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Diffusion of environmental management accounting for cleaner production: Evidence from some case studies

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ABSTRACT

Environmental management accounting provides a set of tools designed to support management to make better decisions about cleaner production. Diffusion of innovation theory provides a foundation for understanding the dynamics of environmental management accounting implementation. Based on five case studies of businesses in Indonesia, the Philippines and Vietnam characteristics of environmental management accounting innovations and temporal path of development are explored. The cases examined reveal the importance of incremental path specific changes to work towards complex sustainability settings and demonstrate the richness and usefulness of fostering cleaner production practices through a multitude of environmental management accounting tools, which rejects the view that one environmental management accounting method such as material flow cost accounting would suffice. Moreover, the findings show the relevance of involving external support and the need for interdisciplinary execution in diffusing environmental management accounting innovations.

1. Introduction: environmental management accounting for cleaner production

Linkages between the environment and organisations have been the subject of considerable research. Environmental accounting has been introduced to provide a foundation for business to make informed decisions because without such information inefficient use of resources, pollution, or even disasters could result (Citroen, 2011). Environmental management accounting (EMA) has specifically been introduced to help companies manage natural resources, energy and pollution. Supported by research and the development of guidelines (e.g. IFAC, 2004), statement documents (UNDSD, 2001), standards (ISO, 2011), workbooks (METI, 2002) and a multitude of case studies (e.g. Herzig et al., 2012) EMA has become an acknowledged approach to fostering cleaner production (e.g. Gale, 2006a), design for sustainable manufacturing (Kishawy et al., 2018), circular economy measures (Zhou et al., 2017), and resource efficiency (Nakajima et al., 2015).

Academic research has for over twenty years focussed on the development of EMA tools in the context of specific management decision situations (Burritt et al., 2002). Burritt et al. (2002) propose a comprehensive decision-making framework using EMA tools based on whether information gathered is: physical or monetary; relates to past or future corporate activities; provides a short- or long-term perspective; and is routine or ad hoc. While the framework provides an overview of sixteen possible decision settings (see Table 1), development paths for using EMA tools in specific companies have yet to be examined.

The matter is important because while academics seek to provide generalisable conceptual frameworks and models to address environmental issues practitioners have to work with the complexity of 'messy', 'wicked' problems facing business (Peterson, 2009), something global organisations such as the United Nations Division for Sustainable Development (UNDSD) (2001) and the International Federation of Accountants (IFAC) (2004) have encouraged through EMA. Nonetheless, there has been little examination of the dynamics of EMA implementation within business, i.e. how EMA tool application develops over time. Such examination could provide a guide to others seeking to introduce

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Table 1
A comprehensive EMA framework (Burritt et al., 2002).

		Monetary EMA		Physical EMA	
		Short-term	Long-term	Short-term	Long-term
Past-orientated	Routinely generated	Environmental cost accounting	Environment induced capital expenditure and revenue	Material and energy flow accounting	Environmental capital impact accounting
	Ad hoc	Ex-post assessment of relevant environmental costing decisions	Ex-post inventory assessment of projects (including life cycle costing – LCC)	Ex-post assessment of short-term environmental impacts	Ex-post inventory appraisal of physical environmental investments (including life cycle assessment – LCA)
Future-orientated	Routinely generated	Monetary environmental budgeting	Environmental long-term financial planning	Physical environmental budgeting	Environmental long-term physical planning
	Ad hoc	Relevant environmental costing	Monetary environmental investment appraisal	Tools designed to predict relevant environmental impacts	Physical environmental investment appraisal

EMA and moving operations towards cleaner, sustainable production. Hence, this paper explores the paths adopted by a set of companies when developing EMA tools and asks the research question: *How does Environmental Management Accounting diffuse within organisations?*

The paper proceeds as follows: Section 2 introduces EMA and examines recent literature detailing what is known about EMA development. It then outlines the theoretical perspective adopted for the paper. In Section 3 the research design is explained. Section 4 explores how EMA tools are linked with each other in different decision settings based on analysis of a set of five in-depth real case studies in South East Asia. Finally, Section 5 provides discussion of the paths emerging, while Section 6, draws conclusions, mentions limitations and suggests areas for future research.

2. Environmental management accounting development and diffusion of innovation

The section is in four parts and considers the definition and development of EMA, the diffusion of innovation theoretical foundation for the paper, incremental and radical forms of innovation, and the characteristics of internal innovation.

2.1. Environmental management accounting: definition and development

EMA comprises a set of accounting tools and practices to support management decision-making relating to environmental impact reduction (Burritt et al., 2002) and enhancement of economic performance (IFAC, 2004). It is “the management of environmental and economic performance through the development and implementation of appropriate environment-related accounting systems and practices” (IFAC, 2004). In other words, the main difference between conventional and environmental accounting is that the latter specifically identifies, measures, analyses, and interprets information about environmental aspects of company activities. Within the conventional approach to accounting this distinction is somewhat unclear.

Two reviews of EMA literature have been conducted recently with the intent of identifying whether as an administrative innovation EMA is getting closer to becoming a mainstream activity. Schaltegger et al. (2013b) undertook a bibliometric review of 814 EMA academic and practitioner publications in English, German and French and conclude EMA remains a young but not yet mainstream discipline. Also Tsui (2014) in a systematic review considered 22 EMA articles with the majority being published in *Accounting, Auditing & Accountability Journal* and the *Journal of Cleaner Production*, both being high level journals in social and environmental accounting and in sustainability. Table 2 summarises the themes of specific academic articles on EMA development as revealed in these publications.

There is a wide consensus that there are two main groups of environmental impacts related to company activities (IFAC, 2004): environmentally related impacts on the economic situation of companies (provided by monetary EMA tools), and company-related impacts on environmental systems (provided by physical EMA tools). Burritt et al.’s (2002) framework for EMA classifies different EMA tools, such as environmental investment appraisal, environmental cost accounting, or life cycle costing, according to the associated decision-making situation and thus provides a basis for managers and other decision-makers to choose an appropriate tool depending on their particular concern and objective.

Because EMA is typically established for internal decision-making it is difficult for interested people outside the organisations to obtain information about the internal accounting processes. Although the implementation of a well-designed EMA system will help achieve a number of environmental and financial aims, there will be various factors that at times might hinder, or

Table 2
EMA themes developed in the literature.

