# Understanding the priorities of designers for an ecodesign support during environmentally sustainable product development

Received 8 December 2020
Revised 9 January 2021
Accepted 13 January 2021

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## Abstract

**Purpose** – The main purpose of this research is to understand the priorities of designers for an ecodesign support, while developing environmentally sustainable products. Also, this study identifies the requirements of the designers for managing the environmental quality of products.

**Design/methodology/approach** – This research is conducted in two phases of survey. In the first phase, various requirements of designers are collected, refined and segregated under certain well defined characteristics of the ecodesign support. In second phase, the designers are asked to rank each characteristic of the ecodesign support in a questionnaire. The responses obtained from the designers are analyzed separately for engineering designers and design researchers by using Henry Garrett ranking technique to identify the priorities of designers for an ecodesign support.

**Findings** – Results show that there is a contrast between the perspective of engineering designers and design researchers, and their priorities for an ecodesign support are opposite to each other. Thus it can be understood that the features which are added by design researchers in ecodesign support may not be adequate for engineering designers to manage the environmental quality of products.

**Originality/value** – The designers play a key role in the development of environmentally benign products through the use of different ecodesign supports (i.e. tools or methods). Therefore, it is important to understand the desired characteristics of the ecodesign support from designer's perspective. Also, the priorities of designers from academia (design researchers) and industry (engineering designers) must be understood because they are the two stakeholders indulged in the development and usage of various ecodesign supports for environmentally conscious product development (ECPD).

**Keywords** Ecodesign, Environmentally sustainable product development, Engineering designers, Design researchers, Henry Garrett technique

**Paper type** Research paper

## 1. Introduction

The increasing awareness about various environmental issues and demand for environmentally conscious products and services have led the industries to adopt the philosophy of ecodesign (Singh and Sarkar, 2019a). Ecodesign is understood as a systematic integration of environmental aspects in the design of a product for its whole life cycle (Bhamra, 2004; ISO, 2011). The onus of transferring the philosophy of ecodesign into products and processes is primarily on designers from industries and academia. However, they must be accompanied with an ecodesign support which can guide them toward the development of environmentally conscious products (Knight and Jenkins, 2009). The supports for developing ecofriendly products are available in the form of strategies, indicators and standards which are further embedded in different tools and methods. The availability of ecodesign tools and methods are in abundance but there is a limited adoption of these tools within the industries, especially in small and medium enterprises (Dekoninck *et al.*, 2016). Although, the reason behind no or less adoption of these tools is not very clear, some authors mentioned that the presence of too many tools can make it difficult for the designers to choose one which is most suitable for them (Boks and Stevels, 2007; Rossi *et al.*, 2016). Another reason behind the less

World Journal of Science, Technology and Sustainable Development
Vol. 18 No. 1, 2021
pp. 76-92

2042-5945
DOI 10.1108/WJSTSD-12-2020-0101

adoption of these tools may be that the actual requirements of designers are different than the available characteristics of existing ecodesign tools (Lindahl, 2006). Most of the ecodesign tools are developed by design researchers in isolation within the universities or research institutes (Tukker *et al.*, 2000). Thus, the characteristics of these tools are based on the perspective of design researchers which might be different from the perspective of engineering designers who are expected to use these tools within the industries. Since, the role of designers is crucial to determine the environmental performance of the products during the design stage and therefore the requirements of designers from an ecodesign support should be clearly understood (Kumar and Sarkar, 2018a).

The contents of this article are arranged in the following manner. Section 2 provides a review of the literature along with the research gap. The methodology adopted for conducting this research is presented under Section 3. The outcomes of the research are discussed under Section 4. The conclusion and directions for future research are presented in Section 5.

## 2. Literature review

Researchers have emphasized that an ecodesign support should be equipped with certain characteristics that can help to achieve the task of environmentally conscious product development (ECPD). A support which does not require a significant environmental knowledge or training and easy to understand can become an automatic choice of engineering designers even if it is not very sound with environmental improvement (Geis *et al.*, 2008). Designers feel motivated if the presentations are in the form of pictures and diagrams rather than too many texts (Pedgley, 1999). A similar observation is made by (Devanathan *et al.*, 2010) that a visual representation of the outcomes of an ecodesign project helps the designer with a feeling of assurance. Thus, visualization is a key aid which should be available in an ecodesign support (Bernstein *et al.*, 2010). Product development is a challenging task because of the high variety of products and the integration of environmental aspects makes it further complex. Therefore, an ecodesign support should have the flexibility to deal with a variety of products rather than being specific (Salo *et al.*, 2019). Early design phases of a product development process are crucial for considering the environmental criteria such as selection of materials and manufacturing process. Therefore, it should be ensured by the support developers that it can be used in early design phases (O'Hare, 2010). However, in such a scenario, the data which is available is generally qualitative in nature and thus the support should be able to deal with such type of data (Lindahl, 2001). Developing new products is always considered as a demanding task and present new challenges for the designers (Kumar and Sarkar, 2018b). Therefore an ecodesign support should be able to integrate environmental considerations into the process of new product development (Olundh, 2006). The support should have the ability to full fill the organizational needs through customizations (Knight and Jenkins, 2009).

### *2.1 Research gap*

Design researchers have been developing various ecodesign tools over the years but many of them are denied by engineering designers to adopt in industries. Some authors have mentioned that there are certain characteristics which are either missing or not implemented properly in the existing ecodesign tools (Jänsch and Birkhofer, 2007; Le Pochat *et al.*, 2007; Luttropp and Lagerstedt, 2006). These studies are focused on finding out that what is missing but do not suggest that what are the actual needs of engineering designers. There is a lack of studies that focus on identifying the actual expectations of designers from an ecodesign support. In this study, the authors focus on identifying the various requirements of designers which are expected from an ecodesign support. Further, the authors argue that there might be a gap between the actual expectations of engineering designers from an ecodesign support and the features which are added in the support by design researchers. It can be identified through an understanding of the perspective and priorities of both, engineering designers and design researchers. This study aims to identify whether there is a gap between the perspective of engineering designers and design researchers that hampers the effective utilization of existing ecodesign tools. If there is a gap, then what measures can be taken to fill this gap.

