounting (MFCA) is an environmental management accounting tool for enhancing eco-efficiency by simultaneously reducing environmental burdens and lowering production costs [1]. Therefore, MFCA can be classified within both the ecological and economic spheres, even though its focus is on the economic scope. Among the range of environmental management accounting tools, MFCA is seen as one of the most promising methods [2].

The purpose of MFCA is to trace the material and energy flows through an organization, to then allocate the production costs to these material and energy flows [3] and finally to categorize them as to 'product output' and 'non-product output' (NPO).[2] in order to identify efficiency potentials. Based on these identified potentials, efficiency improvement measures can be implemented in the company which can also contribute to a reduction of environmental impacts.

One main criticism of MFCA is that the method only takes corporate internal costs into consideration. This is sufficient for all companies that aim to improve their internal efficiency from an economic perspective. However, for a more effective pursuit of environmental improvements, external environmental costs[3] should also be included into MFCA.

Other currently discussed forms of enhancing MFCA refer to the expansion of the system boundaries to the entire supply chain and the product life cycle or are related to linking MFCA with other tools of environmental management accounting, such as Life Cycle Assessment (LCA)[4].

This paper aims at linking MFCA with LCA and at adding depth to the significance of MFCA by the inclusion of external costs.

II. METHOD AND RESEARCH QUESTIONS

Within the frame of this paper the following research questions will be discussed:

- What do MFCA and LCA have in common, what are the main differences and where can common starting points be found?
- What is the potential of a combination of MFCA and LCA and what additional information can be provided?
- Which approaches can be pursued in order to link MFCA with LCA?
- How reasonable is the inclusion of external environmental costs into the method of MFCA and which methodical issues have to be considered?

In order to depict common features as well as the main differences, both instruments will be analyzed in detail by means of a literature review and with the help of a criteria grid (see Section III). In Section IV, a theory based model is presented which illustrates the combination of MFCA and LCA and the integration of external costs. In the course of depicting these theoretical approaches, potential advantages and limitations are discussed.

III. THEORY: COMPARATIVE DISCUSSION OF LCA AND MFCA

For a more effective pursuit of the environmental perspective within MFCA, it makes sense to link MFCA with LCA [8]-[12]. Since LCA identifies all product-related environmental effects according to current knowledge, then externalities can also be depicted. In the context of the impact assessment, environmental effects

2 According to IFAC, NPO is defined as ‚any output that is not a Product Output'. Examples of NPO are solid waste, hazardous waste, wastewater and air emissions [4], [5].

3 External costs are '…non-real monetary flows that can become relevant and be monetized in the decision-relevant future or for which an economic assessment is preferred' [6].

4 Life Cycle Assessment assesses environmental aspects and potential environmental impacts at all stages of a product's life from raw material extraction to processing, manufacture, use, recycling or disposal (from 'cradle-to-grave'). [7].

are assessed and presented by means of impact categories and therefore, the results conclude on a non-monetary level. This differs from the MFCA method, whose results are shown in a monetary form.

It is therefore necessary, that concepts are developed that bring together the results of MFCA with the results of the LCA. One advantage is that in the course of implementation many steps overlap. LCA, for example, can serve as a starting point for MFCA [12], and vice versa [10], [13].

Subsequently, the two instruments are compared in terms of selected criteria (see table 1).

TABLE 1: COMPARATIVE DISCUSSION OF LCA AND MFCA

	Criterion	LCA	Conventional MFCA
Goal and scope	examination scope	- products and product systems	- particular processes / process chains within a company
	examination object	- environmental impacts of the entire product (system)	- costs caused by the existence of non-product-output
	Goal	- improvement of environmental compatibility of product systems within the different life-cycle stages [7]	- enhancement of both environmental and financial performance in organisations through improved material and energy use [14]
Classification	Focus	- ecological	- ecological-economical
	Relation to sustainability strategies	- ecological compatibility strategy	- efficiency strategy
Methodology	Type of allocation	- allocation of environmental impacts to main product and by-product (within the product system) [15]	- allocation of costs to the cost collectors ‘product output’ and non-product output’ [14]
	Illustration of inefficiencies	- implicit illustration of inefficiencies	- explicit illustration of inefficiencies
	Consideration of free goods	- inclusion of free goods	- free goods are not depicted [16]
Results and application	Measuring units of results	- substance and energy-based impact-oriented	- monetary
	Illustration of results	- one-dimensional (e.g. EcoPoints) - multi-dimensional (different impact categories)	- one-dimensional (in monetary units)
	Internal application and relation to third parties	- internal decision support - external communication	- internal decision support

Although there are many differences between the two methods at a first glance, on closer analysis, the similarities are apparent: MFCA as well as LCA pursue a common target to increase transparency of material and energy flows. Both instruments are also within the sphere of environmental management accounting, are period-related and need allocation rules.

Since LCA does not focus on the relationship between product and non-product output, it does not illustrate waste and emission-related inefficiencies. This means that from the viewpoint of an efficient use of resources, LCA merely reflects the status quo of a product system, wherein waste flows and inefficiencies are contained. MFCA can ‘iron out’ this criticism by systematically analyzing and assessing material flow-related inefficiencies [17]. Applying the logic of MFCA, which focuses on the distinction between the two output categories, leads to a gain of information.

By contrast, a major criticism in the context of conventional MFCA is that the tool is not able to show a shift of environmental impacts from upstream or downstream stages within the supply chain, due to its process- or location-based nature.

In addition, within the calculation, only already internalized effects are taken into account. This means, that with MFCA, the ability to come to an ecological rational decision is hampered. Based on the similarities shown, but also in relation to the weaknesses of the methods described, it can be deduced that a systematic combination of both methods would be useful.

IV. RESULTS AND DISCUSSION: THREE APPROACHES FOR ENHANCING MFCA

The following section presents three approaches that build on the methodology of MFCA and include elements of LCA and external costs. The presented approaches are to be interpreted as a phase model, whereas the first approach is the simplest-to-implement method, while the third approach comprises of the most complex methodology.

1. Integrating process-based external costs for emissions into MFCA (process-based non-value-costs)

Based on the conventional framework of MFCA, a first step is to include external costs only for emissions (e.g. damage or abatement costs for carbon dioxide emissions).