EMA Theme	Publication
Regions	Australia (Deegan, 2003); China (Li, 2004); Europe (Bartolomeo et al., 2000; DePalma and Csutora, 2003); Finland (Järvenpää, 2016); Honduras (Jasch et al., 2010); South Korea (Lee, 2011); Japan (METI, 2002; Nakajima et al., 2015); Lithuania (Staniskis and Stasiskiene, 2006); New Zealand (Greig et al., 2006)
Sectors and industries	Automobiles (Jasch and Lavicka, 2006); iron and steel (Zhou et al., 2017); textiles (Laurinkevičiūtė and Stasiškienė, 2006; Schaltegger, Viere and Zvezdov, 2012b); local government (Burritt and Saka, 2006; Qian et al., 2011); printed circuit board (Wang et al., 2017); pulp and paper (Gale, 2006a; Setthasakko, 2010); printed circuit board manufacturing (rice (Burritt et al., 2009); manufacturing and small manufacturing (Jalaludin et al., 2010; Jamil et al., 2015); beer (Schaltegger, Viere and Zvezdov, 2012a); higher education (Chang, 2013); wine (Christ, 2014)
Environmental fields of application	Waste (Gale, 2006b); material flows (Kokubu and Nakajima, 2004; Christ and Burritt, 2016); carbon (Burritt et al., 2011; Schaltegger and Csutora, 2012; Gibassier and Schaltegger, 2015); health, safety and environment (Schaltegger and Herzig, 2012); water (Christ, 2014)
Links	Sustainability (Bennett et al., 2013); innovation (Ferreira et al., 2010; Christ, 2014).

support, the implementation of an EMA system. As recently recognised by the United Nations Sustainable Development Goals the literature indicates companies face different environmental challenges which vary between locations, industries and fields of application as well as over time. The EMA focus has largely been placed on tools for short-run operational decisions based on information about past operations, by applying EMA tools such as material flow accounting and environmental cost accounting (e.g. Schaltegger and Zvezdov, 2015). However, long-run investment decisions with emphasis on physical and intangible aspects of environmental investment have also emerged as important in different industries, and regulatory systems (Burritt et al., 2009). Furthermore, given that sustainable development is a future oriented concept, it could be expected EMA tools dealing with future-oriented information (e.g. budgeting and financial planning; see e.g. Burritt and Schaltegger, 2001) would have to play a role, too. What this development in EMA literature shows is an increasing recognition that the usefulness of EMA goes well beyond approaches to managing eco-efficiency only as, for example, reflected in standards such as the ISO 14051 which is based on material and energy flow (cost) accounting and a small set of tools only. Despite the relevance of studies investigating the techniques of such approaches, it seems that research has also acknowledged the full potential of the multitude of EMA tools and the way in which they can be combined, responding to call made by international organisations such as IFAC (2004) and UNDSD (2001).

However, although literature has considered a range of EMA settings and case studies in which each of the sixteen elements in the Burritt et al. (2002) framework have had a part to play (Herzig et al., 2012), the paths through which EMA tools have been developed over time have not been examined previously and knowledge of the dynamic involved will help guide analysis and practice. This raises the question how EMA as an innovation is taken up and diffused over time within companies.

2.2. Diffusion of innovation theory

An innovation can be viewed as an idea that is new to the organisation adopting it (Bolton, 1993). Damanpour (1991) indicates that the literature discusses different types of innovation with three contrasting pairs having gained the most attention 'administrative and technical, product and process, and radical and incremental.' EMA can be classed with management accounting as an administrative innovation of management concepts and methods designed to help managers improve resource efficiency because it is associated with new administrative procedures, organisational policies and organisational structures. Nevertheless, in practice the advent of new management technologies, such as accounting tools which put knowledge to practical use, somewhat blurs the distinction between technical and administrative innovation (Rikhardsson et al., 2005). Rogers (2003) in his seminal work identified five characteristics inherent in the decision to adopt innovations that are likely to facilitate, or hinder success: relative advantage over existing practice; compatibility with existing values, experience and needs of the potential adopter; overall complexity; observability, or the degree to which the results can be observed and communicated; and triability, meaning the extent to which potential adopters can experiment with the innovation on a limited basis.

Empirical EMA research using Rogers' (2003) approach largely relates to innovation between organisations rather than intra-organisational diffusion. Rikhardsson et al. (2005) considered the spread of EMA between organisations based on efficiency and institutional factors, and Christ and Burritt (2016) used Rogers' (2003) theory to explore the potential take up of material flow cost accounting (MFCA). Neither, however, considers intra-organisational diffusion.

Over twenty years ago, Cool et al. (1997) observed that 'intra-organisational diffusion has long been neglected'. Pae et al. (2002) 'set out to identify the factors that play a tangible role in facilitating the intra-organisational diffusion of innovations', in preparing for examination of internal purchasing decisions they find little prior research to guide them. But Northcott and France (2005) suggest that diffusion of innovation theory can be a useful perspective for understanding the adoption of new management accounting techniques both across and within New Zealand public hospitals. Similar comments are made by Øvretveit et al. (2007) when examining the implementation of electronic medical records in a hospital. There seems to be growth in opinion and evidence that intra-organisational diffusion of innovations such as EMA is worth pursuing.

The roll out process is discussed by Thakur et al. (2012) who explain how the roll out might be achieved building on first movers in a single department or functional area and incrementally rolling out as others areas are 'deemed appropriate' by the relevant managers. Schaltegger et al. (2015) show empirically that different business functions and managers are interested and deal with different kinds of sustainability information. This implies that specific contextual aspects and management functions may require particular developments and results in establishing EMA in an organisation. In a parallel discussion Contrafatto and Burns (2013) when looking at the dynamics of change in rules and routines adopted over time in relation to social and environmental reporting (SEAR) within a multinational company acknowledge that existing 'Management accounting, as a primary source of information within organisations, is paramount to the diffusion of social and environmental accounting and reporting practices and sustainability know-how'. Burns and Scapens (2000) also consider 'how information is fundamental to the cumulative path(s) through which SEAR practices become what they are'. They conclude that working towards sustainability within the system is the only practical way forward, in the face of power disparities, with management accounting being the focal information gathering device. Hence, the focus here on diffusion of the EMA innovation complements and extends such earlier research.

2.3. Incremental or radical innovation in practice

Ettlie et al. (1984) draw attention to the difference between incremental and radical change in diffusion of innovations. Innovations that are extensive and quickly diffused, that is, rapidly and completely adopted by all potential adopters could be considered radical (Ettlie et al., 1984). They usually involve changes of the system with new processes and methods, new knowledge, new products/services (Amis et al., 2004), and new organisational structures (Greenwood and Hinings, 1996).