## 3. Aim and methodology

The main aim of this research is to understand the priorities of designers for an ecodesign support during ECPD from the designer's perspective. However, the objectives of this research are threefold which are mentioned below.

(1) To identify the various requirements of designers expected from an ecodesign support.

(2) To understand the priorities of designers for an ecodesign support (engineering designers versus design researchers).

(3) To investigate whether there is any difference between the perspective of engineering designers and design researchers about the ecodesign support for ECPD.

The methodology of this research is presented in Figure 1 in the form of a flowchart. Various steps of this methodology are mentioned below.

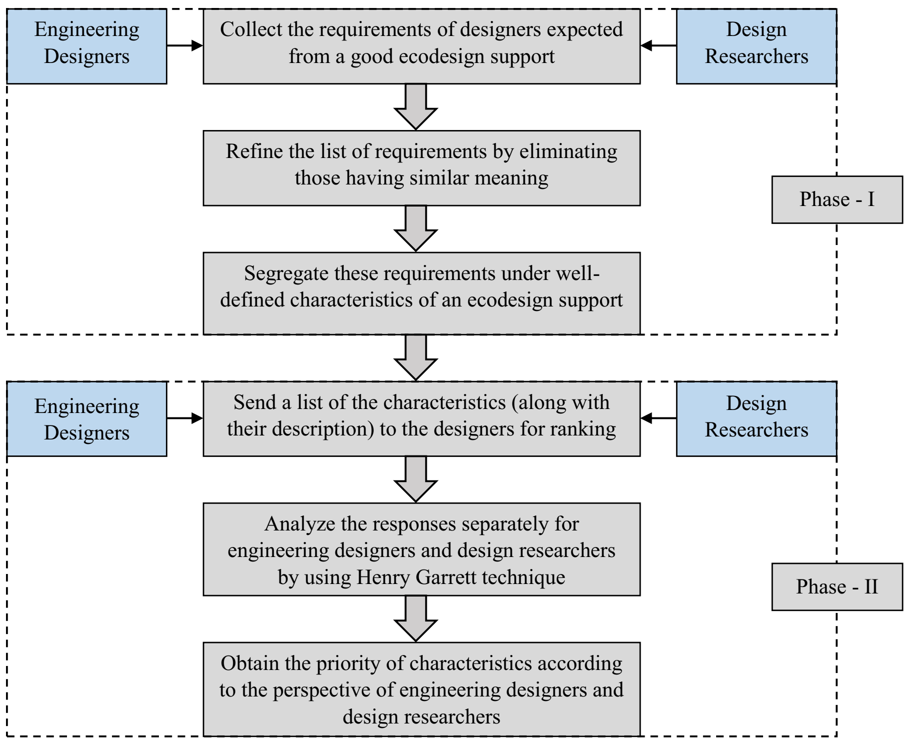


**Figure 1.**
A flow diagram of the research methodology

*Step 1:* Identify the potential respondents (i.e. engineering designers and design researchers) and collect their requirements from an ecodesign support through a survey questionnaire.

*Step 2:* Once the requirements are received, study the requirements provided by each designer and eliminate those having similar meaning. Thus, a list of independent requirements is prepared.

*Step 3:* Categorize these requirements under certain specific characteristics of ecodesign support.

*Step 4:* Prepare a separate list of ecodesign support characteristics. Then, develop a questionnaire by putting each characteristic along with a brief description. Send this questionnaire to the same group of designers who responded to first survey and ask them to rank each characteristic individually.

*Step 5:* Analyze the responses separately for engineering designers and design researchers by using Henry Garrett technique.

*Step 6:* Verify whether there is a gap in the perspective of engineering designers and design researchers for the ecodesign support characteristics. It is verified by conducting a Spearman Rank Correlation analysis.

The details of the respondents and the process used for collection and analysis of data are described below.

### *3.1 Details of the respondents*

A total of 50 designers from industry (i.e. engineering designers) and academia (i.e. design researchers) were contacted through e-mail and phone calls. Engineering designers are mostly related to automotive and electrical appliance industries whereas the design researchers are faculties and post-doctoral fellows with a background in environmental design and sustainability. Each designer has an experience of at least 5 years or more. 32 out of the 50 designers agreed to be the part of this study which includes 15 engineering designers and 17 design researchers. A number of 30 or more respondents is sufficient for a study which requires involvement of the professionals or experts from a specific field (Gardas *et al.*, 2019; Robbins, 1994). Further details of the respondents are presented in Figure 2.

### *3.2 Collection of data*

The data are collected and analyzed in two phases by using semi-structured survey questionnaire. These two phases are discussed below.

*3.2.1 Phase I.* A questionnaire was sent to the designers in which they were asked to list down the requirements which they perceive about an ecodesign support for ECPD. Since this study includes engineering designers and design researchers, therefore the formation of survey was a bit different for both. Engineering designers were asked to mention their requirements that they will seek while using an ecodesign support for ECPD. On the other hand, design researchers were asked to list down the requirements that they will add in an ecodesign support while developing it.