From an ecological-oriented perspective, it is desirable to capture the internal and external costs for the entire NPO. The internal NPO-costs show which costs arise in an enterprise by the existence of inefficiencies in particular processes or process chains. The external (environmental) costs or environmental impact costs[5] related to the NPO, refer in the present approach to the NPO, which dissipates into the ecosphere (emissions). For NPO, which remains in the technosphere (waste, sewage), the monetary valuation of environmental impacts is more complex and can only be made on the basis of the so-called ‘Transfer Functions’ [20].
Capturing external costs of emissions from the site takes account of the fact, that the externalized effects of emissions in the decision-relevant future can be

[5] Environmental impact costs can be seen as an umbrella term for damage costs and abatement costs. Negative environmental impacts are monetized particularly in the context of ecological economics by either damage cost or cost abatement approaches [16]. Examples for monetized damage costs for different impact categories can be found in Steen et al. [5] or Bickel and Friedrich [18]. Examples for abatement costs for carbon dioxide emissions are given by McKinsey & Company, Inc. [19].

internalized as costs and therefore are reflected in the operating cost accounting for the foreseeable future.

Methodology: The MFCA is carried out according to the conventional procedure. For assessing the emissions occurring at the site by means of damage or abatement costs, and for an ecological process optimization, it is necessary to either measure, calculate, or at least to estimate these emissions.

In regards to the monetary valuation of the emissions in terms of externalities, no LCA is necessary. The required data can be drawn from existing studies in the fields of ecological economics. Analogous to the waste charges, the external costs of emission at the site are simply attributed to the NPO-flow and thereby increase the NPO-costs (see figure 1).

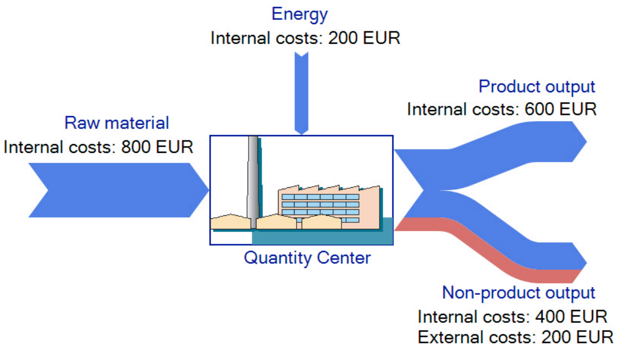

FIGURE 1: EXEMPLARY ILLUSTRATION OF INTEGRATING PROCESS-BASED EXTERNAL COSTS FOR EMISSIONS INTO MFCA.

Appraisal: The internalization of the site-related emissions as externalities, which means the integration of the external costs of these emissions, increases the environmental significance of the material flow cost accounting. The reduction of site-related emissions – especially the non-pagatoric emissions, which are associated with environmental impacts and therefore also associated with damage costs – is given importance. This is not the case in the conventional MFCA method, since non-pagatoric costs for emissions are disregarded.

Additionally, the MFCA – which, in its conventional form is a tool of operational environmental management accounting - obtains a strategic character through the integration of these external costs. A company can therefore anticipate a possible integration of external effects by the environmental legislation.

The difference between the NPO costs, which were calculated according to the conventional methods of MFCA and those NPO costs, which involve the damage or abatement costs of site-related emissions ("process-oriented non-value-costs") [21] can be seen as an indicator of the compatibility of the site ejected emissions. The higher the cost difference is, the more it can be assumed that the ejected emissions are not ecologically compatible.

This approach faces the same criticism as conventional MFCA, in regards to the process- or site-based character. Every process-based assessment of environmental impacts may face a shift of such impacts from one step of the supply chain to another which does not imply that the total environmental impacts of the supply chain are reduced.

2. Environmental impact-oriented assessment of material flows (Material Flow Impact Accounting)

The material flows within the context of conventional MFCA can also be assessed by means of environmental impacts, instead of costs [17]. The economic focus of conventional MFCA is therefore converted into a rather ecological focus in the context of the so-called "Material Flow Impact Accounting" (MFIA).

Methodology: A simple application for the MFIA is to assess material and energy flows on the basis of CO_2-equivalents (in terms of a carbon footprint) or by means of the water footprint instead of a cost-based assessment. The data for the environmental impacts are delivered by LCA or carbon or water footprint analyses with the system boundary "cradle to gate".[6] To avoid too complex calculations or illustrations, it is recommended that only one impact category (like CO_2-equivalents) or other one-dimensional indicators, such as Ecopoints, be included. Figure 2 shows the exemplary methodology of MFIA.

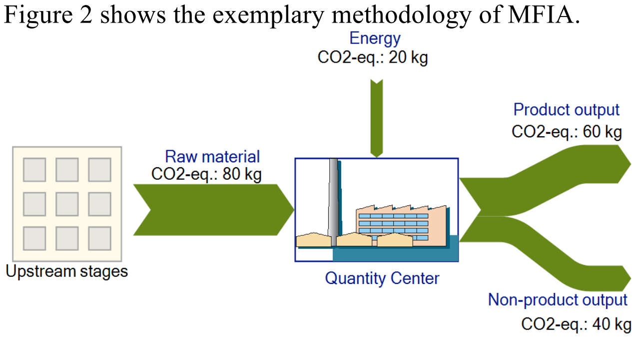

FIGURE 2: EXEMPLARY ILLUSTRATION OF MATERIAL FLOW IMPACT ACCOUNTING (SOURCE: BASED ON VIERE ET AL. 2011 [17]).

Appraisal: The main point of the MFIA is that by avoiding or reducing the NPO at the site a specific amount of environmental impacts over the life cycle (in the upstream stages) can be avoided as well. In other words, this means that a certain amount of CO2-equivalents (e.g. 40 kg in the example in figure 2) is "uselessly produced" in the upstream stages because in the following value chain it becomes NPO.

By the inclusion of LCA results, this approach has a strong life cycle perspective. However, the optimization focus is still on the site or process: it is about the reduction of NPO at the site or in the specific process. The only difference from conventional MFCA is the non-monetary, but impact-related and therefore ecological-oriented assessment of material and energy flows.

The biggest challenge of the MFIA is the availability of the required data. Hardly any small and medium sized enterprise will carry out an LCA "only" for the purpose

[6] For a comprehensive life cycle analysis, the system boundary „cradle to grave" or "cradle to cradle" should be used, which means that also the downstream steps like waste recycling and disposal must be included [22]. As already mentioned, by transfer functions, the environmental impacts of waste can be calculated. A comprehensive life cycle analysis would, however, not only include the NPO, but also the product output and the related environmental impacts due to utilization, recycling and disposal. In the present model, the downstream stages, don't find entrance into the calculation.

of MFIA. Many criticisms of the MFIA are the same as those of the LCA. The question can be raised: how the significance of the results is influenced by reducing the complex environmental impacts to only one category – even if it is a main category, such as the greenhouse effect?

3. Integrating life-cycle oriented external costs for emissions into MFCA (life cycle oriented non-value-costs)

The third approach attempts to methodically connect the first two mentioned approaches: the integration of site or process-related environmental impact costs of emissions with the MFIA.

The ideology here is; the attempt to use costs as a one-dimensional assessment unit in order to integrate internal and external costs, while considering the entire life cycle of materials and energy.

