한국정밀공학회지 제 29 권 9 호 pp. 964-970 September 2012 / 964
Journal of the Korean Society for Precision Engineering Vol. 29, No. 9, pp. 964-970 http://dx.doi.org/10.7736/KSPE.2012.29.9.964

◆ 특집 ◆ 녹색생산 및 응용기술

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Characterization of Eco-Design Checklists

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Manuscript received: 2012.7.1 / Accepted: 2012.8.6

Various eco-design tools have been developed which can be classified into quantitative, semi-quantitative, and qualitative tools. Practitioners are reluctant to utilize quantitative tools in light of their time-demanding nature. Among the qualitative tools, checklists are simple tools that allow a quick and effective evaluation and consideration of environmental impacts over the entire life cycle of a product. A profound and better understanding of eco-design checklists is needed so that practitioners can apply them appropriately to their product development context. Various types of eco-design checklists are analyzed in the present study based on their attributes and classified in a structured way for their efficient utilization in product development contexts.

Key Words: Early Stages of Product Development (제품개발 초기단계), Environmental Impact (환경 영향), Ecodesign Checklist (에코디자인 체크리스트), Characteristics of Checklist (체크리스트 특성), Classification of Checklist (체크리스트 분류)

1. 서론

During last decades, due to increasing awareness on environmental impacts of products such as pollution, global warming, and green energy, companies have come to the conclusion that environmental performance of products will become a significant competitive advantage in the global market. Recently, a substantial shift in the product-based manufacturing companies has been taken place from the end-of-pipe solutions that are aimed at reducing the amount of harmful emissions to the environmental performance of products (Emzer et al., 2003). In parallel to this shift, the product development practices are strongly highlighted because products affect the environment at many points over their entire life cycle from raw material acquisition to their end of life stage. However, when it comes to the context of new product development, environmental sustainability of products performs an essential role. It is of a major importance for addressing the environmental impacts of products' at the early stages of product development where decisions about products are not finalized and design concepts are still flexible to eliminate the environmental impacts. The Design Council (1997) indicates that since 80% to 90% of products' economic and environmental costs are determined at early stages, the environmental impacts of products are largely decided at the early stages of design. Although a more recent

survey revealed that environmental aspects of products are mainly coped with at the later design stages, majority of companies recognize the need for early integration of environmental aspects (Backmar et al., 1998; Baumann et al., 2002; Bhamra et al., 1999).

To improve the performance of a product, the concept and practice of eco-design has been developed which is the systematic consideration of design performance with respect to environment, health, and safety over the entire product life cycle. Note that both eco-design and design for environment (DFE) pursue the same objectives and are used interchangeably in accordance with specific contexts. Multifarious eco-design tools for analyzing environmental aspects of products have been developed (Finnveden and Moberg, 2005; Hojer et al., 2008). The utilities of eco-design tools include (1) analysis and evaluation of environmental performance, (2) selection and definition of priorities for product design improvement, and (3) development of design guidelines and solutions. Eco-design generally can be classified in three categories: quantitative, semi-quantitative, and qualitative tools. The quantitative tools such as life cycle assessment (LCA) and cost-benefit analysis (CBA) are analytical and require a large amount of information, time, and efforts. Semi-quantitative tools such as MET Matrix, Boeing Process Environmental Matrix need somewhat large amount of data and are partially qualitative. Finally, qualitative tools such as checklists, guidelines, strategies, and network diagrams are simpler and require less information and time. Eco-design practitioners are reluctant to apply the quantitative tools in light of their time- and energy-demanding natures and complexity. As a matter of fact, a common LCA quite often needs quantified data which is not available at the earlier stages of product design process and the same holds true for semi-quantitative tools. In contrast, very few exploitable eco-design tools are available which can be applied at the early stages of product design. Among the qualitative tools, checklists are preferred for quick evaluation and consideration of environmental impacts over the entire life cycle of a product. Eco-design checklists are generally a set of items used for assessing a product from environmental viewpoints.

A better understanding on the characteristics of eco-design checklists is necessary for their effective application in the product development context. Despite the fact that various eco-design checklists have been developed so far (Brezet and Hemel, 1997; Gertsakis et al., 1997; Wimmer and Zust, 2003), Lindhal (2005) and Lindhal et al. (2005) articulate that eco-design tools selection is unstructured and sometimes dependent on the specific tool's popularity rather than a real analysis of the need.