Once the responses are received, the statements of the respondents are refined by the authors. The requirements having similar meaning are identified and converted into a single requirement. For example; some requirements obtained in the questionnaire from different designers are as follow:

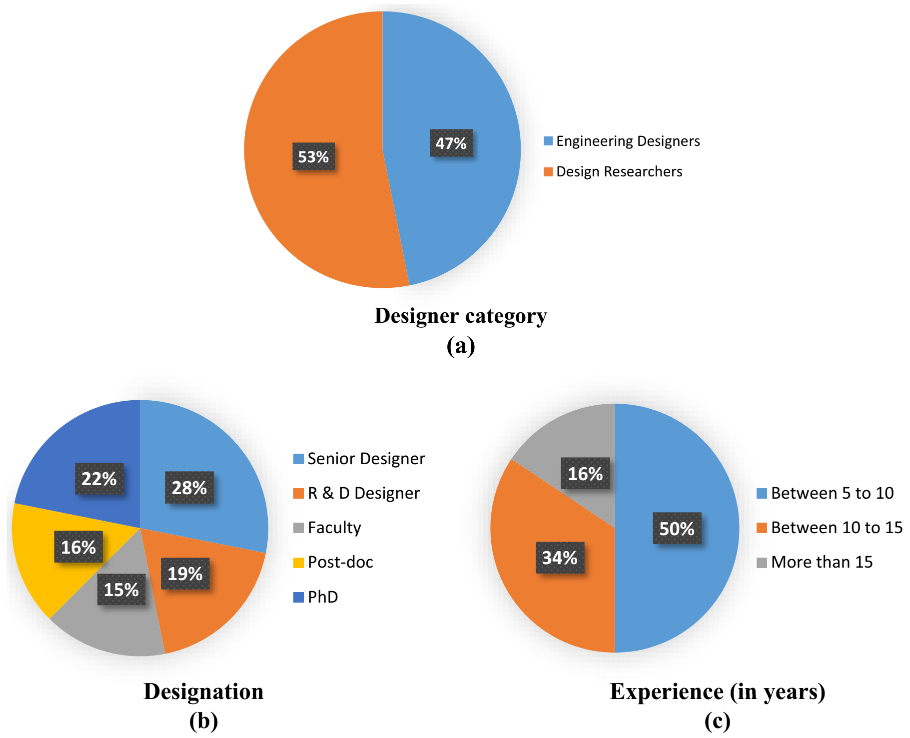


**Figure 2.**
(a). Designer category, (b). Designation, (c). Experience (in years)

Designer A: "*The tool should be customizable*"

Designer B: "*It can be modified to adapt the specific work culture of a company*"

Designer C: "*The designer can modify the tool*"

Designer D: "*It should be easy to modify*"

Designer E: "*Designers can add or remove any feature as per the requirement*"

All the above requirements have a similar nature and therefore these five requirements are replaced by a single requirement as "It can be customized as per the need of the designer" and added with serial number 17 in Table 1. Similarly, all the other requirements of designers are refined and added in Table 1.

Only those statements having a recurrence of 3 (i.e. 10% of the respondents) or more are included to the study and rest are left out. All the requirements of designers are segregated under certain well defined characteristics of an ecodesign support, as shown in Table 1.

*3.2.2 Phase II.* In the second phase, another questionnaire based survey was sent only to those designers who responded in the first survey. It includes a list of the characteristics of an ecodesign support along with a brief description. These characteristics are framed on the basis of the requirements of designers collected in the first survey. Designers were asked to assign individual ranking to each characteristic. The responses received in this survey are analyzed separately for engineering designers and design researchers to understand their individual perspective about an ecodesign support. The responses are analyzed by using

| S. N. | Requirements of the designers | Recurrence* | Related characteristics |
| --- | --- | --- | --- |
| 1 | It should not consume much time in data collection | 11 | Time efficient |
| 2 | It should be able to complete the entire task within few days rather than weeks or months | 7 | Time efficient |
| 3 | It should be useful in the initial phases of a product development process | 10 | Suitable for early design |
| 4 | It should not require a huge amount of data to analyze the design | 6 | Quality of required data |
| 5 | It should guide the user about how to gather the data | 7 | Quality of required data |
| 6 | It should be able to utilize qualitative data | 5 | Quality of required data |
| 7 | It must consider the whole life cycle of products | 12 | Life cycle perspective |
| 8 | It should be easy to learn and adopt | 11 | Basic knowledge required |
| 9 | It should not require environmental expertise to use it | 10 | Basic knowledge required |
| 10 | It should not require a rigorous training before using it | 8 | Basic knowledge required |
| 11 | It should facilitate the ecofriendly development of new products also | 9 | Suitable for new product |
| 12 | The effect of any change in the design should be highlighted by the tool | 7 | Highlighting the trade-off |
| 13 | The results provided by the tool can be observed in the form of some chart or diagram | 16 | Visualization |
| 14 | It should ensure that the designers can realize the outcomes of the project | 7 | Visualization |
| 15 | It should be useful for designing different type of products | 15 | Flexibility |
| 16 | It should provide useful results even if any step is missed in between the process | 6 | Flexibility |
| 17 | It can be customized as per the need of the designer | 5 | Flexibility |
| 18 | It should provide the guidelines to improve the design for lesser environmental impact | 11 | Improvement strategies |
| 19 | The tool should focus on "what to do" as well as on "how to do" | 8 | Improvement strategies |
| 20 | It should follow the environmental standards to improve the design | 16 | Improvement strategies |
| 21 | It should be able to share the data which is related to the outcomes of the project | 4 | Exchange of information |
| 22 | It should follow a multifunctional approach | 3 | Exchange of information |
| 23 | The results should be easy to understand | 8 | Quality of results |
| 24 | Results should be reliable so that it can be reused in future | 5 | Quality of results |
| 25 | Results should be easy to interpret | 11 | Quality of results |

**Note(s)**: *"Recurrence" means the number of respondents who mentioned this requirement

**Table 1.** Various requirements of designers along with the recurrences obtained from first survey

Henry Garrett technique to find out the priority of characteristics of an ecodesign support according to the perspective of both, engineering designers and design researchers. Although, there are other techniques such as analytical network process (ANP), analytical hierarchy process (AHP) and DEMATEL which can be utilized for prioritizing the factors but these techniques are useful only if there is an inter-relationship among the factors. In this research, various ecodesign characteristics are independent of each other and therefore Henry Garrett method is preferred in this study.

