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Product design in the circular economy: Users' perception of end-of-life scenarios for electrical and electronic appliances

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ABSTRACT

In previous years, numerous firms have established environmentally aware strategies with regards to product design, manufacturing and end-of-life (EoL) product management (Cheung et al., 2017). Product developers can choose to design products according to an environmentally favorable EoL scenario. Such strategies may also assist societies in the transition to a more circular economy. However, at the end of a product's useful life, it is uncertain whether the end users will handle the product according to the original intention of the product developers. Situated within this context, this research investigated how end users perceive three EoL scenarios (reuse, recycling and remanufacturing) and two disposal methods (door-to-door collection and delivery at point of purchase) for eight household electrical and electronic products (e-products) spanning a representative range of product categories. To this end, a quantitative Kano survey (N = 146) was used to classify product features related to EoL and disposal methods according to users' preferences. An extension developed by the authors was also deployed to identify differences within user segments in terms of demographic (e.g., age, gender, education level) and relevant psychographic variables (e.g., environmental awareness). Taken collectively, the results showed that the majority of EoL scenarios were actually regarded as *attractive* features in the Kano framework, meaning that users would be very satisfied with a product that can be disposed of according to a favorable EoL scenarios, but may not have any prior expectations at point of purchase. Reuse potential emerged as the most attractive EoL scenario, suggesting that users' preferences are largely aligned with the concept of circular economy. Interestingly, women were found to prefer all EoL scenarios more than men, and were also more willing to pay a premium price for environmentally friendly e-products. These results suggest that gender may be the most important basis for user segmentation (e.g. in the context of product development), and that products targeted towards women are more likely to enter favorable EoL scenarios.

1. Introduction

1.1. End-of-Life (EoL) scenarios

The rapid increase in industrial activities that has brought the human advancement has also resulted in an analogous consumption of natural resources. This unprecedented growth, in turn, has been one of the major threats to resource sustainability. This problem is even more pronounced with regards to electrical and electronic products (e-products), due to the multiple valuable resource used in them (Gu et al., 2016). With the increasing growth in the use of e-products due to the continual technological advancement, societies are challenged with their end-of-life (EoL) management (González et al., 2017). Although the current EoL management mainly relies on conventional waste collection and processing techniques for material recovery (Parajuly et al., 2016), with the growing discussion on circular economy, other EoL options - reuse, refurbishment, and remanufacturing have also proven increasingly relevant for e-products (Parajuly and Wenzel, 2017; Cheung et al., 2017).

In a move towards a more circular business economy, there are efforts seeking to slowing, narrowing, and closing down resource

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loops (Bocken et al., 2016). These strategies correspond to the available EoL scenarios, which ensure the extended circulation of resources in the society in form of products, components, and materials. This requires, among other improvements, the cooperation of all the different stakeholders in the product lifecycle (especially between producers and users) as well as an intentional and proactive improvement from product designers. Nevertheless, such initiatives are often proven challenging in the case of e-products given the complex material composition and the dynamic nature of product design. More importantly, despite the efforts from producers to design a product with a favorable EoL in mind, it is not guaranteed that users of the product will in fact act accordingly. Previous studies have acknowledged and attempted to address this, for example by constructing models and methods for take-back systems where the design of products is intended to trigger certain behavior among users (Huisman, 2003; Ackerman, 2013; Fang and Rau, 2017).

In order for any design for EoL (DfEoL) strategy to function properly, there should be an alignment between producers' intentions and the EoL handling of a product by its users. It is not desirable for a producer, for example, to design a product for better recyclability, if the users are more likely to prioritize repair and reuse of the product. The producer might rather, in that case, seek for options to improve the product design to ensure durability and reparability. This can be further facilitated by making the spare parts, repair tools and guidelines available, and by having an effective communication between the concerned stakeholders (Parajuly, 2017). Given the diversity of e-products, it is reasonable to assume that the DfEoL possibilities, as well the user preferences for EoL scenarios, will vary among product categories and even among specific product types. Moreover, variation may exist among different user segments as defined by e.g. demographics or attitudes towards environmental issues. Some users, for example, may prefer to repair certain appliances while others may be more inclined to return appliances to recycling facilities. Understanding user preferences and features towards different EoL scenarios within specific product categories is thus necessary for manufacturers to guide product development accordingly.