The present study aims to investigate and analyze various eco-design checklists from different perspectives and attributes and classify them in a structured way. Eco-design checklists that have been developed were surveyed, and their characteristics were analyzed in depth, and a classification of eco-design checklists was proposed in the study for their proper application to early stages of product development.

2. 접근 방법

Manufacturing companies employ different eco-design tools and methods. Masui (2009) reports that Japanese manufacturers often use checklists and LCA for assessing environmental aspects of their products. A comprehensive literature search in the present study identified that approximately 21 eco-design checklists have been developed. One of the most prevailing checklists is The EcoDesign Checklist (Brezet and Hemel, 1997) which covers the entire life cycle of a product from needs analysis to the recovery and disposal stage. This checklist provides essential questions which must be addressed to assess environmental aspects of a product and provide a couple of design solutions for every single stage of whole life cycle. Some of checklists such as such Eco-Design Health Check (International Network for Environmental Management, 1991), and ECODESIGN PILOT (Wimmer and Zust, 2003) are mainly used to assess products in terms of their environmental performance. Some other checklists such as Environmental Policy Checklist (International Network for Environmental Management, 1991) and Environmental Weather Map (International Network for Environmental Management, 1991) are intended for strategy developing or policy making.

To analyze and classify checklists, the present study followed four major steps: (1) review of eco-design tools,

(2) selection of eco-design checklists, (3) analysis of eco-design checklists, and (4) classification of eco-design checklists.

Step 1: Review Existing Eco-Design Tools

More than 100 eco-design tools in the literature were found and reviewed. As mentioned earlier in this article, these tools generally are categorized as quantitative, semi-quantitative and qualitative tools as displayed in Table 1. Eco-design tools in each category could be further categorized based on the type of tools. For instance, the quantitative tools are categorized in three sub-groups: analytical, accounting-based, and input/output driven tools.

Table 1 Classification of Eco-Design Tools

Category	Tool Type	Tool Name
Quantitative	Analytical	LCA
		...
	Accounting-Based	Cost-Benefit Analysis (CBA)
		Life-Cycle Cost (LCC) Analysis
		Eco-Value Analysis (Eco-VA)
		...
	Input/Output-Driven	Substance Flow Analysis (SFA)
		Environmental Input-Output Analysis (IOA)
		Energy and Material Flow Analyses (EMFA)
		...
Semi-Quantitative	Matrices	MET Matrix
		AT&T Matrix and Target Plot
		Boeing Process Environmental Matrix
		...
	Assessment-Based	Eco-Estimator
		Cumulative Energy Demand Analysis (CED)
		Environmental Impact Assessment (EIA)
		Strategic Environmental Assessment (SEA)
		Environmental Risk Assessment (ERA)
		Environmental Effect Analysis (EEA)
		...
Qualitative	Matrices	Dominance Matrix
		Eco Design Priority Matrix
		...
	Network Diagrams	Eco-Compass
		Spider Diagram
		...
	Manuals and Guidelines	Ecodesign Navigator
		Ten Golden Rules
		...
	Checklists	The EcoDesign Checklist
		Eco-Design Health Check
		ECODESIGN PILOT
		...

Step 2: Identify Applicable Tools at the Early Stages of Product Development

Most of the eco-design tools are not applicable to the early stages of product development. Quantitative tools such as LCA need a plenty of quantified data that are not accessible at the early stages of product design and development. Semi-quantitative tools also are not applicable for this purpose because of their data-intensive nature. However, some qualitative tools can be utilized at the early stages of product development, and of them checklist tools are the best option for quick evaluation and consideration of environmental impacts through the whole life cycle of a product. Therefore, the research scope was narrowed down specifically to review, analyze and classify eco-design checklists for integration at the early stages of product development as shown in Figure 1.

