

Products in environmental management systems: drivers, barriers and experiences

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Received 23 May 2003; accepted 22 December 2003

Abstract

Do standardised environmental management systems (EMS) lead to improved environmental performance? This depends on to what extent these systems lead to changes in important flows of material and energy, which for manufacturing companies, in turn, mean that the product development process is important. Consequently, it appears vital to investigate the connection between EMS and 'Design for the Environment' (DFE), i.e. the connection between these management systems and concepts that deal with environmental issues in product development.

This paper presents product-oriented environmental management systems (POEMS), including characteristics of existing models, experiences from projects where these models have been tested and experiences concerning the product connection in 'normal' EMS. It includes a discussion of important factors influencing to what extent DFE activities are integrated into EMS and/or the outcome of such integration.

There are many motives for integrating the two concepts. Firstly, DFE thinking might enrich EMS by contributing with a life-cycle perspective. If EMS encompassed products' life cycles to a greater extent, they would be a better complement to the often facility-oriented legal requirements and authority control. Secondly, EMS might remove the pilot project character of DFE activities and lead to continuous improvement. Thirdly, integration could lead to successful co-operation, both internally and externally. However, existing studies show that there is a mixed picture concerning the extent 'normal' EMS currently encompass products. © 2004 Elsevier Ltd. All rights reserved.

Keywords: Product oriented environmental management systems; POEMS; Design for the Environment; DFE; Eco-design; ISO 14001; EMAS

1. Introduction

Today, more than 57,000 companies are using standardised environmental management systems¹ (EMS) in the world² [3] and this number is expected to continue to grow steadily [4]. Therefore, it is interesting to study if and how standardised EMS's affect companies' environmental impact. It is the authors' experience that many companies, authorities and individuals regard a certification in accordance with ISO 14001 as a guarantee for good environmental performance. However, it appears to be too early to draw any general conclusions on

the connection between standardised EMS and environmental performance, because there are research findings pointing in both positive and negative directions [5].

Since environmental impacts are intimately connected to flows of materials and energy, and the most important flows, at least for manufacturing companies, are closely linked to products (cf. [6,7]) it seems urgent for management systems to encompass products and product development. Consequently, it is of great interest to illuminate how standardised EMS are related to Design for the Environment³ (DFE), i.e. to what extent

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¹ i.e. EMS fulfilling the requirements of ISO 14001 [1] and/or the European Union's regulation Eco-Management and Audit Scheme (EMAS), [2].

² July 2003.

³ DFE is defined as: "A practice by which environmental considerations are integrated into product and process engineering procedures. Design for Environment (eco-design) practices are meant to develop environmentally compatible products and processes while maintaining product, price, performance and quality standards" ([8], a definition of eco-design).

they encompass the products and product development procedures. To deal with these issues, this paper aims to elucidate the following topics:

- What are the incentives to strengthen the connection between EMS and DFE?
- How can DFE activities be incorporated into standardised EMS?
- How common is it that EMS encompass DFE activities?
- What are the experiences from projects where EMS and DFE activities have been integrated?
- Which important factors influence to what extent EMS and DFE activities are integrated and/or the outcome of such integration?

2. Products in environmental management systems

Historically, DFE and EMS have, to a large extent, existed in separate spheres [9]. Reading through ISO 14001 it is clear that product development is not emphasised and that most product-related requirements leave substantial room for interpretation [10]. Therefore, it is uncertain to what extent normal EMS encompass and influence the environmental load of products. However, in 1995 the Dutch government introduced a product policy with the intention of changing the behaviour of producers ([11], as referred to in [12]). This was to be accomplished through the implementation of product-oriented environmental management systems (POEMS). A POEMS is an EMS with a special focus on the continuous improvement of a product's eco-efficiency (ecological and economic) along the life cycle, through the systematic integration of eco-design in the company's strategies and practices [13]. This Dutch product policy can be seen as a starting point for the wide use of POEMS. Since such management systems are constructed to handle product issues they serve well as a basis for this paper. We distinguish between 'normal' EMS and POEMS, where the first category includes standardised EMS that may encompass products and the second comprises systems prepared to specially deal with product-related issues. POEMS may be based on an existing normal EMS, but this is not necessary.