### 3.3 Henry Garrett technique

It is a statistical technique which is used to identify the significant factors through a ranking approach. This technique was introduced by Garrett (1969). Henry Garrett technique is useful for analyzing the factors which are independent of each other. This technique has been used in variety of application such as understanding the impact of work stress on the performance of employees (Thamilchelvam, 2017), preferences of users among various e-resources (Dhanavandan, 2016) and the factors affecting the purchase decisions of consumers (Rao *et al.*, 2019). The steps of Henry Garrett technique are as follows:

*Step 1*. Collect the data from respondents in the form of ranking of each factor and tabulate it.

*Step 2*. List down the frequency of each rank "$f_i$" corresponding to each factor.

*Step 3*. Find the percent positon of each rank by using the following formula:

$$\text{Percent position} = \frac{100(R_{ij} - 0.5)}{N_j} \quad (1)$$

where $R_{ij}$ = the rank assigned to $i$th factor by $j$th respondent

$N_j$ = number of factors ranked by $j$th respondent

*Step 4*. Convert the percent position into a Garrett score "$S_i$" by using the Garrett chart, as given in Table 4.

*Step 5*. Determine the total score for each factor "$T_i$" by using Eq. (2).

$$T_i = \sum f_i S_i \quad (2)$$

*Step 6*. Calculate the mean scores for each factor by using Eq. (3).

$$\text{Mean score} = \frac{T_i}{n} = \frac{\sum f_i S_i}{n} \quad (3)$$

where, "$n$" is the number of respondents.

*Step 7*. Assign rank to each factor on the basis of the mean score.

The step by step calculation is provided in Section 4.2.1.

### 3.4 Spearman rank correlation

It was introduced by Spearman, a psychologist. It is generally used to measure and verify the association between two things. This is one of the oldest rank statistical approach. This approach is based on a coefficient "$\rho$" which is often called as Spearman's rank correlation coefficient. The coefficient "$\rho$" is computed as given below.

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2 - 1)} \quad (4)$$

Where, "$n$" is the number of factors and "$d$" indicates the difference of ranking for two samples.

## 4. Results

The results obtained through two phases of the study are separately provided in the following sub-sections.

### *4.1 Results of phase I*

The results obtained from the first round of the survey include a diverse requirements of the designer respondents. Only those requirements having a recurrence of 3 or more are included to the study and rest are left out. These requirements are refined so as to bring a commonality between them without altering their actual significance. Thus, a total of 25 distinct requirements are identified, as provided in Table 1. These requirements are studied thoroughly and segregated under 12 well defined characteristics of an ecodesign support for ECPD. All requirements along with their related characteristics and recurrences are provided in Table 1. "Improving the design of products by following the environmental standards" and "presenting the outcomes of tools in the form of charts or diagrams" are the two highly mentioned requirements of the designers with each having a recurrence of 16. The ability of ecodesign support to assist the development of different types of products is another requirement mentioned by 15 designers. Only 3 respondents mentioned that the support should follow a multifunctional approach. Also, only 4 respondents were concerned about the ability of ecodesign support to share the data related to the outcomes of a project.

### *4.2 Results of phase II*

In the second phase of the study, the responses obtained through the survey are analyzed separately for engineering designers and design researchers for identifying the priority of characteristics of an ecodesign support as per the perspective of engineering designers and design researchers. Also, it will help to understand if there is any difference in the perspective of engineering designers and design researchers while choosing or developing a support for ECPD. The analysis of data is carried out by using Henry Garrett technique. First, the analysis is carried out for the data obtained from engineering designers as discussed below.

*4.2.1 Analysis of the data obtained from engineering designers.* The data obtained from engineering designers is tabulated and the frequency of each rank corresponding to each characteristic is calculated, as shown in Table 2.

| | Frequency of ranks ($f_i$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Characteristics | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th |
| Time efficient (C1) | 3 | 5 | 3 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| Suitable for early design phases (C2) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 2 | 3 | 6 |
| Quality of required data (C3) | 0 | 1 | 0 | 1 | 1 | 2 | 1 | 2 | 4 | 2 | 0 | 1 |
| Life cycle perspective (C4) | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 | 3 | 2 |
| Basic knowledge required (C5) | 1 | 2 | 5 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| Suitable for NPD (C6) | 7 | 3 | 1 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| Trade-off (C7) | 0 | 1 | 0 | 0 | 2 | 0 | 3 | 5 | 2 | 0 | 1 | 1 |
| Visualization (C8) | 1 | 1 | 0 | 1 | 2 | 5 | 2 | 0 | 1 | 1 | 0 | 1 |
| Flexibility (C9) | 1 | 0 | 2 | 2 | 1 | 2 | 4 | 1 | 0 | 1 | 1 | 0 |
| Improvement strategies (C10) | 1 | 1 | 1 | 3 | 6 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Exchange of information (C11) | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 5 | 3 |
| Quality of results (C12) | 1 | 0 | 2 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

**Table 2.** Analysis of data obtained from engineering designers

Then, the percent position of each rank is calculated by using Eq. (1). The calculation of the percent position for each rank is shown in Table 3. Further, a Garrett score is assigned to each rank on the basis of a chart (given in Table 4). The Garrett score corresponding to each rank is presented in Table 3.

The frequency of each rank (given in Table 2) is multiplied by the corresponding Garrett score (given in Table 3) and then a mean Garrett score is determined for each characteristic of the ecodesign support, as given in Table 5.