Methodology: The procedure is similar to that of the MFIA: In addition to conducting a conventional MFCA, LCA data for each relevant incoming material is collected (from cradle to gate).[7] The LCA results, however, which are environmental impacts, are not left standing at the level of impact categories, but are monetized by abatement cost approaches[8] according to the ecological economics. Hence, the entire life cycle of specific material and energy flows are considered.

The flow-related environmental impact costs, which are determined by multiplying the monetized environmental impact costs per kilogram with the quantity of each material are added to the internal costs and then divided into product output and non-product output. As shown in figure 3, internal and external cost flows are shown separately in order to illustrate individual significance.

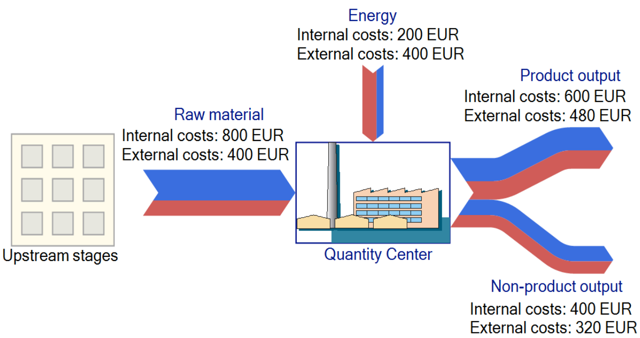

FIGURE 3: EXEMPLARY ILLUSTRATION OF INTEGRATING LIFE CYCLE ORIENTED EXTERNAL COSTS FOR EMISSIONS.

Appraisal: Compared to the first approach, here the life cycle perspective is taken into account. Not only the environmental impacts of the site-related emissions are expressed in costs, but all environmental impacts that occur in the course of the specific product life cycles are also monetized. This requires that the data for all environmental impacts of the materials used, as well as the external costs for each impact category are available for the organizations.

A large difference between external costs and the market price for a specific material indicates a lacking internalization of externalities and can serve as an indication for possible future environmental regulations.

According to the first approach, the sum of internal NPO-costs and the life cycle oriented external costs for NPO are called "life cycle oriented non-value-costs".

By dividing these monetized environmental impacts of the respective materials into product output and non-product output, it is shown again which abatement costs in the upstream stages would not be incurred if the company had not any inefficiencies, in other words, if the company did not "produce" any NPO.

Similar to the second approach, a major drawback, however, is the availability of data: for each material used, LCA results and external costs for each impact category are necessary.

V. CONCLUSION AND PERSPECTIVES

This paper presented three different theoretical approaches to integrate external costs for emissions or environmental impacts into MFCA in order to enrich the ecological perspective of this method. For each approach the justification, preconditions and drawbacks have been discussed.

Some of the main criticisms have already been mentioned, such as the availability of the required LCA data or the availability of data for monetized externalities for each relevant environmental impact category.

The main strength of the conventional MFCA – namely the wide applicability and its practicality – could be limited by the presented expansions, especially for small and medium sized enterprises which face limited cost and time budgets.

Moreover, it must also be critically examined why organizations should try to voluntarily internalize externalities and costs at all. A first response might be that it is in the interest of the company to anticipate political restrictions or to overtake social responsibility in the sense of a sustainable development.

The current need for research concerns the expansion of MFCA – particularly in regard to a full and easy applicability in small and medium sized companies and in regard to an expansion to the supply chain or even to complete product life cycles. For this purpose, MFCA-models adapted to the complexity of organizations should be developed.

Concerning the inclusion of external costs, the proposed approaches could be illustrated in case studies and best practice examples in order to assess the real efforts and benefits. The provision of data on the economic valuation of environmental impacts as well as the results of LCA is also seen as a necessary condition for the integration of externalities into MFCA.

[7] Analogous to the MFIA, the system boundaries can also be drawn from „cradle to cradle" (see also Footnote 5).

[8] While damage costs show a stronger environmental focus, abatement costs constitute an anticipation of externalities to be internalized and thus have a stronger economic focus.

References

[1] METI – Ministry of Economy, Trade and Industry of Japan, *Environmental Management Accounting (EMA) Workbook*, Tokyo, 2002.

[2] K. Kokubu, M. Nakajima, *Material Flow Cost Accounting in Japan: A New Trend of Environmental Management Accounting Practices*, Fourth Asia Pacific Interdisciplinary Research in Accounting Conference, Singapore, 2004.

[3] EN ISO 14051, *Umweltmanagement – Materialflusskostenrechnung – Allgemeine Rahmenbedingungen* (ISO 14051:2011), Wien, 2011.

[4] IFAC – International Federation of Accountants, *Environmental Management Accounting*, New York, 2005.

[5] C. Jasch, "Environmental and Material Flow Cost Accounting, Principles and Procedures," in *Eco-Efficiency in Industry and Science, Volume 25*, A. Tukker, Eds. Dordrecht: Springer, 2009.

[6] B. Steen et al., "Integrating External Effects into Life Cycle Costing," in Environmental Life Cycle Costing, D. Hunkeler, K. Lichtenvort, G. Rebitzer, Eds., London, New York: CRC Press, 2008, pp. 59-76.

[7] EN ISO 14040, *Umweltmanagement – Ökobilanz, Grundsätze und Rahmenbedingungen* (ISO 14040:2006), Wien, 2006.

[8] METI – Ministry of Economy, Trade and Industry of Japan*, Guide for Material Flow Cost Accounting,* (ver. 1), Tokyo, 2007.

[9] A. Moeller, M. Prox, *From Material Flow Cost Accounting to MFA and LCA*, Proceedings of the Eigth International Converence on EcoBalance 2008 – The Challenge of Creating Social and Technological Innovation Through System-thinking, Dec 10-12, Tokyo, 2008.

[10] T. Viere, A. Moeller, M. Prox, "Materialflusskostenrechnung – ein Ansatz für die Identifizierung und Bewertung von Verbesserungen in der Oekobilanzierung," in *Oekobilanzierung 2009 – Ansaetze und Weiterentwicklungen zur Operationalisierung von Nachhaltigkeit,* S. Feifel, et al., Eds., Karlsruhe: Universitaetsverlag Karlsruhe, 2009, pp. 45-54.

[11] B. Wagner, M. Nakajima, M. Prox, "Materialflusskostenrechnung – die internationale Karriere einer Methode zu Identifikation von Ineffizienzen in Produktionssystemen," *uwf*, 18, pp. 197-202, 2010.

[12] T. Viere, A. Moeller, M. Prox, *A Material Flow Cost Accounting Approach to Improvement Assessment in LCA,* Conference Paper for the International Symposium on a Sustainable Future (ISSF 2010), Mumbai, 2010.