2.1. Motives to integrate EMS and DFE concepts

Sinding [14] argues that traditional environmental policy in many respects encourages an internal, firm-centred focus. He wants companies to apply an approach that transcends the boundaries of the individual firm and to actively engage in inter-organisational environmental management. However, it is clear that products and product development are not within

the main focus of ISO 14001 and its application [10,15]. According to Cramer [16] the primary focus of EMS has initially been on procedures to reduce emissions through process improvements. Moreover, Klinkers et al. [17] are of the opinion that EMS are usually directed at site levels, which is supported by others [9,10,12,18]. This indicates that EMS often lack a life-cycle perspective and are not primarily focused on products. Ries et al. [18] state that, in spite of the inclusion of 'activities, products and services' in vital parts of the ISO 14001 standard [1], many companies have a very narrow perception of their environmental impacts, which is mostly limited to site-specific activities. All these facts show that there is an obvious risk that EMS are not directed at the most important environmental aspects. Environmental managers that Ries et al. [18] have interviewed stated that companies generally have very limited knowledge regarding the environmental aspects of their products. Further studies by Ammenberg and Hjelm [15] and Hjelm et al. [19] show that there are certified EMS without a strong link to products.

From an environmental standpoint, it is important to regard the whole life cycle of a product. In this respect, 'DFE thinking' or 'life-cycle thinking' could function as an important complement to EMS by contributing a better understanding of which flows of materials and energy are most important (cf. [20]), which would reduce the risk of sub-optimisations. A substantial idea behind POEMS is that they should improve the co-operation in the entire supply chain (from material extraction to end-of-life treatment). POEMS are supposed to lead to concerted environmental action among the actors within a product's life cycle, which is to be commercially beneficial [12]. This is in line with the thoughts of Sinding [14], whose inter-organisational environmental management is intended to lead to learning about environmental impacts throughout the supply chain and to interaction with other firms in the supply chain to reduce these impacts. A change in focus of EMS, from site-specific to encompass the life cycle of products, is also motivated from an environmental policy perspective. If EMS to a greater extent encompassed products' life cycles, they would be a better complement to the often facility-oriented legal requirements and authority control.

Many researchers have developed tools for integration of environmental aspects into the product development process⁴. Although there are quite a lot of DFE-tools developed by academia and industry, few have made a significant breakthrough so far. According to McAloone [22], not much effort has been made on how to integrate these methods into the design process (cf. [23]). Lenox and Ehrenfeld [24] state that many tool

⁴ For a good description and characterisation of various DFE (eco-design) tools, see e.g. [21].

developers fail to consider the organisational context in which tools are to be imbedded. In addition, many DFE initiatives have a pilot project character [20,25]. This is seen as a problem, since companies tend to return to ‘business as usual’ after completing such DFE projects, i.e. the long-lasting strategic and organisational changes and the accompanying product improvements are missing. Brezet and Rocha [25] state that “It is recognised that eco-design activities will be limited if they are not integrated into strategic management and the daily operations of companies in a dynamic process of continuous environmental performance improvements” (cf. [26]). Standardised EMS have the potential to remove this barrier to DFE implementation by establishing an organisational structure where procedures for the inclusion of environmental criteria are facilitated and such procedures are made permanent.

It is the authors’ experience that an EMS, generally, is designed and administered by environmental managers. To what extent such systems reach out to different groups of employees varies greatly amongst companies. Both for EMS and DFE activities, it is crucial to motivate and involve the right persons within the firm. One important question concerns to what extent managers and staff responsible for product development co-operate. Charter and Belmane [20] state that DFE activities tend to be managed by environmental management functions rather than being integrated into mainstream product development. They also conclude that POEMS require higher co-operation amongst different business functions compared to conventional product development. In a study by Grüner et al. [27], it was found that cross-functional groups, for the integration of environmental aspects into product development, were only implemented in a few of the investigated companies, and even in those companies, the groups met too seldom to have a real influence.

3. Models for POEMS

Every firm has its individual needs, capabilities, etc. Consequently, it is not possible to develop a POEMS model that expressly fits every company. On the contrary, a model for a wide application must address the integration of EMS and DFE on a general level, allowing flexibility. In this section, some general characteristics of such existing POEMS models are presented and discussed.

Many of the POEMS models presented in the literature are based on the Deming cycle⁵, i.e. the same management cycle as is the basis for ISO 14001 and ISO 9001 (*‘Plan-Do-Check-Act cycle; PDCA cycle’*). The

basic idea behind this approach is to facilitate the establishment of POEMS that are compatible with many companies’ existing or future management systems or practices, which seems wise. For example, Brezet et al. [29] conclude that companies having a quality management system have major advantages in taking a structured approach to product-oriented environmental management⁶ (cf. [30]). According to Charter and Belmane [20], an existing normal EMS can easily be extended to a POEMS.