Depending on the scope considered, extensive potential adoption may refer to all potential organisations in the market, or all managers and departments in an organisation. Relative to practice this approach would be somewhat utopian as managers address specific environmental and social issues raised by media, regulators, customers, employees, etc. as specific information needs of different management functions (Schaltegger et al., 2015) and budgetary constraints can restrict the introduction and scope of innovations (Silva and Carreira, 2012). In practice it has been suggested diffusion works through experimentation by different managers to manage risks, gain experience over time and build confidence through incremental learning (Ellis, 1965). Learning curves conceptually typify the gains to be made as links between experience and performance over time become apparent from

incremental repetition (Yelle, 1979). Hence, benefits from pursuing an innovation can accumulate over time whilst engaging in its experimentation (Thomke, 2001) thereby producing triable situations where compatibility with existing systems can be tested and implemented, and relative advantages of new tools assessed.

Also, it has been suggested small wins in relation to improved performance are taken where available with each experiment exposing the support for and barriers to the innovation and this facilitating incremental learning and adaptation (Weick, 1984). Empirical analyses considering time lags found that improvements of disclosure quality in carbon management accounting lead to subsequent improvements of carbon performance in the next time period (Qian et al., 2018). This indicates that internal improvement of managing environmental information can lead to performance improvements in the future. The benefits of small, incremental wins become apparent and encouraged, generating confidence or even optimism about future wins. Similarly, small flops are less threatening as the negative resource implications of any flop are reduced, demands on any individual are more modest, and skills to deal with the situation a closer match to capabilities. Weick (1984) explains, in practice complexity needs to be broken down into manageable, incremental, experimental steps because individuals have limited cognitive capacity and may be too personally stirred up by issues they are involved with in daily business so they have difficulty dealing with massive complex problems, such as the implementation of the complete set of EMA tools in an organisation. His suggestion, based on evidence in organisational practice from a range of ad hoc examples, is to refocus on small problems which are easier to solve (Weick, 1984). Lessons are learnt from pragmatic experiments conducted largely at a local level, step by step, and not threatening survival of the organisation (Krohn and van den Daele, 1998). The implication is that EMA tools might be expected to be developed over time through learning about small wins.

2.4. Characteristics of internal diffusion of EMA tools

Based on the literature about factors affecting internal diffusion of innovations a number of characteristics are classified and integrated with Rogers' (2003) five category scheme (see Table 3).

The theoretical set of sixteen internal decision settings behind the EMA framework (Table 1) has the potential for a comprehensive approach to be implemented once benefits of the toolkit are perceived. The issue to be explored is how these EMA tools are taken up – holistically or incrementally.

3. Research method

The researchers employed an innovation action research approach (Liu and Pan, 2007) in order to engage closely with selected companies as a kind of research "client organisations" and to explore the application and development of EMA through the lens of Rogers' (2003) diffusion theory. Similar to Liu and Pan (2007) advice was sought from the researchers by the five companies that build the basis of this study to explore the opportunities for EMA implementation and assist in the development and implementation of the tools. For both, the researchers and the companies, the implementation of EMA tools in the three developing countries Indonesia, the Philippines and Vietnam was a largely under-investigated field of research, in particular, as technical and conceptual developments had mainly taken place in Western and more industrialised countries and related research had only shown marginal interest in the process of intra-organisational diffusion of EMA tools over time. Hence, the study represents unique circumstances to pioneer the analysis of intra-organisational diffusion of EMA tools and how organisational members who encounter EMA tools use them over time.

Overall, the researchers carried out twelve company case studies as part of a larger project on EMA diffusion in South-East Asia (Herzig et al., 2012). Five of them were selected for the purpose of this analysis on the grounds of two aspects: the application of a multitude of EMA tools (other cases were too limited in scope, i.e. based on a few tools only) and long-term engagement through which the researchers obtained a rather intimate understanding of what the people involved in the EMA application do and why they do it (again, other cases did not appear to be suitable to learn enough about the complex set of practices involved in EMA diffusion). Similar to other innovation action research studies such as the one by Liu and Pan (2007) the researchers had a dual role of researching and consulting in a transdisciplinary research sense (see e.g. Schaltegger et al., 2013a). However, they were not paid for their involvement as the research was funded by the German Federal Ministry of International Cooperation and Development through one of its agencies, InWEnt – Capacity Building International (nowadays part of GIZ). Hence, there was no particular interest or bias in providing advice with regard to certain technologies or tools. Nevertheless, the company-based projects included the commitment to provide feedback and recommendation whilst this in turn committed the companies to provide the researchers with information necessary for the analysis.

Generally, case studies were used in the project as a research strategy to analyse decision-making and internal accountability

Table 3
Diffusion of innovation characteristics.

Characteristics – Rogers, 2003.	Characteristics Revealed – Case Analysis	Source
Relative Advantage	Relative advantage - Costs and liabilities	Ferreira et al. (2010).
	Relative advantage- Hierarchy of authority, control and communication	Damanpour (1987).
	Relative advantage - Centralised or decentralised organisation	Ettlie et al., 1984; Lundblad, 2003.
	Relative advantage – Individual leadership champion or gatekeepers	Lundblad, 2003; Schaltegger and Zvezdov, 2015.
Compatibility	Compatibility - System openness	Lundblad (2003).
	Compatibility - Compatibility with existing social and env. values	Rogers (2003).
	Compatibility - Existence of sustainability-related management systems	
Complexity	Complexity – Small wins and flops, experimentation	Weick (1984).
	Complexity -Individual ability to address complexity	
	Complexity - Presence of internal use of interdisciplinary functions	
Observability	Observability - Communication of the results	Lundblad, 2003; Bennett et al., 2013; Rogers 2003.
	Observability - Personal involvement in issues	
Trialability	Trialability – Incremental projects	
	Inter- and extra- organisational - Involvement with industry associations, external bodies or consultants	

processes in depth in the context of cleaner production measures, how environmental information influences these processes, and with what results. They served as a guide to establishing a frame for data collection, seeking to understand practice as it happens and understand contexts influencing the application of specific EMA tools that are used to provide necessary information for decision-making. Case studies are particularly suitable for research areas where there are few prior theoretical pieces of literature or empirical research work (Eisenhardt, 1989) and the most appropriate research questions are those asking 'how' and 'why' (Yin, 2003) rather than those requiring broad statistical analysis.

In order to access potentially rich data and to cover a wide range of perspectives, several sources of evidence were used and cross-validated (data triangulation).The multiple data sources include a large spectrum of contact persons such as environmental, production, and financial managers, accountants, company owners and senior management as well as a variety of research methods. Data collection methods included interviews, direct observation, documentation, archival records, and a questionnaire for initial selection of cases. Moreover, interviews and observation were mainly carried out in pairs and via different groupings of researchers (across cases). The participant observation including watching their activities and interacting with them through questions and joint endeavours allowed to investigate whether certain paths for implementing EMA exist and whether some tools serve as a foundation for the application of other tools over time. The fact that the cases are from different sectors is an inevitable result of the self-application process by which companies demonstrated their interest and willingness in acting as a case study company. Whilst this adds to the richness of perspectives, a sector-specific analysis would have provided other opportunities, e.g. for further comparative analysis.