Previous research has explored a variety of angles related to this work. The willingness to pay for products with reused or recycled content, for example, was found to be related to the perceived functional risk of products. Moreover, users were more likely to purchase new products when the perceived functional risk was high and the price margin was low (Hamzaoui Essoussi and Linton, 2010). Another study found that the willingness to pay for refurbished products is in general low, but may be increased by including eco-certification on the products (Harms and Linton, 2016). The connection between perceived quality of refurbished products and willingness to pay has also been related to the users' tolerance for ambiguity, where manufacturers have been advised to reduce ambiguity levels associated with remanufacturing processes (Hazen et al., 2012). A study on willingness to pay for refurbished mobile phones has demonstrated that a market potential is present for such phones given that certain updates are provided for the devices, such as battery upgrades and software updates (Mugge et al., 2017). The same study also found that highlighting the environmental benefits could be an incentive, which correlates with other studies where eco-certification was found to increase the willingness to pay for refurbished products (Harms and Linton, 2016; Mugge et al., 2017). It has also been shown that users tend to reject or not consider refurbished phones due to the lack of knowledge of refurbishment in general (van Weelden et al., 2016). In the light of previous research, it becomes even clearer that an alignment of users' acceptance of EoL scenarios with the manufacturer's intentions becomes the key to a successful, intended life cycle management of a product. It also implies that designers are designing their products not only for the first users, but also potentially for the second users of the products.

1.2. The Kano model

One method to study the importance of product features from an end user's perspective is by using the Kano model (Kano et al.,). The model quantifies the relative importance of different product features for user satisfaction, which allows developers to understand whether individual features are required, wanted, or should be improved. Recent theoretical developments within the Kano model literature furthermore allow developers to easily visualise which combination of features and user segments provide the highest level of satisfaction (Atlason et al., 2016).

The Kano model for user satisfaction was originally proposed by Noriaki Kano in 1984 (Kano et al.,). The method has proven its usefulness to address efforts and rate of implementation of features related to the sensed needs of users. The model is based on a questionnaire approach to study how users may respond to functions and/or features of products, systems, or services. The basic philosophy of the Kano model is that product features influence user satisfaction differently, with some being non-linearly related to satisfaction:

1.2.1. Must-be features

These are the basic features of a product which, when not fulfilled, cause dissatisfaction among users. However, the fulfillment of these features, in and of itself, will not increase the user satisfaction. The possibility of sending text messages is, for example, a must-be feature for mobile phones.

1.2.2. One-dimensional features

One-dimensional features have a linear relationship with user satisfaction. The more these features are fulfilled, the more satisfied users will become. Battery life is an example of a one-dimensional feature for portable electronics.

1.2.3. Attractive features

Attractive features are regarded as the most important and sought-after by product developers (Sauerwein et al., 1996). These features are not expected by the users as such, and neither the exclusion of such features will necessarily lead to decreased satisfaction. However, the inclusion of an attractive feature may greatly increase the user satisfaction. For example, on the recent smartphones, the possibility to run two applications simultaneously is an attractive feature.

Fig. 1 shows the relationship between the implementation of the various classes of product features and user satisfaction.

The Kano model can assist during the product development stage, where some trade-offs are inevitable. A Kano model can help product developers to make informed decisions based on which features will result in the highest user satisfaction. For example, a product already fulfilling the "must-be" features should not be fine-tuned further in that direction, as doing so will not increase the satisfaction of users. This allows the product developers to use their resource to focus on one-dimensional and attractive features that will potentially improve user satisfaction.

The Kano method has previously been used to study user perception for the environmental aspects of products, in particular product packaging (Williams et al., 2008; Löfgren and Witell, 2008). These studies have shown, for example, that recyclable materials in packaging is considered as an attractive feature by users (Williams et al., 2008), suggesting that EoL scenarios are important to users