For example, the mean Garrett score of C1 i.e., "Time efficient" is calculated by using Eq. (3) as:

**Table 3.** Percent position and corresponding Garrett score of each rank

| Rank | Percent position | Garrett score ($S_i$) |
|---|---|---|
| 1st | 100 * (1–0.5)/12 = 4.17 | 83 |
| 2nd | 100 * (2–0.5)/12 = 12.50 | 73 |
| 3rd | 100 * (3–0.5)/12 = 20.83 | 66 |
| 4th | 100 * (4–0.5)/12 = 29.17 | 61 |
| 5th | 100 * (5–0.5)/12 = 37.50 | 56 |
| 6th | 100 * (6–0.5)/12 = 45.83 | 52 |
| 7th | 100 * (7–0.5)/12 = 54.17 | 48 |
| 8th | 100 * (8–0.5)/12 = 62.50 | 44 |
| 9th | 100 * (9–0.5)/12 = 70.83 | 39 |
| 10th | 100 * (10–0.5)/12 = 79.17 | 34 |
| 11th | 100 * (11–0.5)/12 = 87.50 | 27 |
| 12th | 100 * (12–0.5)/12 = 95.83 | 17 |

**Table 4.** Garrett ranking conversion table

| Percent | Score | Percent | Score | Percent | Score | Percent | Score |
|---|---|---|---|---|---|---|---|
| 0.09 | 99 | 11.03 | 74 | 52.02 | 49 | 90.83 | 24 |
| 0.20 | 98 | 12.04 | 73 | 54.03 | 48 | 91.67 | 23 |
| 0.32 | 97 | 13.11 | 72 | 56.03 | 47 | 92.45 | 22 |
| 0.45 | 96 | 14.25 | 71 | 58.03 | 46 | 93.19 | 21 |
| 0.61 | 95 | 15.44 | 70 | 59.99 | 45 | 93.86 | 20 |
| 0.78 | 94 | 16.69 | 69 | 61.94 | 44 | 94.49 | 19 |
| 0.97 | 93 | 18.01 | 68 | 63.85 | 43 | 95.08 | 18 |
| 1.18 | 92 | 19.39 | 67 | 65.75 | 42 | 95.62 | 17 |
| 1.42 | 91 | 20.93 | 66 | 67.48 | 41 | 96.11 | 16 |
| 1.68 | 90 | 22.32 | 65 | 69.39 | 40 | 96.57 | 15 |
| 1.96 | 89 | 23.88 | 64 | 71.14 | 39 | 96.99 | 14 |
| 2.28 | 88 | 25.48 | 63 | 72.85 | 38 | 97.37 | 13 |
| 2.69 | 87 | 27.15 | 62 | 74.52 | 37 | 97.72 | 12 |
| 3.01 | 86 | 28.86 | 61 | 76.12 | 36 | 98.04 | 11 |
| 3.43 | 85 | 30.61 | 60 | 77.68 | 35 | 98.32 | 10 |
| 3.89 | 84 | 32.42 | 59 | 79.17 | 34 | 98.58 | 9 |
| 4.38 | 83 | 34.25 | 58 | 80.61 | 33 | 98.82 | 8 |
| 4.92 | 82 | 36.15 | 57 | 81.99 | 32 | 99.03 | 7 |
| 5.51 | 81 | 38.06 | 56 | 83.31 | 31 | 99.22 | 6 |
| 6.14 | 80 | 40.01 | 55 | 84.56 | 30 | 99.39 | 5 |
| 6.81 | 79 | 41.97 | 54 | 85.75 | 29 | 99.55 | 4 |
| 7.55 | 78 | 43.97 | 53 | 86.89 | 28 | 99.68 | 3 |
| 8.33 | 77 | 45.97 | 52 | 87.96 | 27 | 99.80 | 2 |
| 9.17 | 76 | 47.98 | 51 | 88.97 | 26 | 99.91 | 1 |
| 10.06 | 75 | 50.00 | 50 | 89.94 | 25 | 100.00 | 0 |

| | [Frequency of ranks ($f_i$) * Corresponding Garrett score ($S_i$)] | | | | | | | | | | | | Mean Garrett | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ch | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | score | Rank |
| C1 | 249 | 365 | 198 | 61 | 0 | 52 | 48 | 0 | 39 | 0 | 0 | 0 | 67.47 | *2* |
| C2 | 0 | 0 | 0 | 0 | 0 | 52 | 0 | 88 | 39 | 68 | 81 | 102 | 28.67 | *12* |
| C3 | 0 | 73 | 0 | 61 | 56 | 104 | 48 | 88 | 156 | 68 | 0 | 17 | 44.70 | *9* |
| C4 | 0 | 0 | 0 | 0 | 0 | 52 | 48 | 44 | 39 | 204 | 81 | 34 | 33.47 | *11* |
| C5 | 83 | 146 | 330 | 122 | 0 | 52 | 48 | 44 | 39 | 0 | 27 | 0 | 59.40 | *3* |
| C6 | 581 | 219 | 66 | 0 | 112 | 0 | 0 | 44 | 39 | 0 | 0 | 0 | 70.73 | *1* |
| C7 | 0 | 73 | 0 | 0 | 112 | 0 | 144 | 220 | 78 | 0 | 27 | 17 | 44.73 | *8* |
| C8 | 83 | 73 | 0 | 61 | 112 | 260 | 96 | 0 | 39 | 34 | 0 | 17 | 51.67 | *7* |
| C9 | 83 | 0 | 132 | 122 | 56 | 104 | 192 | 44 | 0 | 34 | 27 | 0 | 52.93 | *6* |
| C10 | 83 | 73 | 66 | 183 | 336 | 52 | 0 | 0 | 39 | 0 | 0 | 17 | 56.60 | *4* |
| C11 | 0 | 73 | 66 | 0 | 0 | 0 | 48 | 44 | 39 | 68 | 135 | 51 | 34.93 | *10* |
| C12 | 83 | 0 | 132 | 305 | 56 | 52 | 48 | 44 | 39 | 34 | 27 | 0 | 54.67 | *5* |

**Table 5.** Final ranking of the characteristics as per the perspective of engineering designers

{(3 × 83) + (5 × 73) + (3 × 66) + (1 × 61) + (0 × 56) + (1 × 52) + (1 × 48) + (0 × 44) + (1 × 39) + (0 × 34) + (0 × 27) + (0 × 17)}/15 [Here, 15 is the number of respondents, i.e. engineering designers in this case]

= {249 + 365 + 198 + 61 + 0 + 52 + 48 + 0 + 39 + 0 + 0 + 0} [as presented in first row of Table 5]

= 1012/15

= 67.47

Similarly, the mean Garrett score is calculated for remaining characteristics. Then, final ranking is assigned to each characteristic on the basis of its mean Garrett score, as provided in Table 5.