A cursory study of different POEMS models, e.g. models presented by Cramer and Alders [31], Karlsson [9], Klinkers et al. [17], Rocha and Brezet [13], and Rocha and Silvester [32], show that they are quite similar on a general level. However, different terminology is used and the categorisation of what belongs in the different steps of *Plan*, *Do*, *Check* and *Act* varies. On an overall level, and based on the references cited above and the authors’ own experience, the following general steps of most of the product-related parts of a POEMS model can be stated as follows⁷, see Fig. 1. The described process is mainly focused on the first implementation of a POEMS, which could be carried out by companies with or without an existing EMS or other management systems.

Firstly, a review of the product portfolio from a life-cycle perspective is carried out. This is supposed to contribute with knowledge about the products’ environmental impact, which means that product-related environmental aspects are illuminated and it is determined which of these aspects are significant. Since this review to large extent should involve the products’ life cycles it encompasses important actors in the supply chain, contradictory to many reviews within normal EMS [10]. Parallel to this process, a review of organisational aspects of DFE relevance should be conducted. This review brings knowledge together about the capabilities and weaknesses of the organisation and includes an investigation and clarification of the product development process. It is advantageous if these two review phases yield information on the existing and future market (e.g. information on future customer needs).

Secondly, responsibilities and resources should be allocated and environmentally related procedures written for the product development process. It is recommended that environmental concerns should be incorporated from the beginning of the design process and handled as any other design parameter [9]. Furthermore, as much work as possible should be performed before the product development process, since the possibilities to make

⁶ This concerns a project where the PDCA cycle has been used for the POEMS model.

⁷ The traditional EMS activities are not within the scope of this paper. They are carried out parallel to the more product-related activities listed.

⁵ See [28] for more information on the ‘Deming cycle’.