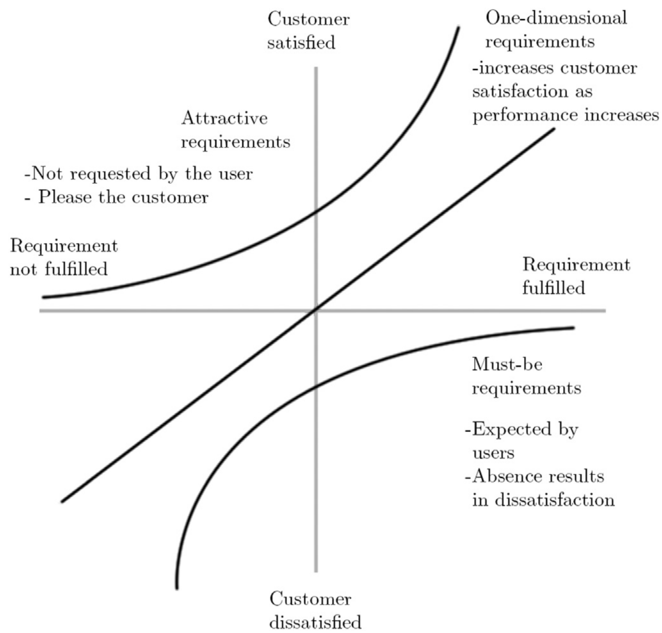

Fig. 1. Relationship between implementation of product features and user satisfaction (Clegg et al., 2010).

and warrants further studies. However, even though some studies have looked at user perception of recycled or refurbished products, no other study has investigated users' perceptions of EoL scenarios directly or specifically with regards to e-products. In this study, we expand the use of the Kano model - from the traditional focus on the 'use' stage of a product lifecycle - to cover the 'EoL' stage. Considering EoL management as a product feature, we analyze users' perception in order to investigate the most preferred EoL scenarios and disposal methods (see next section) for a large range of electrical and electronic household appliances. We focused in particular on the following three EoL scenarios, as defined in (MacArthur, 2013):

- *Reuse*, defined as the use of the product again for the same purpose in its original form or with little advancement or change;
- *Remanufacturing*, defined as the process of disassembly and recovery at the subassembly or component level. Functioning, reusable parts are taken out of a used product and rebuilt into a new one. This process includes quality assurance and potential enhancements or changes to the components;
- *Recycling*, defined as the process of recovering materials for the original purpose or for other purposes, excluding energy recovery.

The Kano model has traditionally been used to analyze functional and physical features of products and the user perception with regards to such features. In this study, a novel approach is taken where EoL scenarios are treated as functional requirements of products. The rationale behind this is that EoL scenarios are being considered as a part of the design process, which may guide the physical composition of products in some way. In addition, users have become more aware of EoL possibilities and therefore they can be expected to understand the concept of different EoL scenarios.

1.3. Disposal methods

In addition to the product design, the disposal methods available to users also will have a significant impact in whether a product will have a desirable EoL fate. The most common practice today is to bring EoL products to designated recycling centers. Existing EoL collection systems are designed mainly to facilitate the material recovery process and does not capture the reuse and remanufacturing potentials of EoL products (Parajuly and Wenzel, 2017). In order for these potentials to be realized, the collection system should respect the remaining functionality of the discarded products. This will require users to be willing to act accordingly and get involved in the process. There is a need to investigate disposal methods preferred by users of the case products, which may help us to evaluate the feasibility of alternative collection approaches. In order to investigate the users' perception, we considered the Danish e-waste management system as the reference (which is also commonly used by other EU members). The users in Denmark can discard of their EoL items at the civic amenity sites (or recycling centers), where they are collected in different fractions. More than 95% of the EoL products thus collected belong to the above-mentioned four categories (Large household appliances, Small household appliances, It & telecommunication equipment & Consumer electronics). The 2012 recast of the Waste Electrical and Electronic Equipment (WEEE) Directive (article 5, 2(d)) requires:

> *For WEEE from private households, Member States shall ensure that: distributors provide for the collection, at retail shops with sales areas relating to EEE of at least 400 m^2, or in their immediate proximity, of very small WEEE (no external dimension more than 25 cm) free of charge to end-users and with no obligation to buy EEE of an equivalent type, unless an assessment shows that alternative existing collection schemes are likely to be at least as effective.*

This means the distributors (e.g. hypermarkets and electronic stores) will have the responsibility to provide a collection facility in their vicinity. The understanding of the users' perception and their preferred disposal method will allow the design of such facilities to efficiently collect the targeted products. Moreover, such a collection approach, if supplemented with careful handling of the EoL products, may increase the possibility of reuse and remanufacturing. The present study contributes to this understanding by investigating users' attitudes towards the following two possible collection scenarios: 1) Door-to-door collection: The EoL products get collected from the users households for free and 2) Point-of-purchase collection: Users bring the EoL products to the nearest store which accepts the appliances without any fee or need of purchasing a new product.