4. Results: paths of diffusion in exploratory cases

To address the research question 'How does Environmental Management Accounting diffuse within organisations?' the take up of individual and sets of EMA tools over time need to be analysed. Such paths of EMA diffusion are now considered for five South-East Asian companies where EMA tools have been introduced. Each case is examined in turn in relation to the potential considerations identified that might influence the tools taken up.

4.1. LinenCo

The Indonesian textile manufacturer LinenCo produces towels and other bathroom fabrics for retailers around the world. The family-owned, medium-sized company is overseen by a general manager and several department directors. To satisfy customer requirements concerning environment, health & safety issues the company also employs a top management representative in charge of internationally standardized environmental, health and safety management systems such as ISO 9001 and 14001 (see Herzig et al., 2012 for a detailed single case study description of LinenCo).

Prior to the case study, environmental management measures were not aligned with the company's cost or management accounting routines. After gaining insight into the overall idea of EMA, the top management representative spoke with engineers and managers from the environmental, production and accounting departments to identify and implement promising EMA tools. As a first step, the interdisciplinary team established a physical accounting for material and energy flows within and between major production steps. They made use of various formerly isolated data sources within the company including hand-written production protocols, cost accounting records, and waste management entries. The results provided new insights for all functions involved, for instance greater transparency on the drivers of energy and auxiliary use or major waste contribution processes.

In a subsequent step, the physical accounting approach provided a basis for conducting a material flow cost assessment (MFCA, see e.g. Nakajima et al., 2015) to analyse the financial consequences of material losses. Results highlighted the importance for minimizing the excess production of intermediate yarns. Due to batch processing in spinning processes the amount of yarn produced did not necessarily match the customers' demand for the final towel products. Hence, the excess yarn was either stored or used to produce second-grade products for local markets. MFCA revealed the portion of material, energy, auxiliary, and labour cost embodied in these "undesired" products and their negative profit margin.

In parallel to MFCA application, physical accounting results were used to assess two pending improvement measures. The company's engineering team was considering to replace the outdated furnace of the coal-fired steam supply system by a new one. The new one was capable of burning a different type of coal with a higher energy density and was expected to reduce maintenance time. An ad hoc appraisal of the measure revealed its economic and environmental advantages.

The second improvement option had been developed by environmental engineers to improve environmental performance. They had suggested to recycle a large fraction of waste water from dyeing processes in order to reduce both, overall amount of fresh water intake and final waste water discharge. Integrating cost information into the overall assessment convinced top management to approve the measure as purchasing cost for required equipment were compensated by reduced water and waste water fees.

Following these successful applications of EMA tools the team went one step further and scrutinized the existing product pricing routines. Physical accounting data for the main production line was detailed further to explore product-specific differences, such as different energy demands for dark or light colour dyeing, percentage of cutting leftovers per product type etc. The resulting production cost differences per type of product were compared to existing product pricing rules to improve these and eliminate unprofitable customer orders in the long run.

The successful EMA applications mentioned before led to a new set of monthly key performance indicators for top management meetings that include important material and energy usage figures as well as related costs and expenditures.

The diffusion process of EMA within LinenCo sheds light on several diffusion of innovation characteristics elaborated beforehand. Diffusing EMA did not require radical change. Instead, existing environmental management approaches were aligned with accounting and production functions and information and led to incremental change. This required the set-up of an interdisciplinary team and a rearrangement of available data using spreadsheet software well known to all staff involved. Therefore, the efforts for first EMA applications were foreseeable and manageable. Greater transparency on production processes and more precise figures on the cost of material losses were some of the innovation's quickly achieved benefits.

LinenCo featured some characteristics that eased the diffusion of EMA. Awareness for environmental issues was evident prior to EMA application and demonstrated, amongst others, by the existence of an environmental management system and a top management representative for environmental issues. The representative had all means necessary to quickly establish a cross-functional, interdisciplinary team, which supported the implementation of EMA greatly. Furthermore, a monthly report for top management on several EMA key performance indicators helped to increase the visibility and observability of EMA diffusion.

The EMA diffusion process was started by the company's participation in EMA seminars conducted by (environmental) industry associations and the follow-up support by EMA experts in the initial implementation stages. While these inter-organisational aspects had importance in the initial phase of EMA, the company managed to continue and diffuse EMA without further interaction thereafter. This was largely due to the role of the environmental top management representative who acted as an intrapreneur within the company. He was convinced that EMA is beneficial for the company and at the same time had the power and means to use the required resources to achieve successful implementation.

Another important characteristic of EMA diffusion within LinenCo can be linked to the concept of small wins and flops. LinenCo used an incremental approach to implement EMA that led to quick intermediate benefits that in return motivated all involved functions to explore next steps.

4.2. PlatingCo

PlatingCo, a small private company operating in Manila, the Philippines, is part of the environmentally sensitive copper, nickel and chrome electroplating industry producing goods for customers in diverse industries such as automobiles, sewing machines, plumbing and musical instruments. Significant environmental regulations have been introduced in the Philippines for electroplating requiring information be submitted to local environmental authorities about expected environmental impacts of operations, planned improvements, monitoring processes, and compliance with the regulations. There is a lack of institutional enforcement of the legal rules for production; nevertheless, the need for EMA is not only driven by a regulatory outside-in approach to data gathering for reporting. In addition, pressure is voluntarily brought to bear by purchasers of PlatingCo's products as they require environmental management certification of environmental quality.

PlatingCo was in the process of re-establishing itself in a new location and had a need to demonstrate compliance both with environmental regulations and competitive market requirements. EMA information was needed for confirming its operating credentials in this new setting. First, a physical assessment of the environmental impact of operations was used to indicate whether PlatingCo was in compliance. Conventional accounting information was not of use as physical information about chemicals spills and clean ups, wastewater and air quality tests was collected by environmental management staff, with overall control being exercised by one of the owners who acted as the principal contact officer for the case study. When certain non-compliance activities were discovered EMA information was used to appraise investment needed to bring PlatingCo into compliance.

Second, in order to build the clean production credentials of its products for marketing to large multinational purchasers, PlatingCo developed and used EMA information for regular support of its environmental management procedures based on the plan-do-check-act process required for ISO 14001 certification. Such voluntary certification to meet the needs of external purchasers was considered desirable as a response to competitive pressures from large multinationals keen to reduce potential environmental risks passed up the supply chain from electroplating activities. The information was also used for planning and assessing how best to introduce continual improvements to reduce environmental impacts. In summary, based on initial compliance requirements the merits of different EMA tools were voluntarily examined and implemented in a piecemeal fashion.