*4.2.2 Analysis of the data obtained from design researchers.* A similar approach is followed for analyzing the data obtained from design researchers. The ranking of each characteristic of ecodesign support with the perspective of design researchers is provided in Table 6.

### *4.3 Priority of characteristics of an ecodesign support (engineering designers' vs design researchers)*

The priority of characteristics of an ecodesign support is presented in Figure 3 separately for engineering designers and design researchers.

It is clear from Figure 3 that the characteristics which are highly ranked by engineering designers are given least preferences by the design researchers and vice versa. Suitability of the support for new product development is perceived as the most significant characteristic by engineering designers. Most of the engineering designers utilize their experience rather than ecodesign tools for ECPD (Sherwin, 2000). Therefore, they face difficulty during a new product development as there is no past experience available for designing such products. This concern of engineering designers might have led them to choose "suitability of the support for new product development" above all other characteristics. Other key characteristics obtained from the responses of engineering designers are, "Time efficient", "Basic knowledge required" and "Improvement strategies" which are ranked at 2nd, 3rd and 4th positions, respectively. It shows that engineering designers prefer that the support should be less time consuming and can be managed with the basic knowledge, i.e. they need not to develop any additional skills to use the support. The way engineering designers have chosen their priority of characteristics, it clearly shows that they are much concerned about the fact that the adoption of an ecodesign support should not add anything new to their routine task.

**Table 6.**
Final ranking of the characteristics as per the perspective of design researchers

| Ch | [Frequency of ranks ($f_i$) * Corresponding Garrett score ($S_i$)] 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th | Mean Garrett score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 0 | 0 | 66 | 0 | 56 | 0 | 96 | 44 | 0 | 68 | 162 | 68 | 32.94 | *11* |
| C2 | 664 | 219 | 132 | 0 | 112 | 52 | 0 | 0 | 39 | 0 | 0 | 0 | 71.65 | *1* |
| C3 | 83 | 146 | 198 | 305 | 56 | 52 | 48 | 0 | 39 | 34 | 27 | 0 | 58.12 | *4* |
| C4 | 249 | 511 | 132 | 122 | 56 | 0 | 48 | 0 | 39 | 0 | 0 | 0 | 68.06 | *2* |
| C5 | 0 | 0 | 0 | 61 | 56 | 52 | 48 | 88 | 195 | 68 | 54 | 34 | 38.59 | *9* |
| C6 | 0 | 0 | 0 | 61 | 0 | 52 | 144 | 264 | 117 | 34 | 54 | 0 | 42.71 | *8* |
| C7 | 166 | 146 | 396 | 122 | 0 | 104 | 0 | 44 | 78 | 0 | 0 | 0 | 62.12 | *3* |
| C8 | 83 | 0 | 0 | 122 | 112 | 104 | 192 | 88 | 39 | 34 | 27 | 17 | 48.12 | *7* |
| C9 | 83 | 73 | 66 | 61 | 112 | 312 | 96 | 44 | 0 | 34 | 0 | 17 | 52.82 | *6* |
| C10 | 83 | 146 | 132 | 122 | 336 | 0 | 0 | 44 | 78 | 34 | 0 | 0 | 57.35 | *5* |
| C11 | 0 | 0 | 0 | 61 | 0 | 52 | 48 | 44 | 0 | 102 | 81 | 119 | 29.82 | *12* |
| C12 | 0 | 0 | 0 | 0 | 56 | 104 | 96 | 88 | 39 | 170 | 54 | 34 | 37.71 | *10* |