Legislative actions, such as the WEEE directive, are an important factor when it comes to the disposal behavior of users. However, despite intentions of increasing correct disposal of electronic products, such directives have also the potential to increase cost or complexity for users. Even though this study does not address the effects of differently designed strategies to increase correct disposal, their importance should not be understated.

1.4. Recycling behavior and willingness to pay for environmentally friendly products

It is of importance to know whether users do or do not intend to conduct recycling of any sort in near future. Such knowledge can be used to plan the relevant EoL scenarios. For instance, a user may find an EoL scenario attractive but may not act accordingly, which keeps the EoL product from entering the desired EoL path. Users' attitudes and behavior with regards to handling of EoL products are therefore included in this research. It is also investigated whether preferences for EoL scenarios and disposal methods differ across users' segments as defined by their current recycling behavior. In this study, only Danish users took part. This study therefore intrinsically describes Danish users and their preferences, although the findings may be applicable in culturally and economically similar countries.

Although most users may hold positive attitudes towards environmentally favorable EoL scenarios, this does not necessarily mean that they are also willing to make any active effort or to pay any possible premium price. To assess this possible gap between attitudes and behavior, users' willingness to pay for environmentally friendly product EoL solutions should therefore also be explicitly evaluated.

1.5. Research aims

Summarizing, the overall aim of this work is to investigate users' preferences for different EoL scenarios using the Kano model. In particular, we aim to:

- understand users' perspective on EoL features of household appliances,
- investigate users' preferences on possible disposal methods of EoL products, and finally
- examine the patterns among the different segments within the participants.

On a methodological level, we demonstrate a recently developed (Atlason et al.,) methodological approach based on the Kano model to investigate user perception to EoL scenarios, which can be applied to other case studies to gain insights for developers, engineers and designers.

2. Methodology

This research adopted a stepwise process which consisted in 1) selecting a representative sample of e-products to elicit users' preferences on, 2) conducting a quantitative Kano survey with e-products users and 3) analyzing the data at both aggregated- and individual segment level. This process is visually depicted in Fig. 2 and described in more details in the following three sections.

2.1. Product selection

In order to increase the robustness and generalizability of the results, a wide range of e-products were considered in this study. To this end, we selected eight most common household products from four different product categories as listed in Annex II of the European Directive on Waste Electrical and Electronic Equipment (European Parliament, 2012). These products represent a significant share of all marketed e-products as well as the EoL items collected under the corresponding categories (Parajuly and Wenzel, 2017; Parajuly et al.,). The case products used in the Kano survey are listed in Table 1.

2.2. User survey

A convenience sample of 146 Danish users took part in the study. They were recruited at a local recycling center over two consecutive days and received a small token as incentive for their participation. Users were informed about the nature of the study and gave verbal consent to participate. Each questionnaire consisted of 40 Kano questions probing users' satisfaction if a feature was present or absent from a target e-product, with the features being the three EoL scenarios and the two disposal method (Table 2). The response options for each questions were 1) *I like it that way*, 2) *It must be that way*, 3) *I am neutral*, 4) *I can live with it that way*, and 5) *I dislike it that way*. These particular response options are proposed by Xu et al., and therefore used in this study (Xu et al., 2009).

To reduce the cognitive burden for the participants, each of them evaluated only four e-products (one per category). The order in which the questions appeared in the ballot was also randomized to improve processing and reduce "satisfying" behavior. After the Kano survey, participants were asked to provide some background demographic information. Their self-evaluated recycling behavior was also recorded to enable further segmentation using the scale developed by Park & Ha (Park and Ha, 2014) consisting of a set of Likert items rated on 7-pt scales and resulting in a composite score ranging from 0 to 10. Finally, users reported on their willingness to pay for a more environmentally friendly electronic product using the scale by Cranfield et al. (2003). The respondents were asked the following question "Suppose you have chosen to buy an electronic product that costs 1000 DKK[1]. Assuming no difference in performance and functionalities, would you pay slightly more for a version of the same electronic product that can be disposed of with a lower impact on the environment?". The possible responses were: a) No, b) Yes, between 10 and 50 DKK more, c) Yes, between 50 and 100 DKK more, d) Yes, between 100 and 200 DKK more, e) Yes, more than 200 DKK more. Detailed information on the participants can be seen in Table 3. (See Table 4)

Table 1
Products and product categories selected for this study.