Diffusion of EMA tools involved a linear development commencing from external pressure for compliance with physical environmental standards for hazardous chemicals, waste water and solid waste, fumes from the use of hydrochloric acid and dust. It expanded to include growing internal awareness of the potential use of different tools in other parts of PlatingCo's business for assessing environmental performance, planning and control.

4.3. RiceCo

RiceCo is a family owned rice mill located in the Philippines. One major environmental problem with rice-milling involves the non-product output of rice husk, the shell containing each rice seed. The rice husk has to be removed before milling and in the Philippines context leads to considerable volumes of waste being accumulated and air and land pollution through smoke, open burning destroying land productivity, and transport of white ash up to 25 km in the face of frequent typhoons. Social issues are also involved in open burning of the husk because children and adults trample over the burning waste heaps looking for grains of rice which remain from the de-husking and which act as a source of food. They often seriously burn their limbs and in the absence of a public system for free medical treatment the company accepts a moral responsibility to pay for treatment. EMA information has been important in providing support for cleaner production decisions involving the conversion of waste rice husk to useful by-product and input to energy supply for the rice mill.

Initial involvement of RiceCo in EMA was through PhilRice, a Philippines rice government funded research institution, which could see the benefits of developing a case to illustrate how rice husk could be converted from waste to product using new clean technology available for import from Japan. The owner of RiceCo could also see how EMA might assist with the relatively large investment decision. The automated carbonisation technology would help to close the loop on waste by burning rice husk under controlled circumstances onsite to produce carbonated rice husk rather than in distant open fields.

Regulation also played a part in the need for the rice-milling industry to clean up its act as the large volumes of waste were recognised to be a sustainability issue and legislation for cleaner production declared burning of solid waste, such as rice husk, to be a criminal offence. Assistance to small companies was to be provided for research into alternative possibilities to open burning and although implementation of the legislation was not being enforced in practice the potential for avoiding risk from future enforcement provided an incentive to act.

RiceCo began the process of assessment by looking as the financials of importing the technology, seeking out uses for carbonated rice husk and, later, considering how to use waste heat from the carbonisation process in order to make savings on energy costs. Conventional payback was used as the method to assess the cash flows of the investment as this accorded with the technique favoured by the Japanese technology company, rather than discounted cash flows. EMA provided the physical investment and the monetary investment data as the foundation for making the decision which indicated a potentially favourable outcome and the decision to invest was made.

A pilot project commenced and for six months the carbonisation process was trialed using different numbers of automated carbonated husk units and different volumes of carbonated husk. Not all husk could be processed because technological capacity and process time were incompatible with total husk produced. Ex post assessment of the trials indicated production and sales volumes of the carbonated rice husk to be overestimated, labour supervision greater than anticipated, and demand for by-product such as organics fertiliser from the white ash generated to be low and slow to grow. The investment on this basis had failed.

The EMA information was then used in a process of continuous

development to support a strategy to develop organic certification of the by-product to increase demand and develop the international market and examine an investment in co-generation by which heat from the boilers would be used to generate electricity for the rice mill. A second environmental investment appraisal, aimed at electricity self-sufficiency through introduction of a separate power plant, was undertaken based on using potential revenues from the United Nations Cleaner Development Mechanism introduced under the Kyoto Protocol to encourage projects that reduce carbon emissions. To assess this process expected reduction in physical emissions relative to business-as-usual was needed and assessment made of sales from Carbon Emission Reduction certificates.

Through the use of physical and monetary EMA information at RiceCo it was possible to examine situations where the company's carbon emissions could be reduced by: eliminating the dumping of husk and its burning in open fields, substituting combustion for fossil fuel for the rice mill, and exporting electricity to the grid from previously used diesel generators. The model allowed environmental and monetary impacts of actions to be demonstrated over time and make projections about future actions to assist eco-efficiency improvements.

4.4. CoffeeCo

CoffeeCo is a medium sized coffee refining and exporting company located in Vietnam. As a subsidiary of its German parent which is one of the largest coffee traders, CoffeeCo is part of an international supply chain linking small farmers in emerging economies and multinationals involved at the wholesaler, roaster and trader end of the global supply chain in developed countries.

Coffee production is beset with unfavourable environmental impacts related to deforestation, biodiversity loss, eutrophication, depletion of energy and water resources, and soil erosion. Techniques are available for ameliorating impacts on the environment but as Vietnam is the producer of downmarket Robusta coffee beans emphasis is on price competition for the commodity rather than differentiation through advantages stemming from improving environmental and social reputation. In the contemporary highly competitive situation the only way CoffeeCo is likely to be motivated to consider environmental issues is if there is an economic benefit from cost reduction. EMA provides a toolkit which can help CoffeeCo to realise this result. A combination of physical environmental and monetary pairings of tools is the most likely sequential development for appraising ad hoc investments in supply chain improvements and operational pricing decisions based on reductions in material flows in refining and export.

Material and energy make up more than 90% of total sales value of export coffee therefore potential gains from eco-efficiency are of great significance for the company (Viere et al., 2007). Options for such improvements on the operational level have been rather limited though as all major material and energy inputs and transformation occur up- and downstream of the company's borders.

Using life cycle assessment relative impacts on environmental performance at various stages of the supply chain were assessed, with first and last stages being particularly salient, with the downstream consumption stage being out of the company's control leading to a focus on the costs of upstream cultivation and processing. While environmental cost reductions in the supply chain can be identified by EMA the political means for determining equitable distribution of such gains across the supply chain is the subject of considerable controversy. For example, fertiliser makes up about 40% on average of the total costs of CoffeeCo's supply chain and large improvements in terms of reduction of excess fertilization are possible. Financial and environmental gains from such reductions do benefit all participants and competitors in the chain. While EMA identifies financial gains for upstream suppliers collaboration can be used to transfer some of the benefit to CoffeeCo through charges for management, such as training in environmental performance improvement and reduced waste for which the suppliers pay.

Finally, inter-organisational cooperation between upstream, downstream and focal companies provides a critical process for diffusing knowledge about improving environmental performance in operations and consumption and redistributing equitably across the supply chain the economic gains from removing environmental hotspots. Identification and prioritisation of EMA tools developed sequentially in an ad hoc way for investment and operating decisions at CoffeeCo. The aim was to improve environmental investment and cost reduction in operations as this was the basis of competition. Reduction in environmental impacts was an add-on win-win benefit from the introduction of supply chain costing.