[13] A. Moeller, M. Prox, *From Material Flow Cost Accounting to MFA and LCA*, Proceedings of the Eigth International Converence on EcoBalance 2008 – The Challenge of Creating Social and Technological Innovation Through System-thinking, Tokyo, Dec. 2010.

[14] ISO 14051, *Environmental management – Material flow cost accounting – General framework,* Geneva, 2011.

[15] W. Klöpffer, B. Grahl, *Oekobilanz (LCA),* Weinheim: Wiley-VCH Verlag GmbH & Co. KGaA., 2007.

[16] H.K. Prammer, *Integriertes Umweltkostenmanagement, Bezugsrahmen und Konzeption fuer eine oekologisch nachhaltige Unternehmensführung,* Wiesbaden: Gabler, 2009.

[17] T. Viere, et al., „Implications of Material Flow Cost Accounting for Life Cycle Engineering," in: *Glocalized Solutions for Sustainability in Manufacturing, Proceedings of the 18th CIRP International Conference on Life Cycle Engineering,* J. Heselbach, C. Herrmann, Eds., Braunschweig: Springer, 2011, pp. 652-656.

[18] P. Bickel, R. Friedrich, *ExternE externalities of energy: methodology 2005 update*, European Communities, Eds., Luxemburg, 2005.

[19] McKinsey & Company, Inc., *Costs and Potentials of Greenhouse Gas Abatement in Germany, A report by McKinsey & Company, Inc., on behalf of „BDI initiativ – Business for Climate,"* McKinsey & Company, Inc., 2007.

[20] A. Braunschweig, R. Mueller-Wenk*, Oekobilanzen für Unternehmungen, Eine Wegleitung fuer die Praxis,* Bern, Stuttgart, Wien: Verlag Paul Haupt, 1993.

[21] H.K. Prammer, H.K., „Strategieinduzierte Umweltkostenansätze. Das Nachhaltigkeits-Wertkorrektiv – Ein Maß zur nachhaltigkeitsorientierten Korrektur der Wertschöpfung," in: *Unternehmenspraxis und Nachhaltigkeit, Herausforderungen, Konzepte und Erfahrungen,* R.J. Baumgartner, H. Biedermann, D. Ebner, München: Rainer Hampp Verlag, pp. 111-129, 2007.

[22] H. Baumann, A.M. Tillman, *The Hitch Hiker's Guide to LCA, An orientation in life cycle assessment methodology and application,* Lund: Studentlitteratur AB, 2012.

Material and Cost Flow Analyses in Chemistry

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***Abstract*: Systematic environmental and sustainability management is namely important to the chemical industry which generates new materials with features that did not exist before. Additionally undesired residues are produced in considerable amounts. To meet this challenge it is necessary to use goal-oriented management instruments. They help to increase productivity (resource efficiency) and to reduce environmental burden and costs!**

This article presents an integrated management instrument (BTC-System) that takes into consideration technical goals (material efficiency, integrated environmental protection etc.) and economic goals (costs, value added etc.) as well [1]. The Material Flow Analysis and the Cost Flow Analysis are integral parts of the overall system. During the last 25 years this system was used for the analyses of several hundred syntheses in the chemical industry. Some of the main results are reported here.

I. INTRODUCTION

1. *Large Amounts of Residue Despite High Yields*

In chemical syntheses not only the target products are formed but also undesired residues. When manufacturing specialty, for instance pharmaceutical and fine chemicals, it is common for more than 60 % of the raw materials to end up as residues. This fact shows that the material efficiency is a key problem in the chemical industry!

Chemical engineers have learned to use the (stoichiometric/relative) yield as technical Key Performance Indicator (KPI) of chemical processes. This KPI is still generally used in chemistry to measure the process quality. Therefore it is not surprising that it is mostly very high in practice (nearly 90 %) despite the large amounts of residues produced by the industrial syntheses. The used KPI consequently turns out in practice to be a misleading indicator regarding productivity (resource efficiency).

2. *Product Costs as KPI in Practice*

In chemical companies the product costs (Herstellkosten) are generally used as an economic KPI also in Research and Development (R&D) and Production and Technology (P&T) units. Everybody working here knows from his own experience that the use of the product costs causes many errors and misunderstandings in practice. This is particularly true in the case of joint production or when overhead costs are (partly) included in the product costs.

3. *Requirements - Objectives*

The systematic increase in productivity and the systematic decrease in costs require goal-oriented management instruments which consider simultaneously technical goals (e.g. productivity, environmental protection) and economic goals (e.g., costs, value added) as well. These management instruments have to

1. operationalize the goals, i.e., make them measurable,
2. allow identification of the weak points of the processes,
3. show the potentials for process improvements, e.g., reducing potentials for resources, residues and costs.

That means for example that the productivity – nowadays often called resource efficiency – has to be quantified and measured. The engineer or chemist must also understand what parameters and variables can be adjusted to maximize the desired results.

II. MATERIAL AND METHODS

1. *Focus on the Primary Value Added Chain*

The ability to compete depends essentially on the performance of the chemical processes, i.e., on their productivity (resource efficiency), integrated environmental protection and costs. This performance is established in the process development and improvement from the laboratory to production [Figure 1]. As the competitiveness of chemical companies depends to a great deal on the Process Life Cycle Management (PLCM) we focus our attention on it. The PLCM is an integral part of the management of the primary value added chain ('Innovation Chain'). Many companies focus on the Supply Chain Management (SCM) and overlook that the Innovation Chain Management (ICM) is just as crucial and important for the competitiveness and company success.

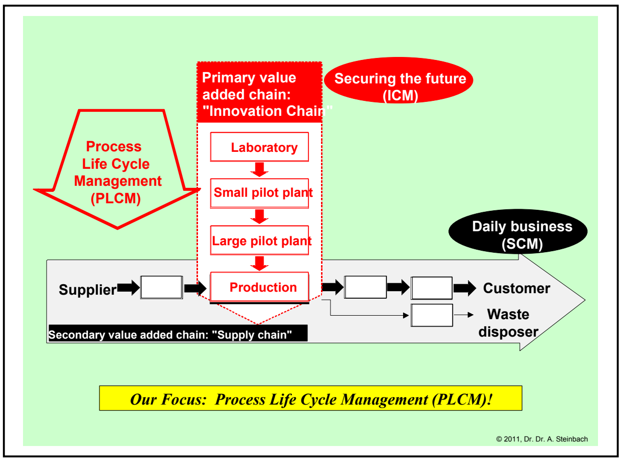

FIGURE 1: GOAL-ORIENTED INNOVATION CHAIN MANAGEMENT (ICM)

The management instruments of the primary value added chain have to focus on the

- systematization
- goal-orientation and
- acceleration of the decision making.