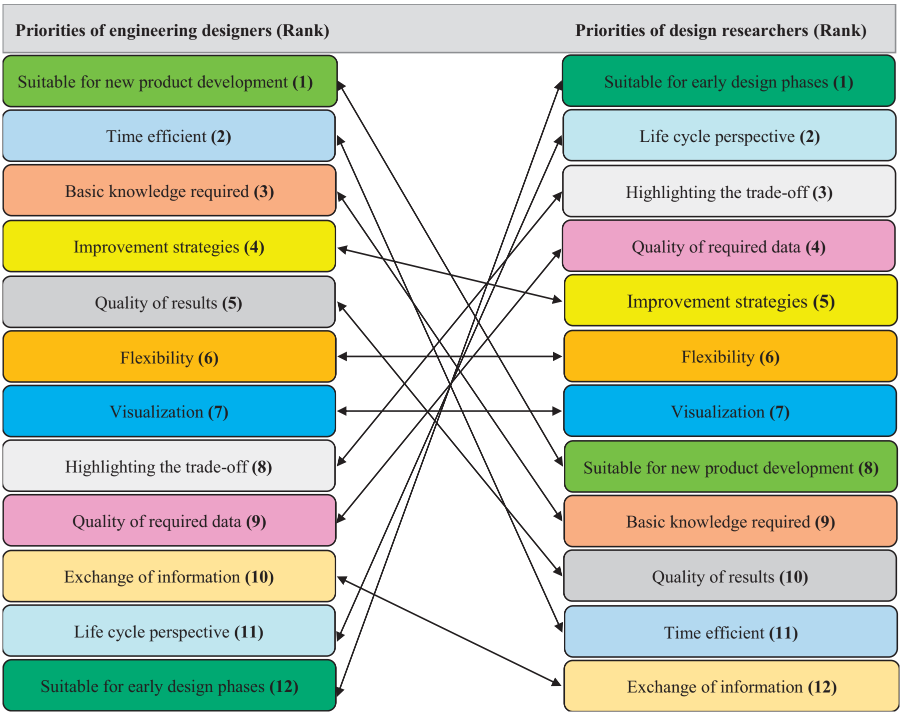


**Figure 3.**
Priority of characteristics of an ecodesign support (engineering designers' vs. design researchers)

It can be understood that engineering designers need a support which is generic in nature and can take care of various environmental needs. It throws a challenge on design researchers to develop a support which is simple yet effective for ECPD.

On the other hand, design researchers give the highest preference to the ability of the support to be adopted in early design stages of a product development. Generally, design researchers gain their experience from the relevant literature and it is well established in the literature that most of the design decisions related to the life cycle of a product should be taken in early design stages of a product development. It is easy to modify the design in early design stages (Frei, 1998; Hallstedt *et al.*, 2013; McAloone and Evans, 1996). The characteristic which is assigned 2nd rank by design researchers is "Life cycle perspective". Researchers have emphasized that a life cycle perspective should be followed while developing environmentally conscious products (Byggeth and Hochschorner, 2006; Ritzén, 2000). If the focus is given to only one phase of a product life cycle, then it is possible that it can cause some undesired changes to other life cycle phases which may not be realized due to the focus on a single phase only. "Exchange of information" is considered as the least significant characteristic and assigned with 10th and 12th rank by engineering designers and design researchers, respectively.

*4.4 Difference between the perspective of engineering designers and design researchers*

The result obtained from the analysis of the data provided by the designers is presented in Figure 4 in the form of the score achieved by each characteristic of ecodesign support. It is clearly evident from this figure that there is a difference between the perspective of engineering designers and design researchers while choosing a support for ECPD. A quantitative measure of the difference in the perspective is provided in Table 7 for a better understanding.

It can be observed from Table 7 that the most significant difference occurs in case of the characteristic "Suitable for early design phases". From the perspective of design researchers, the suitability of an ecodesign support to be adopted in early design phases achieves a score of 71.65 whereas the score assigned to this characteristic by engineering designers is 28.67 only. Thus, it reflects a difference of about 60% in their perspective. It shows that engineering designers are not much concerned about the ability of ecodesign support to be adopted in early design phases. But the perspective of design researchers is justified in this scenario because almost 80% of the decisions are taken in early design phases that determine the environmental performance of a product (Singh and Sarkar, 2019b). On contrary, time efficiency of an ecodesign support is provided with a score of 67.47 by engineering designers whereas design researchers assign this characteristic with a score of 32.94. In this case, the difference in the perspective comes out to be about 51%. In this scenario, the concern of

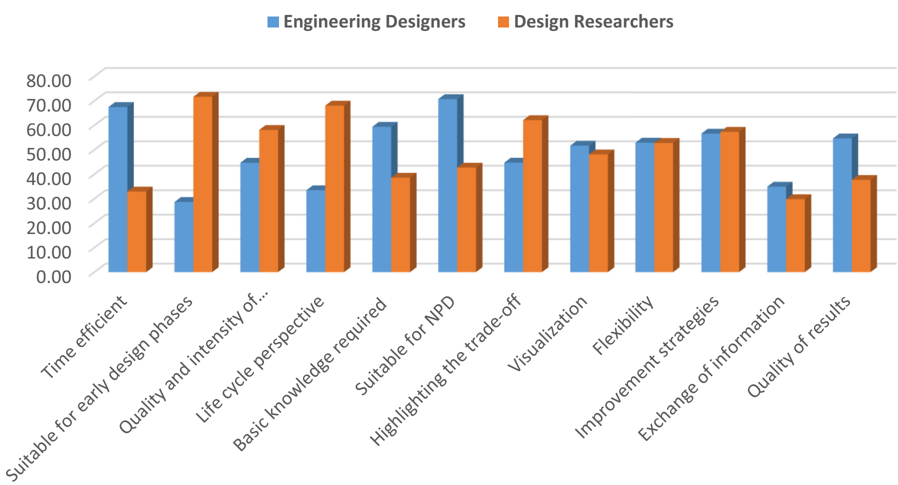


**Figure 4.** Comparing the perspective of engineering designers and design researchers about different characteristics of an ecodesign support

| Characteristics | Mean Garrett score Engineering Designers | Design researchers | Difference in perspective |
|---|---|---|---|
| Time efficient | 67.47 | 32.94 | 51% |
| Suitable for early design | 28.67 | 71.65 | 60% |
| Quality of required data | 44.70 | 58.12 | 23% |
| Life cycle perspective | 33.47 | 68.06 | 51% |
| Basic knowledge required | 59.40 | 38.59 | 35% |
| Suitable for NPD | 70.73 | 42.71 | 40% |
| Highlighting the trade-off | 44.73 | 62.12 | 28% |
| Visualization | 51.67 | 48.12 | 7% |
| Flexibility | 52.93 | 52.82 | 0% |
| Improvement strategies | 56.60 | 57.35 | 1% |
| Exchange of information | 34.93 | 29.82 | 15% |
| Quality of results | 54.67 | 37.71 | 31% |

**Table 7.**
A quantitative measure of the difference in the perspective of designers

engineering designers about the time efficiency of ecodesign support is justified because they are always under pressure to finish the projects on time (Luttropp and Lagerstedt, 2006). Some other characteristics with a noticeable difference in the perspective of engineering designers and design researchers are, “Life cycle perspective (51%)”, “Suitable for new product development (40%)” and “Basic knowledge required (35%)”. However, there are certain characteristics of the ecodesign support for which both, i.e. engineering designers and design researchers have almost a similar perspective. These characteristics are, “Improvement strategies (1%)”, “Visualization (7%)” and “Flexibility (0%)”.