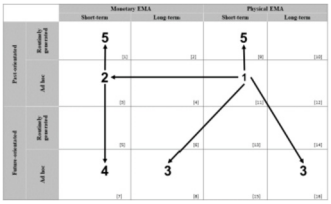
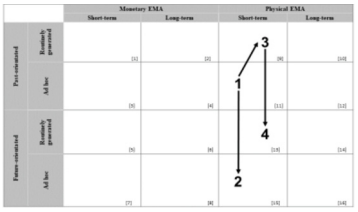
4.5. SnackCo

SnackCo is a medium-sized snack manufacturer located in Manila, the Philippines, producing peanuts, peas and watermelon seeds largely at a low price for consumers in the lower socio-economic group. SnackCo is a subsidiary of a large privately-owned corporation. Physical environmental performance was of concern and a group of managers and engineers had been working on improvements over time. However, this group worked in a silo with top management showing little interest as environmental performance was not transformed into monetary measures or a business case. This simple case study reveals the benefits from integrating environmental and monetary performance information using the mechanism of material flow cost accounting (MFCA) as defined in ISO 14051. These benefits from MFCA include the short term tracking and costing of material flows used for products and wasted on non-product output.

Environmental concerns of food production are legion and as a food processor two particular concerns are to the fore for SnackCo. First is waste management, especially packaging waste as the snacks are wrapped in plastic foil, and, second, is energy usage. Extra packaging is associated with the marketing strategy, sale of low volume of nuts, etc in each packet so that it is affordable in the local community. SnackCo has a long record of environmental management extending back to the 1990s when wastewater treatment was implemented along with software with wide monitoring capacity over production, electricity, waste and waste water treatment through environmental performance indicators. The indicator taskforce consisted of environmental management staff, head of research and development, the plant and quality control managers. Key environmental targets were introduced such as reductions in water and electricity use, waste segregation, and investments improving ventilation in working areas which were hot from the machinery, and moisture expellers to avoid product contamination.

The indicator taskforce of SnackCo adopted EMA because it wished to convince senior managers of the business case for improving environmental and social performance. Several suggestions for environmental improvements had been rejected by senior managers because no information was available about possible financial gains. Nevertheless the taskforce felt that reduction of non-product output waste and costs could be demonstrated through physical and monetary EMA data gathered in a regular way. As direct material flows accounted for 98% of SnackCo's costs MFCA seemed just the tool to help demonstrate to senior management the relationship between the effect of waste and water reduction and energy saving on financial flows.

Table 4
Comparison of all EMA diffusion cases.

Company	LINEN CO medium-sized Indonesian towel manufacturer	PLATING CO Philippine electroplating SME
Diffusion process in chronological order (numbers in brackets refer to EMA framework, see Table 1 and depiction below)	1) data integration to establish physical accounting for material and energy flows and identification of drivers of energy, auxiliary, and waste contribution processes [11] 2) MFCA to analyse and minimize the excess production of intermediate yarns [3] 3) eco-efficiency assessment of cleaner production improvement options [8 and 16] 4) revision of product pricing routines based on physical data [7] 5) monthly key performance indicators for top management [1 and 9]	1) physical assessment of environmental impact of operations (compliance check) [11] 2) environmental investment appraisal to terminate non-compliance activities [15] 3) regular support of environmental management procedures for ISO 14001 [9] 4) continual improvements to reduce environmental impacts [13]
Factors enabling diffusion	- awareness for environmental issues evident - existence of an environmental management system - environmental top management representative acting as intrapreneur - strong interdisciplinary effort	- top management involvement - external pressure (regulatory/competitive)
Diffusion depiction using EMA framework		

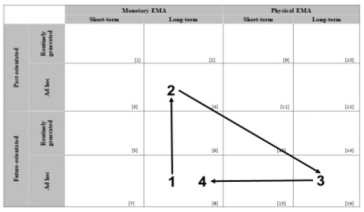
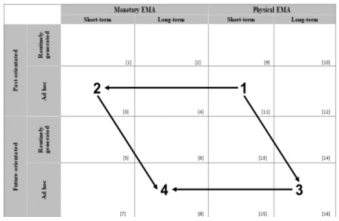
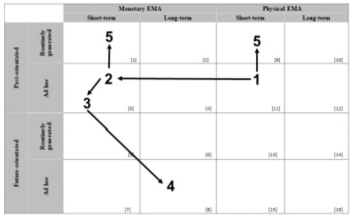
MFCA was rolled out in an incremental way first on one line of peanut production by identifying material losses from peanut skin, used oil, seasoning and spoilt peanuts. The accounting department became involved as direct and indirect system costs were added to the physical waste flows. MFCA data revealed 10% of total production costs were caused by material losses thereby establishing the case to take to senior management for reducing such environmental waste. In addition the data stimulated the call for further action. More efficient semi-closed steam technologies to remove peanut skin were investigated, thereby saving on the constant supply of hot water previously required. Ways of converting waste to by-product were identified by using peanut skin as animal feed, and as a fuel in biogas combustion. Employee training was approved and a suggestion scheme introduced to reward employees when they could identify practical ways to reduce material flows leading to continual improvement in environmental and financial bottom lines, and benchmarking for products in terms of energy, raw materials, utilities and packaging and the benefits demonstrated through processes to improve eco-efficiency. As environmental costs were demonstrated to be significant, information about product costs and material losses became the regular way of reporting about performance. The new continual improvement mindset of managers in relation to removal of waste (non-product output) and the financial benefits from doing so affecting the environment was opened to possible extension to consider externalities and supply chain dimensions. Furthermore, successes at SnackCo were diffused among other group members.

5. Discussion

The five case studies illustrate the ways in which different EMA tools were developed over time within organisations operating in different countries and industries. Table 4 summarises and categorizes the EMA diffusion pathways within the five cases. It puts the diffusion process followed in each company in a chronological order, outlines key factors supporting diffusion and depicts these pathways within the EMA framework of Table 1.

Accepting the complexity of environmental problems, the broad range of EMA tools available, the novelty of EMA, and the changes in stakeholder and media priorities among different sustainability issues, the cases indicate that managers start with one or a few tools and then expand their knowledge base and implement additional tools as these appear to be relevant.