2. *Decision-oriented Method*

The management instruments have to deliver the information tailored to the requirements of the decisions concerning process development and improvement. The systematic decision making procedure consists of three steps [Figure 2]:

1) Model-based depiction of the chemical processes including the balancing of the material streams,
2) Goal-oriented process analysis regarding technical, economic and ecological goals,
3) Decision making concerning the measures in practice (synthetic route, process improvements, priorities).

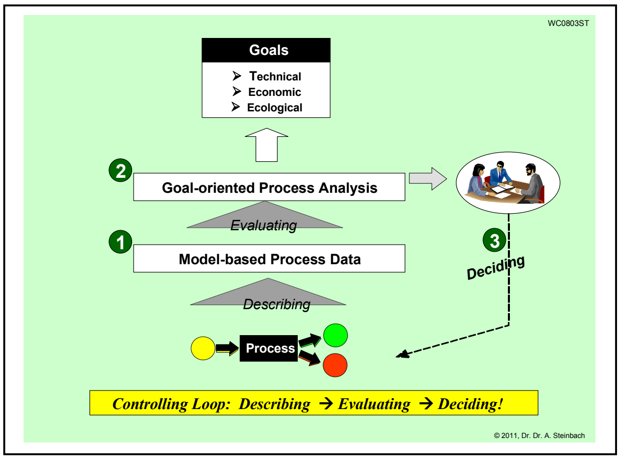

FIGURE 2: SYSTEMATIC CONTROLLING OF THE INNOVATION CHAIN (ICM)

The "Business Economic and Technical Controlling System (BTC-System)" is a computer-supported management instrument that meets these requirements. It supports the decisions concerning the development and improvement of chemical processes (in R&D and P&T). Characteristic of the BTC-System is the depiction according to standardized principles and the goal-oriented evaluation on the technical and economic level. The main goals are:

1) technical goals such as productivity (resource efficiency) in the subsystem Material Flow Analysis (Materialflussanalyse, MFA)

2) economic goals such as costs, value added and profit in the subsystems Cost Flow Analysis (Kostenflussanalyse, KFA) and Value Flow Analysis (Wertflussanalyse, WFA).

The results of the analyses are the basis for decisions on suitable measures to improve the chemical processes [step 3 in Figure 2]. Within this controlling loop one of the possible decisions can be to keep the process the way it is, without any changes.

3. *Technical Accounting of the MFA*

The basis of the overall BTC-System is the subsystem "Material Flow Analysis (MFA)". Its Technical Accounting contains the model-based process data [step 1 in Figure 2] with the amounts of all resources in technical units (kg, kWh etc.). The material resources (material flow) and the non-material resources are depicted differently. The MFA is the source of all process data. It contains the process knowledge now always available for the whole organization (Knowledge Management).

The main focus of interest is here the material/chemical aspect. The material flows are structurally balanced in the MFA. The basic balance sheet is the 'identity card of the process'. It depicts the material flows and the process structure respecting the laws of chemistry. On the basis of the basic balance sheet the computer-supported BTC-System generates automatically the material flow chart. Thus the flow chart of a chemical process is nothing else as its visualized balance sheet [Figure 3].

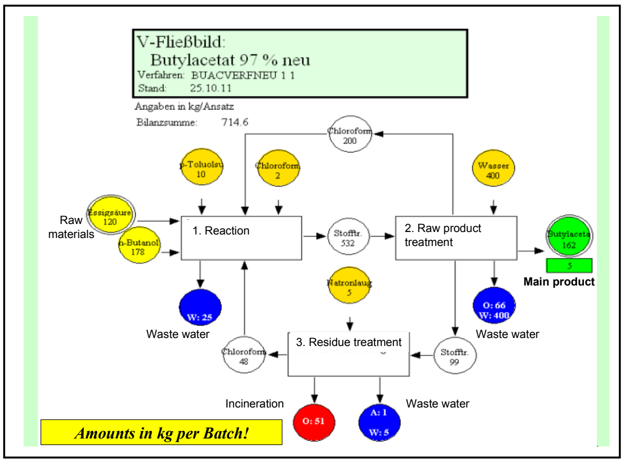

FIGURE 3: FLOW CHART = VISUALIZED BASIC BALANCE SHEET OF THE BUTYLACETAT PROCESS

4. *Process Cost Accounting of the KFA*

The economic KFA-subsystem adopts the structures and amounts of resources from the technical MFA-subsystem and values them with prices. Thus the technical

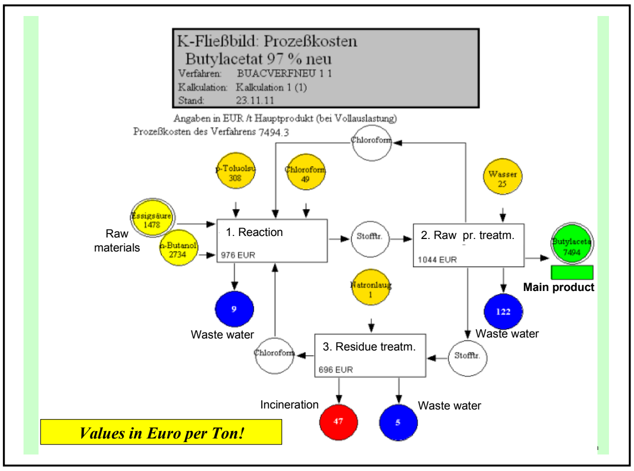

FIGURE 4: COST FLOW CHART OF BUTYLACETAT

process documentation (Technical Accounting) is the basis of the process costs. This method introduces the logic of chemical law into the cost calculation (KFA). The cost flow chart [Figure 4] created automatically has the same structure as the material flow chart [Figure 3].

The KFA is decision-oriented: It provides the cost building blocks which are necessary for the oncoming decisions. E.g. in a multi-step process normally only some steps are concerned by the process improvement decisions. Therefore it is important to quantify the subprocess costs and to make them visible. So the cost flow chart [Figure 4] shows the material costs (circles) and the conversion costs (rectangles) of each subprocess.

III. THEORY/CALCULATION

1. Goal-oriented Process Analyses

In the second step [Figure 2] the model-based process data are evaluated respecting technical goals (MFA) and economic goals (KFA) as well. On the technical level the data of the Technical Accounting and on the economic level the Pocess Cost Accounting are evaluated with the help of index numbers (KPI).