Product category	Product 1	Product 2
Large household appliances	Refrigerators	Microwave ovens
Small household appliances	Electric coffee makers	Vacuum cleaners
It & telecommunication equipment	Smart phones	Laptop computers
Consumer electronics	Digital cameras	Televisions

Fig. 2. A graphic representation of the study process.

Table 2
Question wording for the Kano survey in both functional and dysfunctional forms.

Product feature	Functional	Dysfunctional
EoL 1 (Reuse)	If your [PRODUCT] can be used again by someone else after you decide to discard it, how do you feel?	If your [PRODUCT] cannot be used again by someone else after you decide to discard it, how do you feel?
EoL 2 (Remanufacture)	If the components of your [PRODUCT] can be built into new ones after you decide to discard it, how do you feel?	If the components of your [PRODUCT] cannot be built into new ones after you decide to discard it, how do you feel?
EoL 3 (Recycle)	If your [PRODUCT] is made in a way that maximizes the amount of materials that can be recycled, how do you feel?	If your [PRODUCT] is made in a way that makes it difficult to recycle the materials, how do you feel?
Disposal method 1	If your [PRODUCT] can disposed of at the nearest store for free and without obligation to buy a new one, how would you feel?	If you need to drive to the nearest recycling center to dispose of your [PRODUCT], how do you feel?
Disposal Method 2	If your [PRODUCT] is going to be collected at your house when you want to dispose of it, how do you feel?	If you need to take care of the disposal of your [PRODUCT] yourself, how do you feel?

Table 3
General description of the participants.

Background variable	*N*
Gender	
Males	65
Females	81
Age	
19–29	91
30–49	30
50+	25
Education	
Primary school	12
High school	3
Short higher education	23
Medium long higher education	54
Long higher education	54
Recycling behavior	
0–4	8
4–6	89
6–10	49

Table 4
The combination matrix used to identify good fits between user segments and functional features.

Segments/FR	$\int_0^1 FR1$	$\int_0^1 FR2$	$\int_0^1 FR3$	…	$\int_0^1 FRn$	$\sum Segment$
Segment 1						
Segment 2						
Segment 3						
…						
Segment *n*						
$\sum FR$						

2.3. Data analysis (Kano modeling)

As customary for Kano survey results, we first classified features (EoL scenarios and disposal methods) based on the mode of answers from the population (Atlason et al., 2016; Clegg et al., 2010; Xu et al., 2009). This was initially done on a product by product level. After doing so, customer satisfaction (*CS*) and dissatisfaction (*DS*) values are calculated according to the formulas proposed in (Clegg et al., 2010). Those values represent, respectively, the user satisfaction when a feature is fully implemented, and dissatisfaction when a feature is completely excluded (*DS*). Attributes are then described based on their classification. Three types of functions were used to model the effect of product features: linear functions for *one-dimensional* features, positively exponential for *attractive features*, and negatively exponential for *must-be* features (Xu et al., 2009). Since the original Kano model lacks the possibility to go beyond aggregated responses, we adopted a stepwise approach that extends the traditional Kano model and allow to systematically analyze and combine multiple segments. The approach works as follows:

1. A traditional Kano analysis was conducted for the different segments following the procedure just outlined (Clegg et al., 2010). After defining user segments according to their background characteristics (Table 3), the results were listed in a table for identifying the features, and the CS and DS values were calculated to create relationship functions;
2. Subsequently, these functions were integrated between $x = 0$ and $x = 1$ and the integrals were inserted into a combination matrix crossing segments and product features;
3. Product features with the highest sum across the chosen segments were identified. In a traditional Kano model, product features resulting in the highest satisfaction would be selected. Our analysis enabled us to also investigate user differences, as well as to identify the user segments that would be most receptive to the different EoL and disposal methods.

3. Results

3.1. User perception of EoL scenarios

Aggregated, raw results from the Kano model regarding EoL scenarios are shown in Table 5. This table shows CS and DS value for each EoL scenario on a product by product basis, with the corresponding equation describing the relationship between the implementation of each feature with user satisfaction (note that the shape of the function depends on the specific feature type). A CS value demonstrates the user satisfaction (on the scale −1 to 1) if the feature is fully implemented, while the DS value demonstrates the user satisfaction (again on the scale −1 to 1) if the feature is fully excluded. There are essentially two ways of interpreting the results. The first way is by looking at a function when $x = 1$. The higher a function is on the *y* axis, the more attractive is the feature to users when fully implemented. Another way to look at the functions is by studying the integrals, where a larger integral means that the feature has a higher potential for user satisfaction when looking at partial implementation of features. Fig. 3 illustrates the resulting functions plotted for each product category. The Figure demonstrates the development of satisfaction among users the more a certain EoL attribute is implemented. When x = 1, the highest possible implementation has been achieved, and the user satisfaction is then demonstrated on the y-axis. The Figure is separated into four quadrants, each representing a product category. A developer would then want to include all must-be requirements (which are none in this case), and then include and try to maximise the combined satisfaction of other attributes taking economic factors into account, i.e. how much will the firm need to spend when including such factors.