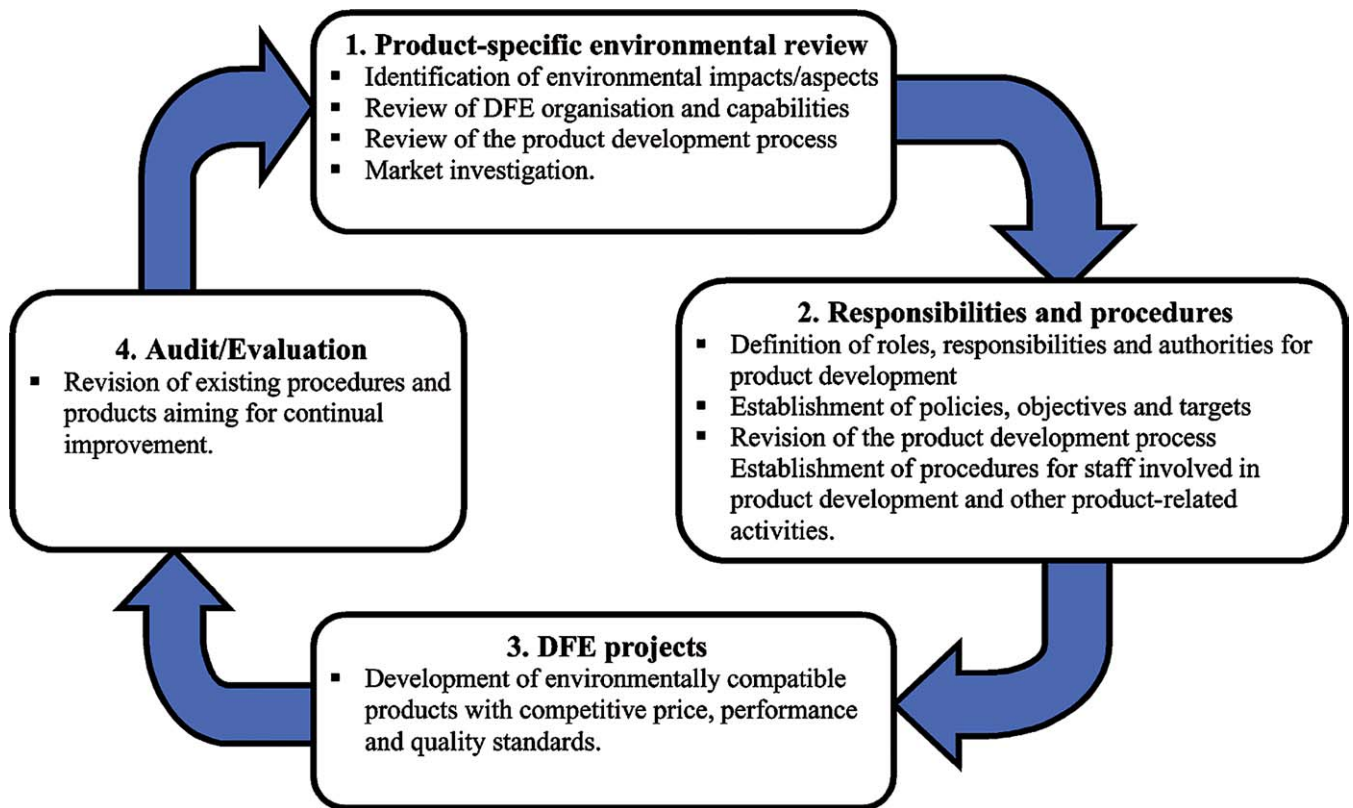


Fig. 1. General steps of a POEMS model.

changes in product design decrease with time, as the cost for these changes increases with time [33]. It is important to have support from top management and to ensure that corporate visions, strategies and policies are in line with the intentions of the environmentally adapted product development process. Based on the initial reviews and relevant policies, product-related environmental objectives and targets should be established.

Thirdly, DFE projects should then be performed at the operational level. These DFE activities should follow the procedures established in the second step and as much as possible use the information gained in the first step. If new products are designed that are clearly different from existing ones, new investigations will be needed. It should be observed that POEMS might include several parallel Deming cycles, as one concerns the overall EMS and others are focused on single-product projects. This implies that the third step may include several more or less separate PDCA cycles. Naturally, it is advantageous if the environmental concerns do not negatively affect the time for market introduction, price and quality. Cornerstones are a motivated and competent staff, projects involving the right persons (cf. [34]), available information on environmental impact and the market situation, well-known usable tools and methods, and sufficient technical capabilities.

Fourthly, the POEMS activities must be evaluated/audited, which is supposed to lead to a good base for reaching continual improvement. Based on these audit procedures, measures should be taken to continually improve the product-related environmental performance.

4. Experiences concerning POEMS and products in normal EMS

Studies investigating the environmental and commercial effectiveness of standardised EMS are scarce [5]. There are only a few studies on to what extent products are encompassed by such normal EMS. Furthermore, there is a lack of knowledge concerning the effectiveness of POEMS. Hence, it is far too early to draw any generally applicable, statistically significant, conclusions on to what extent EMS and DFE principles are integrated and how such integration affects environmental performance and business. However, it is possible to use existing studies, both of normal EMS and of POEMS, to draw up a picture of to what extent EMS include product issues and of the potential benefits and drawbacks of POEMS. It is noteworthy that many of the studies of POEMS that this paper is based on involved action research. This means that the researchers have been actively involved in the process they have

studied. Nevertheless, this is a methodological aspect that has not been given much attention in their reports and papers. This means that it is even more difficult to comprehend to what degree POEMS projects are dependent on and influenced by participating researchers and consultants. In the following paragraphs, the experiences from a recent study conducted by the authors and the most important results found in the literature are summarised.

4.1. *Experiences with POEMS*

Rocha and Silvester [32] studied 10 companies that have participated in a Dutch programme, which was intended to stimulate the adoption of POEMS. These researchers defined 34 different POEMS activities and studied their adoption. The results clearly show that the POEMS projects evaluated have led to a significant number of POEMS activities. Only 6% of the activities were conducted before the beginning of the project. However, the results also show that 122 out of 340 activities were discontinued, i.e. 36%. Two of the 10 companies did not continue any of the activities that were introduced by the project. Consequently, an interesting finding is that many activities arose due to the project, though it is somewhat unclear as to what extent the pilot project character of DFE activities has been eliminated. Fortunately, from an environmental point of view, 31% of the total number of activities were commenced after the project and were judged as continuous activities, of which many occurred at the operational level.

Brezet et al. [29] have investigated the experiences of 40 Dutch companies that participated in a subsidy scheme, where PO were implemented. They conclude that most companies felt positive about the outcome in terms of gained knowledge and established environmental goals. However, the companies seemed to have problems maintaining contacts with the actors in the production chain. An important reason for this was that many firms regarded themselves as small in the chain, i.e. with limited possibilities to influence.

Van Berkel et al. [12] point out collection and processing of environmental product information as a key bottleneck of POEMS, in particular for small and medium-sized enterprises (SMEs). In addition, they believe that POEMS efforts will benefit significantly from simplified and sector-specific life cycle assessment tools.