2. The Importance of the Goal "Productivity"

Productivity (resource efficiency) is the key technical goal of sustainable management. However it is not systematically used in practice, its definition is even nearly unknown. According to its economic definition, productivity is the ratio of the output of desired product(s) to the input of production factors. In the material transformation process that characterizes chemical production, the material productivity is particularly important. By it, the output of the desired product(s) is related to the input of raw materials. [Figure 5]

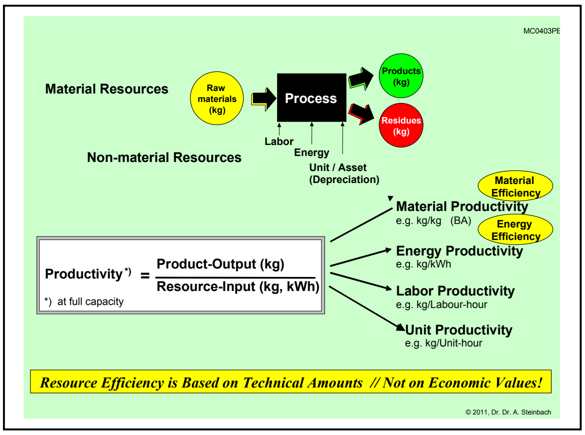

FIGURE 5: PRODUCTIVITY / RESOURCE EFFICIENCY (KPI)

We call the material productivity (material efficiency) Balance Yield (Bilanzausbeute, BA) because it is calculated in a standardized manner from the basic balance sheet of the MFA (a little bit simplified):

BA = (main product amount)/ (balance sheet total input)
The BA becomes even more significant with increasing shortage of the resources. It is the most important key performance indicator (KPI) of sustainable management.

3. Process Analysis with Productivity Function (MFA)

A goal-oriented increase in productivity requires the knowledge of the main influencing parameters. These parameters and their influences can be expressed in terms of a so-called "productivity function"[2]:

Each chemical synthesis has a particular maximum value for its balance yield (BA). This is the theoretical balance yield (BA_t). Whereas the BA pertains to a particular, actual process, including its process engineering aspects, the BA_t is related more to the underlying chemistry. It is calculated on the basis of the theoretical basic balance sheet (stoichiometry). If there are different chemical process paths to a given product, each of those paths has its own BA_t.

For a given actual process application the ratio of the balance yield to the theoretical balance yield (BA/BA_t) shows how close the BA of a particular process approaches the theoretical limit associated with that particular process. This quotient called the "specific balance yield" (spezifische Bilanzausbeute, spBA) is a measure of the degree of optimization of the process (BA/BA_t = spBA). From that the following productivity function equation is obtained:

$$\mathbf{BA = BA_t \times spBA}$$

Thus, we see that for the productivity (BA) of a given synthesis process , there are two "adjustment screws":

1) The theoretical maximum of the balance yield (BA_t) fixed by the synthetic route and
2) The degree of optimization (spBA).

A differentiated view of the degree of optimization (spBA) leads to a more detailed form of the equation for the productivity function:

$$\mathbf{BA = BA_t \times (RA \times MA_{TR}) \times EA_P}$$

where:
BA = the balance yield actually achieved (from the basic balance sheet of the MFA),
BA_t = the theoretically achievable balance yield (from the theoretical basic balance sheet),
RA = the relative or stoichiometric yield calculated with respect to the principal raw material,
MA_{TR} = the factor accounting for any excess of primary raw material (the proportion of the theoretically necessary amount to the amounts actually used),
EA_P = the primary raw materials portion of the total of the basic balance sheet.

Consequently there are in total four "adjusting screws" for the maximization of the material productivity/efficiency (BA). The optimization of chemical processes respecting the BA-goal is performed by maximization of the percentage of each parameter [Figure 6].

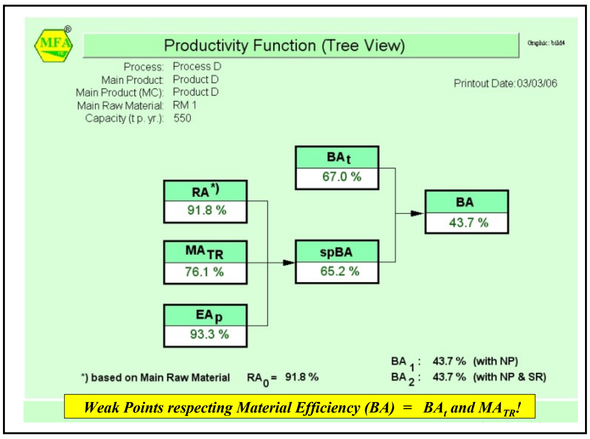

FIGURE 6: PRODUCTIVITY FUCTION OF THE PROCESS D

The problem in practice is that the chemical engineers have learnt to maximize the RA (i.e. conversion and selectivity) – they do not have learnt to maximize the material productivity/efficiency (BA)! That's the main reason why the RA-values are usually high and the BA-values are relatively low in practice [Figure 7].

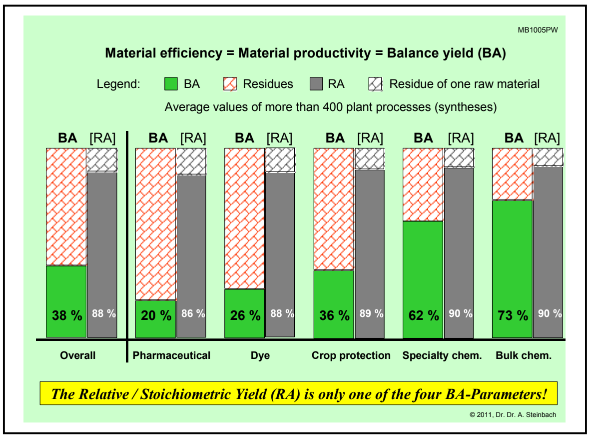

FIGURE 7: MATERIAL EFFICIENCY (BA) IN CHEMISTRY

Recycling of excesses of raw materials (increase in MA_{TR}) and recycling of solvents and other auxiliaries (increase in EA_P) are often performed in the chemical industry. These physical recycling methods increase the productivity (BA). They don't contain any chemical conversion process. To our great surprise we discovered that in some processes also a chemical recycling can be performed.[1] That increases significantly the BA_t and therefore the material productivity/ efficiency (BA).

Conclusion: The productivity function is important to a systematic environmental and sustainable management: It is the key to higher material productivity/efficiency (BA) and pollution prevention. Herein the physical and chemical recycling methods play a key role.

4. *Cost-oriented Process Analysis (KFA)*

The goal-oriented increase in productivity (BA) already discussed requires the knowledge of its main influencing parameters. In a similar way the goal-oriented decrease in process costs requires the knowledge of the main influencing cost-parameters. The goal is to identify the cost drivers and the costly process weak points as well as the cost reducing potentials.

Each assessment and each determination of a potential include a comparison. In the KFA the comparison of the material costs of a particular actual process with those of the corresponding theoretical process plays a key role: The actual material costs (= raw material costs + waste material costs) are calculated by valuing the amounts of the basic balance sheet with prices. In a similar way the theoretical material costs are calculated by pricing the amounts of the theoretical basic balance sheet (equation of the overall reaction). The theoretical material costs are the minimum value of the material costs at a given price level. The difference between the actual material costs and the theoretical material costs is the material cost reducing potential [Figure 8].