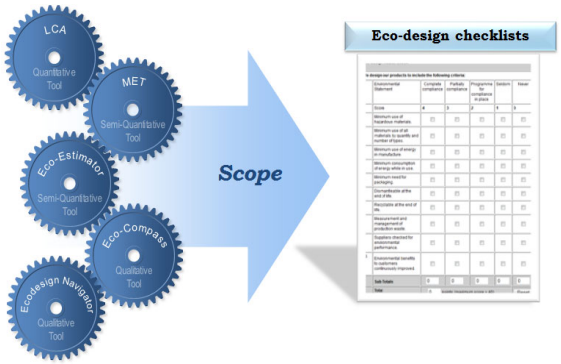

Fig. 1 Selection of eco-design checklists for application to the early stages of product development

Step 3: Analyze Eco-Design Checklists

Twenty-one eco-design checklists found in the literature were reviewed in-depth based on their attributes,

characteristics, advantages, and shortcomings. Most of the checklists suffer from quantitative analysis which makes them inappropriate tools for application to the early stages of product development. In the critical analysis of this step, the following five essential questions were developed which must be addressed precisely to understand the characteristics of each single checklist before application:

1) What is the target of assessment?
2) What is the coverage of life cycle span?
3) What type of input is needed?
4) What level of analysis is required?
5) What type of output is demanded?

By answering to these questions as illustrated in Table 2, eco-design practitioners can recognize their own specific needs in product development context.

Table 2 An Analysis of The Eco-Design Checklist (illustrated)

Brief Description	Inventor/Author
- This checklist analyzes a product's impact on the environment - It suggests eco-design strategies for areas where environmental problems are identified	Brezet, H. E. Hemel, C. V. (1997)

Advantage	Disadvantage
- It has one stage primer to the traditional life cycle of a product - It provides eco-design strategies for each life cycle	List of questions are not comprehensive in life cycles

Objective	Life-Cycle Perspective	Application Time	Level of Analysis	Weighting
Analysis of a product's impact on the environment	Needs Analysis + whole life cycle	Moderate (1 to 3 hrs.)	Medium (Adequate Data Needed)	No

Step 4: Classify Eco-Design Checklists

Through addressing the key questions developed in previous step, six main features and characteristics of eco-design checklists were identified: (1) assessing target, (2) coverage of life cycle, (3) qualitative screening, (4) quantitative screening by subjective evaluation, (5) quantitative screening by objective measurement, and (6) strategy and guidance. Consequently, these main features were used to classify the existing eco-design checklists.

3. 결과

The outcome of the research approach through the four steps was the classification of eco-design checklists as shown in Table 3. The existing checklists were analyzed based on the five key questions in the eco-design checklist analysis stage (step 3) and then classified based on the 6 main features and characteristics identified in the eco-design classification stage (step 4). The screening features of the eco-design checklists include qualitative and quantitative parts since a couple of checklists provide quantitative screening in addition to qualitative screening. Note that checklists with less than 20 check items were categorized as rough and those with more than 20 check items as detailed. The same holds for the Guidance & Strategy part. A number indicated in parentheses indicates the number of check items for each checklist. This classification can be utilized to assist product designers to choose a proper eco-design checklist for application into their specific contexts of product development.

To apply the proposed checklist characterization, a company that intends to assess environmental aspects of its products must choose those checklists which have been developed for this target, i.e., assessing target is product. In the next step, from the life cycle perspective, proper checklists can be selected, i.e., covering the whole life cycle of products or just covering one single phase such as materials selection or end-of-life. The next step determines the type of data which is required to apply the checklist. The company must decide whether or not they prefer to use a quick and rough checklist; otherwise, they must use a more detailed checklist. The following step is the level of analysis by the tool which can be rough or detailed analysis. Finally, this classification requires the type of output data that the company desires to obtain. Few existing checklists provide this final step which includes eco-design guidance and strategies.