Inspecting Table 5 it is noticeable, first of all, that all EoL scenarios were classified as one-dimensional and, especially, attractive features. No EoL scenario was classified as must-be. For all product categories, inspection of CS values in Table 5 revealed that

Table 5
Kano results and classification on a product level.

Customer requirements	CS Point	DS Point	a	b	f(x)	S = af(x)+b
Large household appliances						
One-dimensional						
(2) Recycle, Refrigerator	1, 0.52	0, −0.52	1.03	−0.52	x	$f(x) = 1.03x - 0.52$
(7) Remanufacture, Microwave	1, 0.72	0, −0.49	1.21	−0.49	x	$f(x) = 1.21x - 0.49$
(8) Recycle, Microwave	1, 0.68	0, −0.65	1.33	−0.65	x	$f(x) = 1.33x - 0.65$
Attractive						
(1) Remanufacture, Refrigerator	1, 0.75	0, −0.44	0.69	−1.13	e^x	$f(x) = 0.69e^x - 1.13$
(3) Reuse, Refrigerator	1, 0.77	0, −0.41	0.69	−1.10	e^x	$f(x) = 0.69e^x - 1.10$
(4) Collect at house, Refrigerator	1, 0.79	0, −0.46	0.73	−1.19	e^x	$f(x) = 0.73e^x - 1.19$
(5) Nearest store for free, Refrigerator	1, 0.63	0, −0.37	0.58	−0.95	e^x	$f(x) = 0.58e^x - 0.95$
(6) Reuse, Microwave	1, 0.74	0, −0.44	0.69	−1.13	e^x	$f(x) = 0.69e^x - 1.13$
(9) Collect at house, Microwave	1, 0.77	0, −0.34	0.65	−0.99	e^x	$f(x) = 0.65e^x - 0.99$
(10) Nearest store for free, Microwave	1, 0.71	0, −0.36	0.62	−0.98	e^x	$f(x) = 0.62e^x - 0.98$
Small household appliances						
One-dimensional						
(13) Recycle, Vacuum cleaner	1, 0.72	0, −0.62	1.34	−0.62	x	$f(x) = 1.34x - 0.62$
(18) Recycle, Electric coffee machine	1, 0.60	0, −0.57	1.17	−0.57	x	$f(x) = 1.17x - 0.57$
Attractive						
(11) Reuse, Vacuum cleaner	1, 0.77	0, −0.41	0.69	−1.10	e^x	$f(x) = 0.69e^x - 1.10$
(12) Remanufacture, Vacuum cleaner	1, 0.79	0, −0.37	0.68	−1.05	e^x	$f(x) = 0.68e^x - 1.05$
(14) Collect at house, Vacuum cleaner	1, 0.83	0, −0.38	0.70	−1.08	e^x	$f(x) = 0.7e^x - 1.08$
(15) Nearest store for free, Vacuum cleaner	1, 0.62	0, −0.36	0.57	−0.93	e^x	$f(x) = 0.57e^x - 0.93$
(16) Reuse, Electric coffee machine	1, 0.68	0, −0.35	0.60	−0.95	e^x	$f(x) = 0.6e^x - 0.95$
(17) Remanufacture, Electric coffee machine	1, 0.73	0, −0.46	0.69	−1.15	e^x	$f(x) = 0.69e^x - 1.15$
(19) Collect at house, Electric coffee machine	1, 0.77	0, −0.31	0.63	−0.94	e^x	$f(x) = 0.63e^x - 0.94$
(20) Nearest store for free, Electric coffee machine	1, 0.77	0, −0.34	0.65	−0.99	e^x	$f(x) = 0.65e^x - 0.99$
IT & Telecommunications equipment						
One-dimensional						
(21) Reuse, Laptop	1, 0.71	0, −0.49	1.20	−0.49	x	$f(x) = 1.20x - 0.49$
(23) Recycle, Laptop	1, 0.58	0, −0.58	1.16	−0.58	x	$f(x) = 1.16x - 0.58$
(28) Recycle, Smartphone	1, 0.71	0, −0.59	1.30	−0.59	x	$f(x) = 1.30x - 0.59$
Attractive						
(22) Remanufacture, Laptop	1, 0.66	0, −0.43	0.63	−1.06	e^x	$f(x) = 0.63e^x - 1.06$
(24) Collect at house, Laptop	1, 0.8	0, −0.26	0.62	−0.88	e^x	$f(x) = 0.62e^x - 0.88$
(25) Nearest store for free, Laptop	1, 0.67	0, −0.32	0.58	−0.90	e^x	$f(x) = 0.58e^x - 0.90$
(26) Reuse, Smartphone	1, 0.75	0, −0.34	0.63	−0.97	e^x	$f(x) = 0.63e^x - 0.97$
(27) Remanufacture, Smartphone	1, 0.69	0, −0.39	0.63	−1.02	e^x	$f(x) = 0.63e^x - 1.02$
(29) Collect at house, Smartphone	1, 0.71	0, −0.41	0.65	−1.06	e^x	$f(x) = 0.65e^x - 1.06$
(30) Nearest store for free, Smartphone	1, 0.68	0, −0.27	0.55	−0.82	e^x	$f(x) = 0.55e^x - 0.82$
Consumer electronics						
One-dimensional						
(33) Recycle, Digital camera	1, 0.59	0, −0.62	1.21	−0.62	x	$f(x) = 1.21x - 0.62$
(37) Remanufacture, Television	1, 0.72	0, −0.46	1.18	−0.46	x	$f(x) = 1.18x - 0.46$
(38) Recycle, Television	1, 0.67	0, −0.55	1.22	−0.55	x	$f(x) = 1.22x - 0.55$
Attractive						
(31) Reuse, Digital camera	1, 0.7	0, −0.34	0.61	−0.95	e^x	$f(x) = 0.61e^x - 0.95$
(32) Remanufacture, Digital camera	1, 0.67	0, −0.46	0.66	−1.12	e^x	$f(x) = 0.66e^x - 1.12$
(34) Collect at house, Digital camera	1, 0.66	0, −0.35	0.59	−0.94	e^x	$f(x) = 0.59e^x - 0.94$
(35) Nearest store for free, Digital camera	1, 0.63	0, −0.22	0.49	−0.71	e^x	$f(x) = 0.49e^x - 0.71$
(36) Reuse, Television	1, 0.71	0, −0.39	0.64	−1.03	e^x	$f(x) = 0.64e^x - 1.03$
(39) Collect at house, Television	1, 0.74	0, −0.36	0.64	−1.00	e^x	$f(x) = 0.64e^x - 1.00$
(40) Nearest store for free, Television	1, 0.72	0, −0.42	0.66	−1.08	e^x	$f(x) = 0.66e^x - 1.08$