The cases reveal that no single organisation uses EMA in all 16 decision settings and a radical innovation approach to introducing EMA as a complete set of tools is not evident. In practice implementation is tempered by a range of considerations. In the South East Asian case studies patterns of 2, 3, 4, 5, etc. tools used by individual companies are identified (Herzig et al., 2012). The companies commence the implementation of EMA using different tools which suit their own circumstances and goals, some with a short term operational focus, others with green investments and long term considerations in mind. Likewise, some seek regular information while others use EMA tools to address ad hoc decisions. No dominant combination of tools was observed. Instead, very different patterns emerged and the number of tools adopted was seen to expand through different paths over time. In four of the five cases, ex post assessment of short-term environmental impacts and the collection of physical data was the operational starting point. The motivations, however, were very different ranging from waste (CoffeeCo), health issues (PlatingCo), energy consumption (SnackCo), water availability (LinenCo), or creating a business case (SnackCo). In line with the pragmatist perspective the analysis reveals that the application of one tool often leads to an information situation that created interest in and shows relevance for further kinds of information. As a consquence, new EMA tools were applied and an EMA system characterized by a quite specific pattern of interlinked EMA tools developed in the organisations examined.

RICE CO Philippine rice-milling SME	COFFEE CO Vietnamese medium-sized coffee exporter and refiner	SNACK CO Philippine medium-sized snack manufacturer
1) investment appraisal of cleaner production technology [8] 2) ex post assessment of trials [4] 3) support of strategy development for by-product use [16] 4) investment appraisal of electricity self-sufficiency [8]	1) physical accounting for material and energy flows within production [11] 2) material flow cost accounting to identify saving potentials [3] 3) life cycle assessment to detect supply chain drivers of environmental performance [16] 4) identification of supply chain cost saving opportunities to initiate interorganisational cleaner production measures [8]	1) reassessment of available environmental performance information [11] 2) Integration with cost information for decision support [3] 3) Conduct of material flow cost accounting to identify saving potentials [3] 4) Investment appraisal of cleaner production options [8] 5) Routinely reporting on eco-efficiency performance [1 and 9]
- involvement of external institutions (government funded rice researchers, foreign technology innovation providers) - potential future regulation	- collaboration with supply chain consultants - industry being a spotlight of global environmental concern	- environmental management and environmental performance indicator system in place - interdisciplinary task force established - environmental manager as proactive intrapreneur
		

This research shows the pattern of tool use for each company as a result from a dynamic interplay between EMA tools, which has not previously been apparent.

Table 5 outlines the specific diffusion of innovation characteristics by summaring the development paths of EMA tool application identified for the five different Southeast Asian case studies.

In relation to the diffusion of EMA as an innovation all cases demonstrate a comparative organisational advantage over existing accounting there being a relatively low cost of implementation, the possibility of early savings and little investment in the initial phase, with the exception of the RiceCo carbonisation process. Even at RiceCo expertise from the governmental research and development body and a considerable negotiated discount on plant cost imported from Japan reduced the initial costs thereby boosting the adoption of EMA tools. Secondly, advantages accrued from structure as all the organisations had a centralised hierarchical management with strategic decisions being made by owners or top managers. Lower level managers needed to argue a convincing business case to top managers as for example with SnackCo. Once there was buy-in from top management useful EMA tools were embedded in existing systems, step by step. Thirdly, in all companies leadership on environmental issues or potential leadership were characteristics, mostly with champion or gatekeeper functions.

Voluntary management standards either international (like ISO 14001 or ISO 14051), or self-developed were the norm behind prior experience with social and environmental management. Nonetheless, somewhat in contrast, compatibility with existing values and environmental management systems did not apply in RiceCo which relied on an enthusiastic, networked owner with a business focus rather than an environmental management system guiding action.

Complexity of environmental issues faced was addressed by all companies looking for small wins and accepting small losses as an incentive towards the next steps for EMA tool implementation. Complexity reduction was also aided for four companies through interdisciplinary teams or a defined interdisciplinary scope for owners or top managers to move the focus away from a single discipline mentality. PlatingCo gathered data from different groups (e.g., about chemicals used in electroplating) as a foundation for an integrated approach including financials by the owners. In the fifth company, CoffeeCo, an economic perspective dominated because of its strong need to price competitively and when a win-win could be demonstrated this appealed, but not on environmental grounds. Nevertheless, the starting point for introducing EMA was physical accounting in the form of ex post assessments of environmental impacts. Interdisciplinarity was adopted as a way to address complexity of environmental issues in all cases. In addition, individual ability to address complexity was addressed through various means including, appointment of an experienced top management representative or an internal consultant, recognition that expertise was not yet available, incremental build up of knowledge of complex settings and looking for simple solutions.

Observability through internal communication of results as the basis for accountability of management varied considerably between firms from no communication to monthly reports. Likewise, observability was also assisted by direct involvement in issues in all companies but with the exception of CoffeeCo. Trialability was a feature of all but one company, CoffeeCo, where economic circumstances acted against experimentation.

Finally, although key within company characteristics of diffusion of innovation have been identified and accord with Rogers' (2003) approach to external innovation inter- and extra organisational collaboration with industry associations and other external bodies formed an important part of the process of take up of EMA tools by the companies involved. The cases reveal a heteregenous set of collaborators including consultants (SnackCo, CoffeeCo), national research institutions (RiceCo), local authorities (PlatingCo),

Table 5
Diffusion of innovation characteristics applied to five Southeast Asian case studies.