4.2. *Experiences concerning normal EMS*

The authors recently conducted a study to investigate how external environmental auditors interpret and apply product-related requirements of ISO 14001 at Swedish manufacturing companies in Sweden [10]. The results indicated that the link between normal EMS and

products is rather weak. Product issues are seldom regarded as significant environmental aspects and are therefore not within the main scope of many EMS, which mainly focus on sites. However, all of the interviewed auditors required that some kind of environmental considerations be incorporated into the process of product development, but these considerations are to large extent site-oriented; how they are prioritised in relation to other factors such as economy and business appears to be up to the companies.

Karlsson [9] interviewed 59 environmental managers, or corresponding staff, from the manufacturing and furniture industry in Sweden. These firms ranged from only a few employees to several hundred. Karlsson is of the opinion that many organisations routinely include environmental issues in their product development and the survey showed that product development to a large extent was included in EMS based on ISO 14001, and that the introduction of ISO 14001 had often led to an increase of DFE activities. He says that “many industries that have not considered environmental issues in product development start to do that when they implement ISO 14001. Furthermore, it has been found that a DFE management program can enhance an existing EMS through the broadening of its scope.” This last result appears to be in line with the finding of van Hemel ([35], as referred to in [13]), who concludes that EMS can be a stepping stone towards eco-design and vice versa.

Ries et al. [18] seem to believe in the potential of POEMS, but indicate that Swiss companies, at least a few years ago, had not progressed very far. They state: “Product development is becoming a more and more important part of the EMS of companies. Integrating environmental aspects in early planning stages promises to both improve the environmental performance and customer benefit of products. However, most companies have not reached that far yet. The main difficulty is seen in the poorly developed interface between environmental management functions and departments for research and development.”

Grüner et al. [27] studied 34 German companies using normal EMS. One important result of the study was that no or only a very weak link between EMS and product development was observed. In this respect, EMAS seemed to result in a better integration of product issues than ISO 14001.

Hjelm et al. [19], who have studied a few smaller Swedish companies, conclude that the study clearly showed that it is not, in practice, an absolute requirement that products are included in a standardised EMS. They argue that the number of DFE activities would increase if the external environmental auditors required environmental procedures in the product development process before approving an EMS (cf. [36]). This argumentation is in line with recommendations of

Karlsson [9], who would like to see more DFE competent consultants and auditors. For this to be realised, adjustments in the standard ISO 14001 and its application might be needed.

4.3. Conclusions on experiences

Results on POEMS are scarce. Therefore, general conclusions on the effects of POEMS cannot be drawn. Based on case studies, it is known that POEMS projects driven and supported by, for example, consultants may be fruitful. However, it is not known to what extent companies ‘spontaneously’, i.e. without participation in a particular project, implement POEMS.

Studies of normal EMS show that researchers have different opinions concerning to what extent EMS encompass and affect product issues. Their opinions appear to range from very positive to a bit hesitant. Some results bear witness to the fact that EMS and DFE activities are integrated in reality, while other findings indicate that the link between EMS and DFE is weak.

5. Important factors influencing the use and outcome of POEMS

There is no simple answer that can explain this mixed picture. To what extent companies are willing and can manage to integrate DFE issues into their management systems is dependent on many different factors. It appears reasonable to assume that what is an important factor for EMS or DFE individually is also important concerning their integration⁸. Accordingly, success factors, drivers and barriers that have been presented in the literature as important for either one of the concepts have been gathered and categorised into four different levels, as shown in Fig. 2. The ingredients of each level, all affecting to what extent EMS and DFE concepts are integrated and/or the outcome of such integration, are presented below. It should be observed that several of the factors listed are important on more than one level, although, they are only presented within one of them. In addition, it should be stressed that the list of important factors and the accompanying argumentation are not comprehensive. This section is only intended as a general orientation to factors of importance that may be useful when analysing companies’ possibilities and motives to engage in POEMS activities, as well as helpful when trying to understand why things happen or do not happen in this context.

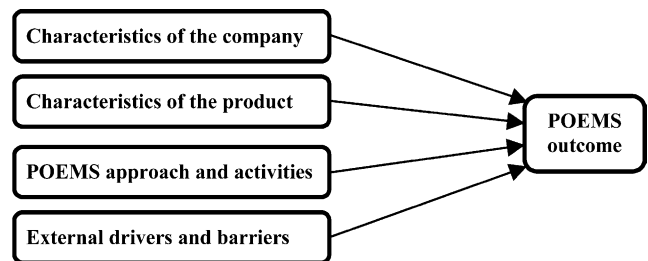


Fig. 2. Four levels of important factors influencing to what extent EMS and DFE activities are integrated and/or the outcome of such integration, based on [32].