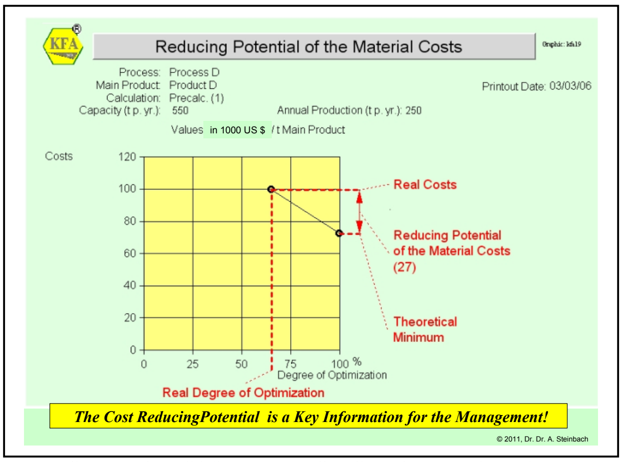

FIGURE 8: COST REDUCING POTENTIAL OF THE PROCESS D

In the detailed analyses performed in practice we identified the different sources of the cost reducing potentials (weak points). The process improvement measures were focused on these weak points.

For a given actual process the ratio of the theoretical material costs (<u>St</u>off<u>k</u>osten <u>t</u>heoretisch, StK_t) and the material costs (<u>St</u>off<u>k</u>osten, StK) shows how close the real material costs approach the theoretical limit. This quotient, called the "specific material cost" (<u>sp</u>ezifische <u>St</u>off<u>k</u>osten, spStK), is a measure for the degree of optimization of the material costs ($spStK = StK_t/StK$). From that the following material cost-function is obtained:

$$\mathbf{StK = StK_t \; / \; spStK}$$

Thus, we see that – not only for the productivity (BA) but also – for the material costs (StK) of a given synthesis process , there are two "adjustment screws":

1) The theoretical minimum of the material costs (StK_t) fixed by the synthetic route and
2) The degree of optimization (spStK).

The smaller the spStK the greater the probability in practice to succeed in cost reduction.

IV. RESULTS

1. Projects with BTC System

In practice low material productivity and high material costs are typical for chemical production (syntheses). Therefore the projects with the BTC-System (performed since the late eighties of the last century) have a strong focus on productivity (BA) and process costs. The projects consist normally of three steps:

1) Quick Analysis/Screening of many (20) processes: Main goal: To detect the processes with the greatest optimization potentials (selection)
2) Detailed Analyses of some (3) selected processes: Main goal: To find out the weak points of each process respecting productivity and costs.
3) Process Improvement Meeting: Main goal: To generate problem solving ideas on the basis of the Detailed Analyses and to decide on measures for process improvement.

2. Project Results

The BTC-System and the projects performed with it serve the particular purpose to support the goal-oriented decision-making in the process development (R&D) and production (P&T) units of chemical and pharmaceutical companies. Ultimately, it helps to improve processes regarding productivity and costs. In most projects significant cost reducing potentials were found [Figure 9].

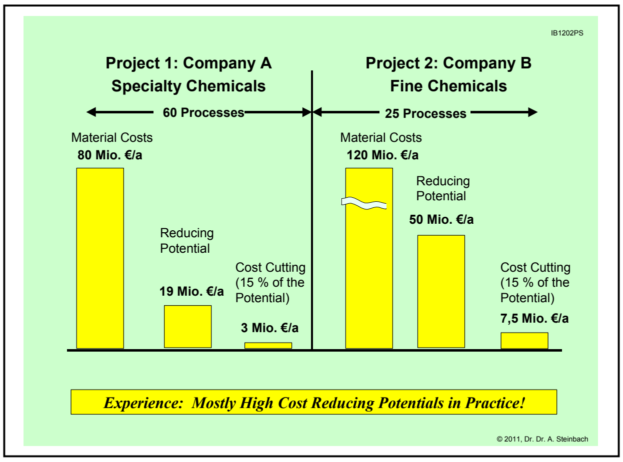

FIGURE 9: TWO EXAMPLES OF QUICK-ANALYSIS SCREENING PROJECTS

In addition the projects led to some general insights concerning our issue: All projects we performed until now show that the processes are better optimized with respect to the material costs (average spStK = 75 %) than to the material productivity (average spBA = 48 %). That is also true for the project shown on the graphic [Figure 10]. We see on the portfolio two degrees of optimization:

1) Degree of Optimization of the MFA (spBA): High spBA means that the material productivity (BA) approaches its theoretical limit (BA_t) closely.
2) Degree of Optimization of the KFA (spStK): High spStK means that the material costs (StK) approach their theoretical limit (StK_t) closely.

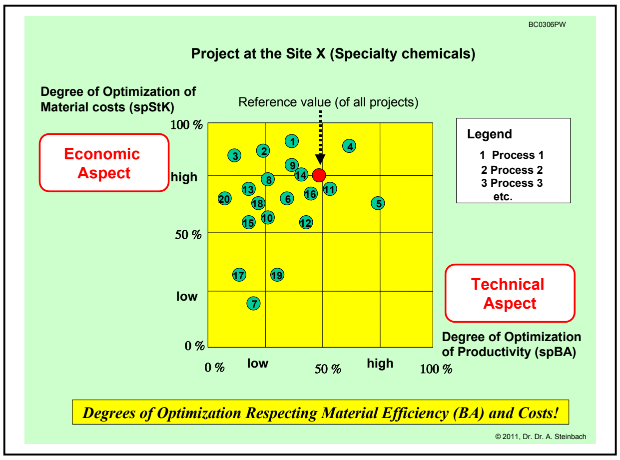

FIGURE 10: DEGREE OF OPTIMIZATION PORTFOLIO

This result proves that in practice the costs are considered as more important than the material efficiency (BA). This efficiency is not even systematically measured.

The overall evaluation of all projects we performed in production units (the projects in R&D units are not included) reveals that the average material efficiency of chemical processes (average BA = 38 %) is rather low [see Figure 7]. We will not hide the fact, that the presented results are not in accordance with the "Factbook 05: The Formula Resource Efficiency" published by the "Verband der Chemischen Industrie"”(VCI) in May 2012. It says: "In relation to the amount of input materials these (waste materials, the author) come only to 2 percent: 98 percent of the raw materials are used" [3]. In this case the resource efficiency problem in chemistry would be negligible.

V. DISCUSSION

1. Limits to Process Improvement

The productivity function is crucial for all improvement activities in practice concerning chemical processes.