Characteristics	LinenCo	PlatingCo	RiceCo	CoffeeCo	SnackCo
Relative advantage - Costs and liabilities	Low initial cost (dedication of work time of some managers and engineers, but no required investment, etc.)	Low costs and liabilities	Low costs and liabilities	Comparably low costs due to ad hoc character of first measures and support by parent company expert	Low cost, immediate savings in the start phase due to removal of unnecessary energy-intensive equipment
Relative advantage- Hierarchy of authority, control and communication	Family-owner as top manager, next hierarchical level with clear functional responsibilities	Family run, co-owner in charge of the env	Family run, co-owner in charge of the env Strong hierarchy driven by top management	See above	Hierarchical, top mgrs. Decide
Relative advantage - Centralised or decentralised organisation	Centralised, but clearly distributed functional responsibilities	Centralised organisation	Centralised	In the middle, influence by parent company, but also separate responsib. for areas such as purchase or production	Centralised for major decisions
Relative advantage – Individual leadership champion or gatekeepers	Env. top mgmt. representative as leadership champion (EMA intrapreneur)	Leader	Looking to take the lead within Philippines rice industry.	Certain functions as gatekeepers (e.g. the preference of acc/control to not change much; internal consultant as innovator within the cp	Interdisciplinary task force as intrapreneur; top mgmt. as gatekeepers (only profits matter)
Compatibility - System openness	Based on existing MS (ISO14001/SA8000) & functions (env. top mgmt. representative)	Thinking of using (ISO14001) system and function (env. top manager)	Weak environmental and social system	System openness not given (Non-compatibility with existing accounting system)	Based on existing systems (EPIs) and supported by a trusted env consultant
Compatibility - Compatibility with existing social and env. values	Values: Env. Awareness and social responsibility in place beforehand	Compatible with existing values (env policy)	No env. and social value orientation apart from small community concerns	Compatible with existing value of transparency and control thinking	Env. Awareness in place; at least for parts of management and workforce
Compatibility - Existence of sustainability-related management systems	ISO 14001/SA 8000 in place	Basic env system in place	No EMS in place	Not for the subsidiary, but env. standards and commitments (codes of conduct) signed by parent company	EPI system acc. to ISO 14031
Complexity – Small wins and flops, experimentation	Small win approach, intermediate positive results motivate for next steps	Small wins and flops approach, intermediate positive results motivate for next steps	Small wins and flops approach, intermediate positive results motivate for next steps	Small wins and flops approach with a flop to begin with. Later results support parent cp's efforts to improve perf throughout the SC	Small win approach, intermediate positive results motivate for next steps
Complexity -Individual ability to address complexity	Top mgmt. representative for env. mgmt. with experience to address complexity	Low and emerging ability only	Built knowledge of environmental and social issues incrementally	Internal parent company consultant used to address complexity	Looking for simple solutions to mirror simple and low price products
Complexity - Presence of internal use of interdisciplinary functions	One top mgmt. representative for env. issues with interdisc. scope of his work	No interdisciplinary functional team, but integrated thinking by owners.	Interdisciplinary use of expertise (in particular external experts)	No interdisciplinary use of functions.	Interdisciplinary team for env mgmt. in place (only accounting expertise had to be added)
Observability - Communication of the results	Monthly EMA reports to top management	No observability	No communication	Difficult, operational issues derived from EMA with low economic and ecological relevance; strategic SC issues of high importance, but difficult to achieve	Easy to communicate results - cost savings due to environmental measures such as waste reduction.
Observability - Personal involvement in issues	high involvement of top mgmt. representative	Personal involvement	Personal involvement of owners	Low involvement, except internal consultant	highly motivated employees in environmental task force
Trialability – Incremental projects	Small projects were introduced in sequence – MFCA introduced, investment in new steam supply system, wastewater recycling introduced, then product pricing revised.	New factory location and need for compliance meant no half measures with trialability as compliance critical.	Rice husk carbonisation pilot process trialled with different volumes processed. Small losses accepted following trial, but spurred additional action to use rice husk for electricity co-generation.	No trialability.	MFCA introduced for one product line and provided foundation for continuous environmental improvement.
Inter- and extra- organisational - Involvement with industry associations, external bodies or consultants	Inter-organisational characteristics (seminars, expert support) important in the initial phase, but declined in importance over time.	Expert support (consultants, and associations) important for the diffusion	Expert support (consultants, government/R&D institute) important for the diffusion	Internal consultant/expert from parent cp was the main driver and addressee of EMA and provided required interdiscipl. knowledge and insights; industry associations gained importance throughout the diffusion due to SC relevance of EMA results	Highly involved and motivated external consultant with long-term and trusted relationship with the company who served as environmental manager

development cooperation agencies (RiceCo), and inter-trade organisations (CoffeeCo).

In terms of the conceptual approach to addressing sustainability issues ideally the full comprehensive EMA system should be introduced as a radical move. Nonetheless, the cases illustrate incremental progress towards improving the environmental contributions is the process of change adopted by all five companies. In the end the result of corporate processes must be radical if environmental disasters are to be avoided in the long run, and sustainable development is a long run notion. The cases show that these two contrasting views, of theory and practice, come together over time as ambition to secure sustainable outcomes increases and more EMA tools are introduced. While it is not possible to claim that the environment is improved at the aggregate level by the individual corporate development and implementation of EMA tools, it is shown that the cumulative, or additive, changes adopted in practice have led to more than incremental gains.

It should be recognised that the exploratory nature of current evidence and the results presented are limited as they relate to five manufacturing companies operating across three countries in South-East Asia. Further research is needed to explore the development paths of EMA in other industries, sectors and countries before broader generalisations can be made. Such broader research would also be able to distinguish EMA take up patterns between smaller and larger organisations. The collection of more information about EMA development paths in organisations would allow for deeper analysis of different circumstances under which faster or slower diffusion happens as well as whether certain patterns relate to specific regulations, incentives, industries or cultural differences.

6. Conclusion

EMA represents an innovative concept embracing a large range of tools that provide managers with information to guide green decision making in companies in various decision-settings. The paper uses diffusion of innovation theory as the foundation for understanding the practice of EMA adoption within organisations as they transition towards ecological sustainability. The case studies reveal some common characteristics of the diffusion process highlighted by theory.

A prevalent feature of EMA diffusion in these cases is small changes rather than re-engineering the whole accounting system. EMA is initially applied to manageable decision settings in an experimental manner to arrive at measurable results quickly. If successful, further and more complex EMA applications are introduced. In the longer term, EMA-based indicators could then be integrated into regular top management information and control processes.

In conformance with the notion of 'small wins', all cases constituted incremental rather than radical changes of management accounting practices. The diffusion of EMA focuses on process innovations and increases in operational (environmental) performance in order to fulfill legal requirements, improve stakeholder relations, or reduce costs. The cases show that the introduction of one EMA tool at the beginning lead to the subsequent introduction of related EMA tools and further development of the environmental accounting system in the organisation. While development could be observed beyond introducing and implementing one incremental step, the questions however, whether, how and when EMA supports and drives more radical changes of organisations towards sustainable development, e.g. a complete change of a company's business model, remains a topic for further research.

Revealed EMA application pathways confirm that they are highly case-specific. On the other hand cases confirm the interaction of physical and monetary information appears to be a common pattern within the pathways. In all cases environmental and monetary information were either required in parallel with or subsequent to initial data gathering. No company only required monetary or physical information within their EMA diffusion paths. This highlights the pragmatic importance of integrating concepts such as eco-efficiency and resource efficiency. It furthermore discloses a potential weaknesses of conventional management accounting that too often only relies on monetary information and environmental management that relies only on physical metrics. In all cases diffusion of EMA required expertise in physical information gathering and analysis. This explains two further important characteristics of EMA diffusion: the involvement of external support and the need for interdisciplinary execution. The former was often required to compensate for an organisation's deficiencies concerning quantitative assessments of environmental performance while the latter is a consequence of the cross-functional character of EMA. In the set of cases examined EMA diffusion is either fostered by transdisciplinary teams including experts on (conventional) accounting, engineering and environment or by a top manager overseeing these different areas.

Declaration of interest

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