5.1. Characteristics of the company

The first level concerns the characteristics of the company. Important factors on this level include human and economical resources; company structures, systems, cultures and attitudes; motivation, knowledge and experience; and the amount and quality of available information (e.g. [29,37]). Many researchers emphasise that especially SMEs may encounter problems in relation to these factors when introducing an EMS or applying DFE concepts (e.g. [38,39]) or when facing environmental challenges in general (cf. [40]). SMEs have special needs for guidance adapted to their size and type of enterprise. Uncritical transfer of strategies developed for large organisations to SMEs is one general problem regarding corporate environmental strategies, tools, etc. (cf. [41,42]). Concerning actual POEMS projects, van Berkel et al. [12], (cf. [17]) point out collection and processing of environmental product information as a key bottleneck. However, POEMS can be used by SMEs and there are results showing successful POEMS projects at small firms (see [35]).

Further, Johansson [43] has conducted a major literature review on important success factors concerning the integration of eco-design into product development. On the company (management) level, the following factors appears vital: provision of commitment and support; existence and clearness of environmental goals; to what extent environmental issues are addressed as business issues; and to what extent environmental issues are included when establishing a company’s technological strategy.

Simonsson [44] conducted a survey among companies and experts within the area of sustainable product development and design (SPDD), which includes DFE activities. It was found that internal and external communication, technical issues and corporate culture either work as obstacles or facilitators for corporate practitioners. Other important barriers found were lack of knowledge, resources and external drivers and as enablers to SPDD; external help, market drivers and specific tools and techniques. External help asked for by the corporate practitioners most often relates to specific

⁸ No comprehensive literature on important drivers and barriers for POEMS has been found.

tools, such as software, or certain knowledge, such as consultancy and training.

5.2. Characteristics of the products

Naturally, different kinds of products have different potentials regarding environmental improvements. The characteristics of the products, which of course influence the range of available alternatives concerning production processes, influence existing opportunities for improvement. For an overview of important factors, see Fig. 3, which shows how Hubka and Eder [45] have classified the product properties into four different classes. Starting at the periphery, the technical system, via the external and internal product properties, affects the product requirements used by designers. The designer determines properties such as structure, form, material content, etc.

It is important to understand that the early design phase can affect the environmental impact caused by products to a large extent. The opportunities to make changes in product design decrease with time, as the cost for these changes simultaneously increases [33]. Early decisions are important later on in the product life cycle. For example, if one wants a product to be designed for disassembly and remanufacturing, parts in the product should be easy to identify, access, separate, handle and also have high wear resistance [46,47]. Moreover, it is advantageous to allow easy access to parts that need to be changed often, which is also a preferable property in the use phase.

Improvements may range from product improvement, product redesign, function innovation to system innovation, demanding clearly different conditions. Obviously, these conditions vary depending on the type of change. For example, the potential for improvements decreases when introducing minor modifications, such