Table 3 Characterization of Eco-Design Checklists

Eco-Design Checklist		Assessing Target	Coverage of Life Cycle	Screening			Guidance & Strategy
				Qualitative	Quantitative		
					Subjective Opinion	Objective Measurement	
1	The EcoDesign Checklist	Product	Whole Life Cycle	Detailed (39)	-	-	Yes (35)
2	Eco-Design Health Check	Product	Whole Life Cycle	Rough (10)	Rating (0 to 4)	-	-
3	ECODESIGN PILOT	Product	Whole Life Cycle	Detailed (216)	Rating (Relevance and Fulfillment)	-	Yes (216)
4	Eco Mark Checklist	Product	Whole Life Cycle	Rough (9)	-	-	-
5	ECMA 341-Environmental Design Consideration for ICT & CE products	Product	Whole Life Cycle	Detailed (81)	-	-	-
6	Smart ecoDesign^{TM} Checklist for Electronic Manufacturers, System Integrators, and Sppliers of Components and Sub-Assemblies (V.2)	Product	Whole Life Cycle	Detailed (55)	-	-	Yes (25)
7	Smart ecoDesign^{TM} Energy Using Devices (EuP) Eco-design Checklist for Electronic Manufacturers, System Integrators, and Sppliers of Components and Sub-Assemblies (Issue 1)	Product	Whole Life Cycle	Detailed (62)	-	-	-
8	EuP Active Electronic Components Checklists	Product	Whole Life Cycle	Rough (11)	-	-	-
9	EuP Passive Electronic Components Checklists	Product	Whole Life Cycle	Rough (11)	-	-	-
10	EuP Printed Wiring Boards Checklists	Product	Whole Life Cycle	Rough (11)	-	-	-
11	EuP Mechanical Component Checklists	Product	Whole Life Cycle	Rough (11)	-	-	Yes (32)
12	Philips Fast Five Awareness	Product	Whole Life Cycle	Rough (7)	No. of times answering “Yes”	-	-
13	Volvo’s Corporate Standard STD 1009,1- Black List	Product	Material Selection	Detailed (32)	-	-	-
14	Volvo’s Corporate Standard STD 1009,11- Grey List	Product	Material Selection	Detailed (42)	-	-	-
15	Volvo’s Corporate Standard STD 1009,2- White List	Product	Material Selection	Detailed (78)	-	-	-
16	Sony’s Green Product Check Sheet and Product Profile	Product	Whole Life Cycle	Detailed (23)	10-Points Rating	Rating (16)	-
17	Recycling Checklist for EC Directive on WEEE	Product	End-of-Life	Rough (6)	-	-	-
18	Product Assessment Checklist/Guideline	Product	Whole Life Cycle	Detailed (89)	-	Detailed (89)	-
19	Environmental Policy Checklist	Corporate Policy	-	Rough (20)	Rating (1 to 5)	-	-
20	Environmental Statement and/or Environmental Report Checklist	Corporate Policy	-	Detailed (39)	Rating (0,1,3,5)	-	-
21	Environmental Weather Map	Corporate Strategy	-	Rough (18)	Rating (Sunny to Rainy)	-	-

4. 결론

Eco-design can be described as the systematic integration of environmental aspects into the product development process with the aiming of eliminating environmental impacts. The most effective way to control the environmental performance of a product is early integration of eco-design tools in the product development stage. Various eco-design tools have been developed, but most of them are impracticable for application to the early stages of product development due to limited available information. Consequently, eco-design checklists are the most useful and practical tools for this purpose. In light of lacking a systematic way to understand the usability of eco-design checklists in the literature, the present study investigated and analyzed eco-design checklist in depth, and broke down the existing checklists in regarding their features and characteristics. Finally, this research classified the existing checklists in a structured way based on their main attributes.

The analysis of the eco-design checklists indicates the major focus and shortages the checklists. First, the focus of most of the checklists was found on the whole life cycle of a product, and there are just two types of existing checklists focused on materials selection and end-of-life. Second, most of the checklists suffer from objective measurement in quantitative screening which might stem from the qualitative nature of checklists. Finally, few of the checklists provide strategy and guidelines for designers, which can be a major shortage of the checklists since not only the evaluation of products in terms of environmental impacts is what product designers look for, but also they seek for solutions to address those impacts efficiently.

As future research, a guidance system of eco-design checklists can be developed to extend the proposed checklist characterization and applied to a real product case study. An eco-design guidance system would be useful to guide product designers what eco-design checklists are most beneficial in their specific design contexts at the early stages of product development process.

후 기

This work is financially supported by Korea Ministry of Environment (MOE) as “Eco-Design Human Resource Development Project” and Ministry of Education, Science and Technology (MEST) as “International Research & Development Program”.

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