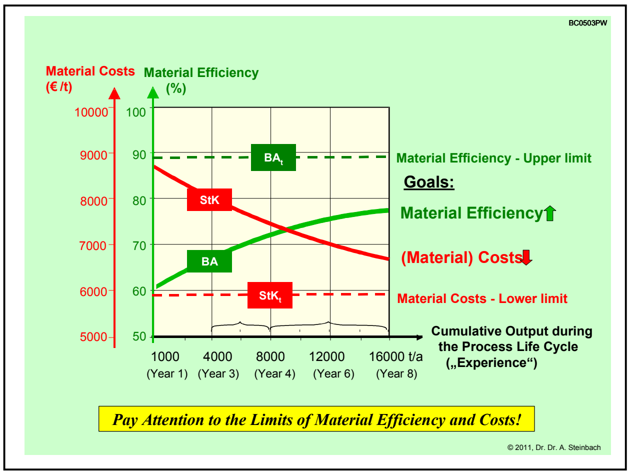

FIGURE 11: CONTINUOUS IMPROVEMENT OF A CHEMICAL SYNTHESIS DURING ITS PROCESS LIFE CYCLE

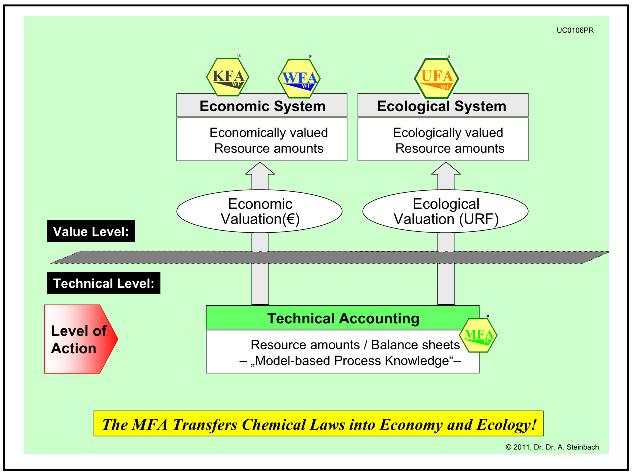

FIGURE 12: VALUATION OF THE RESOURCE AMOUNTS

This function shows the “adjusting screws” but also the limits of the improvement activities with respect to (material) productivity (BA_t) and costs (StK_t) [Figure 11]. These limits are fixed by the synthetic route. There are only two ways to improve unfavourable limits (low BA_t, high StK_t): To look for another synthetic route and/or for a possibility to perform chemical recycling. If the synthesis route remains unchanged the possible improvements lay necessarily within the given limits ($BA < BA_t$, $StK > StK_t$). In all discussions concerning process improvement activities the limits have to be taken into account.

2. *The bigger picture*

The important point is that the BTC-System links the Cost Accounting (KFA) interactively with the technical process models (MFA). So, the chemists and engineers are able to switch readily back and forth between the technical view of the processes (BA and its parameters) to the economic view (costs and related factors).

But there is also another aspect on the value level [Figure 12]: If it is possible – we are convinced it is – to assign numerical environmental value (or harm) factors (Umweltrelevanzfaktoren, URF) to the resource amounts of the MFA, then “Ecological Accounting” becomes possible. This can be evaluated in a similar way [step 2 in Figure 2] as already shown for MFA and KFA. In short, we are talking about a further subsystem called UFA (Umweltorientierte Flussanalyse).

3. *Decision-making in Practice*

A comprehensive assessment of chemical-synthesis proposals, such as investment proposals in a chemical company, requires the consideration of technical, economic and ecological goals, and thus of several assessment categories. – The BTC-System meets these requirements! – Putting it another way, the assessment process is multi-layered; it is divided into a number of interrelated sub-decisions. In practice, the final decision generally involves a compromise among the sub-decisions.

VI. CONCLUSION

The presented integral method contains technical aspects (MFA) and economic aspects (KFA) as well. It affects the courses of study in chemistry, chemical engineering, environmental engineering and industrial engineering (Wirtschaftsingenieurwesen). In particular, the knowledge of the productivity function is basic to all activities aimed at the increase in resource efficiency.

In chemistry the good laboratory practice can’t be restricted to the equation of the reaction. It has to include the basic balance sheet as well. Both, equation and basic balance sheet, form the “identity card” of chemical syntheses. At this basis has to be determined not only the traditional yield (RA) but the balance yield (BA) and the theoretical balance yield (BA_t) as well. The BA and its parameters are very important to resource efficiency and sustainability.

On the economic level the Process Cost Accounting based on the Technical Accounting [Figure 13] is very helpful to chemical companies because it enables to determine systematically the cost reducing potentials and the cost weak points of the processes. It has to be emphasized that the process costs are the goal of the process optimization. The process costs have to be minimized. – The process costs are not an integral part of the tradiditonal cost accounting methods! – Characteristic for the Process Cost Accounting (KFA) is the interrelation between the technical (chemical law) and economic (cost accounting) levels.

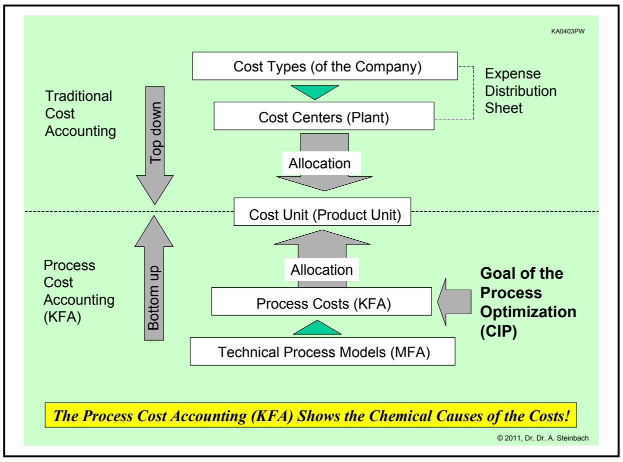

FIGURE 13: TOP DOWN- AND BOTTOM UP-VIEW IN COST ACCOUNTING

REFERENCES

[1] More details in the author’s book currently (March 2013) in print: A. Steinbach, Ressourceneffizienz und Wirtschaftlichkeit in der Chemie – Material-, Kosten- und Wertflussanalysen –, Wiley-VCH-Verlag (Verlag Chemie), D-69469 Weinheim (350 pages, 200 coloured graphics)

[2] A. Steinbach, R. Winkenbach, Choose Processes for Their Productivity, Chemical Engineering (New York), April 2000, 94 –104.

[3] Verband der Chemischen Industrie (VCI), Factbook 05, Die Formel Ressourceneffizienz (2012), Blatt „Welche Indikatoren für Ressourceneffizienz? Zwischen technischer Realität und politischen Zielvorstellungen", 1