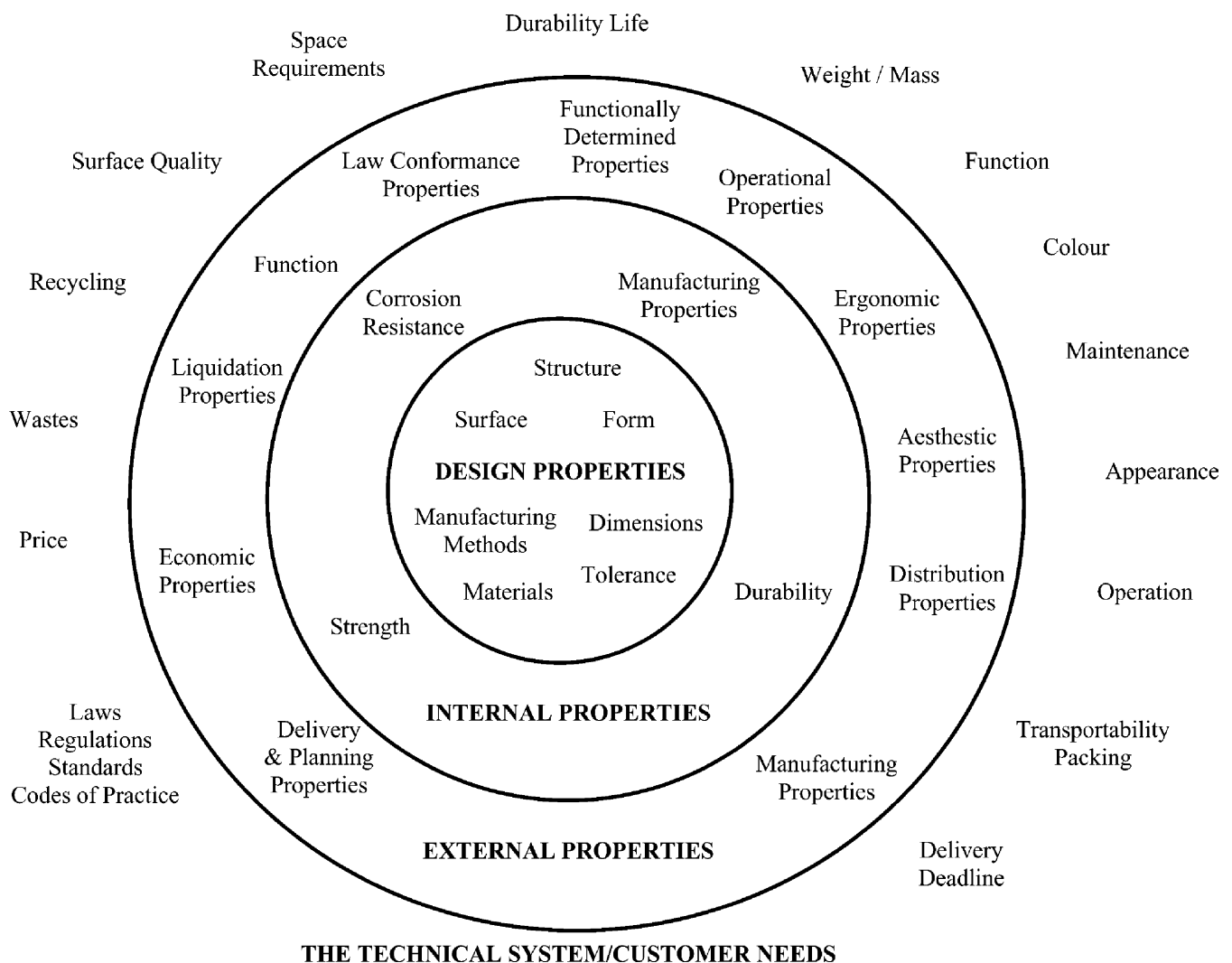


Fig. 3. Relationships between classes of product properties, based on [45].

as changing one material, in comparison to changing the entire system within which the product is used. An example of the latter change is service selling, where focus is shifted from the traditional goods to the function that the customer wants, i.e. the key idea is to focus on the customer's need rather than on the hardware/product itself [47].

5.3. POEMS approach and activities

How the actual management system is prepared and implemented is important. The key factor is to what extent environmental criteria are integrated into the product development process and what priorities these criteria are given. This in turn is dependent on many related factors. For example, the stage at which environmental issues are considered in the product development process affects the outcome [23,48]. Additional factors include to what extent environmental checkpoints, reviews and environmental milestone questions are introduced and if company-specific environmental design principles, rules and standards are used together with support tools [43]. It is often mentioned that suitable DFE tools are lacking (e.g. [29]). Concerning the staff, it is advisable that DFE is performed in cross-functional teams, that sufficient education and training are provided to the product development personnel and other important groups, that an environmental expert supports the development activities, and finally that examples of good design solutions are utilised (ibid.).

5.4. External drivers and barriers

The fourth level is probably the most important one, because it includes the companies' business (market) and societal environment. There are many stakeholders within the supply chain that might influence the motives and opportunities to reach environmental improvements. In addition, actors such as auditors, authorities, banks, competitors, insurance companies, the media, politicians and shareholders may have an important role [49]. The power structures and incentives involved certainly affect the individual firm. For a company to act, sufficient incentives are needed, often in the form of economic benefits (cf. [50]). Large corporations might have a major impact on their smaller suppliers, which has been verified by studies of the actions of, for example, Volvo and IKEA. Johansson [43] mentions a strong customer focus, training of customers in environmental issues and close supplier relationships as important characteristics of successful DFE projects. The important role of consumers should also be stressed. A market investigation showed that less than 4% of the population are willing to pay a significant premium for environmentally adapted products, though