A Spearman rank correlation analysis is also conducted to understand the significance of the difference in the perspective of engineering designers and design researchers. It is provided in Table 8.

The Spearman coefficient “$\rho$” is computed by using Eq. (4) as given below.

$$\rho = 1 - \frac{6\times 448}{12(12^2 - 1)}$$

$$\rho = -0.566$$

| Characteristics | $R_{ED}$ | $R_{DR}$ | $d = R_{ED}–R_{DR}$ | $d^2$ |
|---|---|---|---|---|
| Time efficient | 2 | 11 | −9 | 81 |
| Suitable for early design | 12 | 1 | 11 | 121 |
| Quality of required data | 9 | 4 | 5 | 25 |
| Life cycle perspective | 11 | 2 | 9 | 81 |
| Basic knowledge required | 3 | 9 | −6 | 36 |
| Suitable for NPD | 1 | 8 | −7 | 49 |
| Highlighting the trade-off | 8 | 3 | 5 | 25 |
| Visualization | 7 | 7 | 0 | 0 |
| Flexibility | 6 | 6 | 0 | 0 |
| Improvement strategies | 4 | 5 | −1 | 1 |
| Exchange of information | 10 | 12 | −2 | 4 |
| Quality of results | 5 | 10 | −5 | 25 |
| | | | | $\sum d^2 = 448$ |

**Note(s)**: $R_{ED}$ = Rank of characteristics by engineering designers
$R_{DR}$ = Rank of characteristics by design researchers

**Table 8.**
Spearman rank correlation analysis

The negative value of Spearman coefficient verifies that there is a negative correlation in the perspective of engineering designers and design researchers for the required characteristics of an ecodesign support.

## 5. Discussion and research implications

It is evident from the outcomes of the study that there is a clear gap between the expectations of engineering designers and design researchers from an ecodesign support for developing environmentally conscious products. In fact, it is observed that there is a contrast in their priorities, i.e. the characteristics which are highly ranked by engineering designers are given least preferences by the design researchers and vice versa. It can be observed in Figure 2. It is understood from the results of this study that engineering designers are much concerned about the usage aspects of the support whereas design researchers focus more on adding the technical features to the support. Engineering designers need a generic tool which can help to take care of various environmental needs of products. Apart from the contrasting priorities, there is a significant difference in their perspective for most of the characteristics, as evident from Table 7. These findings show a good agreement with the statements of Lindahl (2006) and Lofthouse (2006) in which they mentioned that there might be a gap between the priorities of support developers (generally design researchers) and the potential users (i.e. engineering designers). This gap might be the reason behind the limited usage of various existing ecodesign tools by engineering designers in industries.

From the above discussion, it can be understood that an ecodesign support can be useful only if it has a generic nature and at the same time it is equipped with the technical features to take care of the complex environmental requirements while producing a product. The flexibility of an ecodesign support tool, i.e. its ability to deal with a variety of products, can be achieved only if it can be customized as per the needs of the designers. A good ecodesign support should be coherent to the traditional product development process. It will help engineering designers to easily adapt it as a part of their routine task. Also, a good ecodesign support should be equipped with a step by step approach to guide the designers about how to identify and implement various environmentally friendly features in the design of a product. A key feature that must be added by design researchers in an ecodesign support is its ability to highlight any potential repercussion in the functionality and environmental performance of a product that may be caused due to any modification in the design of a product. Such a feature will enable the designers to conceptualize the possible outcomes of a change in the design even before executing it. For example, if a designer wish to choose a low cost material for a product, then he should be able to know in advance that how this change will affect the functional aspects of the product such as weight, strength, durability etc. as well as the environmental aspects of the product such as energy consumption, waste generation and recyclability. All these suggested implications can be achieved effectively if design researchers work in consultation with engineering designers while developing an ecodesign support.

## 6. Conclusion and direction for future research

Understanding the perspective of designers is a key step toward the development of environmentally conscious products. This study attempts to identify the various requirements of designers and the key characteristics of an ecodesign support for ECPD. This research involves the designers from industries (engineering designers) as well as from academia (design researchers) so that the perspective of both about an ecodesign support can be understood. It is observed that the characteristics which are highly ranked by engineering designers are given least preferences by the design researchers and vice versa. It shows that there is a gap in the perspective of engineering designers and design researchers about an ecodesign support. This fact leads toward a scenario in which many of the tools developed by the design researchers at academic level may not be used by the engineering designers in industries and may remain idle. Thus, it can be concluded that there is a need for design researchers to work in collaboration with engineering designers while developing a support for ECPD. To achieve this feat, the initiatives like "industry-academia connect" should be given much importance. It will help engineering designers to be accustomed with the environmental needs of products and at the same time, design researchers will have a better understanding of actual expectations of industries from an ecodesign support. In addition, the lack of awareness about existing ecodesign tools and rigidity to accept a change in the work culture are crucial reasons that can make engineering designers reluctant to adopt ecodesign tools. Therefore, industries should take the initiatives to conduct seminars to make engineering designers aware about ecofriendly product development. Industries can also tell their employees that they are open to accept a change in their work culture for a better environment and society.

As far as the future research is concerned, the characteristics of an ecodesign tool which are identified in this study can be used as the criteria for analyzing the existing ecodesign tools. This analysis may help to understand the effectiveness of ecodesign tools for developing environmentally conscious products. However, some additional criteria can be explored which may not have been covered in this study. It will make the analysis of the tools more comprehensive.

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