more than 70% of the market would choose a product/service with similar quality and price if it was environmentally adapted [51]. This stresses the importance of developing environmentally adapted products with a competitive price (cf. [23]). Of course, legislation and other instruments of control have a significant impact [23,52]. For example, extended producer responsibility works as a driver for manufacturing companies to consider environmental issues in their product development process. It is the authors' experience that it is important that influential actors act consistently. For example, if large government-owned actors, when asking for offers from companies, include a lot of environmental requirements and emphasise environmental efforts, it is frustrating for the companies if the same actors later on always choose the lowest price, not even taking the environmental efforts into account. For companies having an EMS in place, the role of external environmental auditors is important, since they influence these companies' behaviour [10,53]. Based on the requirements of ISO 14001 and EMAS, and their interpretations of these requirements, they decide what is needed to get an ISO 14001 certificate and/or become EMAS registered. As standardised EMS are growing in popularity the external environmental auditors are becoming one of the key players in the environmental arena [53].

6. Concluding discussion

This paper has shown that from a theoretical and environmental standpoint there are strong incentives to integrate DFE principles into standardised EMS. DFE thinking could enrich EMS by contributing a life-cycle perspective, helping the organisation to identify the most important flows of materials and energy upon which to focus. Seen from a societal environmental perspective, many pollution problems related to specific sites (point sources) have been solved or clearly reduced. Instead, environmental impact caused by the consumer market, e.g. in the form of diffuse emissions, stands out as vital. Consequently, from an environmental point of view EMS covering a wider scope would be preferable and make EMS a more useful tool when striving for a sustainable development. On an organisational level, integration of EMS and DFE activities could foster better relations with stakeholders, at least those actively involved in the supply chain. It could also improve internal co-operation among members of different departments. At the same time, EMS may be useful to make DFE efforts become more permanent, i.e. lead to consistent and systematic DFE activities. Based on today's situation, it seems appropriate to picture the integration as divided into two parts. The first part concerns the integration of

environmental aspects into the product development process, while the second part relates to the integration of the product development process into the management system of a company.

For companies developing POEMS, there is a common trend to develop these systems based on the PDCA cycle, which facilitates the integration of DFE activities into such frequently used management standards as ISO 9001, ISO 14001 and EMAS. To be able to adapt the models to the individual needs of firms, POEMS models must be flexible. Hence, they normally only include an overall level of the systems, while details have to be addressed in accordance with the conditions for each individual company. However, some general advice for each of the steps in the PDCA cycle could be found in the literature and have been listed in the paper. Rocha and Silvester [32] mention four different categories of activities that are included in their POEMS model, which are of a general character:

- Activities that lead to the concrete definition of environmental objectives and performance criteria for the product, as well as activities aimed for tracking progress;
- operational activities for the improvement of products' eco-efficiency and innovation;
- activities to ensure needed capabilities;
- activities to establish control and routinisation.

It is far too early to draw any general conclusions on the outcomes of POEMS. However, important factors affecting this outcome can be identified on four levels, in accordance with Fig. 2. In short, legislation, incentives (e.g. stakeholder interests), resources, competence, availability of supportive tools and the amount of available information can be mentioned (cf. [54]). It should be stressed that companies need sufficient drivers to engage with POEMS and the outcome greatly depends on to what extent environmental problems and challenges can be transformed into business opportunities.

The literature shows that the theoretical potential for integrating EMS and DFE concepts in some practical applications has been verified. Thus, without doubt, the marriage of the two concepts can be successful. Nevertheless, it is too early for any more general conclusions. It is not known to what degree normal EMS, i.e. systems at companies not participating in a special POEMS project, include products. The literature shows a mixed picture. Some results indicate that normal EMS lead to increased DFE activities, while others show that the link between normal EMS and DFE concepts is weak. Very little is written on how POEMS affect firms' environmental performance.

It appears to be likely that the environmental burden from products' life cycles would be reduced if the product connection was strengthened in existing stand-

ardised EMS, which consequently would increase the environmental efficiency of EMS. Accordingly, efforts to adjust the standard ISO 14001 and the systems for its application would be advantageous from an environmental point of view. External environmental auditors and environmental consultants have important roles in this arena, since they could function both as a driver and a barrier for the integration of standardised EMS and DFE concepts ([10], c.f. [9,53]). However, the paper has pointed out many important factors apart from EMS that must also be adjusted to achieve improvements in environmental performance.

Acknowledgements

This research was sponsored by the Swedish Association of Graduate Engineers, the Swedish EPA and The Programme for Production Engineering Education and Research (PROPER).

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