maximization of reuse potential was regarded as the most attractive feature in general, while recyclability was the least favored option. This difference is more evident in Table 6 where one can see that sum for integrals among all segments are generally highest for the reuse scenario, but lowest for the recycling scenario. Recycling potential for large appliances was in fact poorly regarded by users, where multiple integrals are negative for most segments in Table 6.

In terms of absolute CS and DS values, Table 5 did not suggest major differences between the three EoL scenarios at an overall level. The values were also relatively similar across the different product and product categories. Nevertheless, when considering the analysis at the level of specific user segments, some differences emerged more clearly. This analysis is shown in Table 5. This table shows the integral values from the equations shown in Table 5 (i.e., the area under the curve between $x = 0$ and $x = 1$), the highest scores of segments and highest scores of the product features were calculated. The sums for the segments are shown in the rightmost column, whereas the sums for the features are shown in the bottom row.

Table 6 results indicate that women, in particular, seem to favor products that are designed with their EoL management in mind, much more so than men as the difference in the sum of integral values indicated (0.54 vs 0.85 for men and women respectively). Users with short and medium-long higher education also would be highly interested in products designed with EoL scenarios in mind. Finally, the data also revealed that people in the age group of 30–49 are the user segment which regard EoL scenarios the highest (Table 6). With regards to the contribution of EoL scenarios to user satisfaction, the analysis again confirmed that maximization of reuse potential was regarded the most attractive feature for all product categories. The least favorable feature, maximization of recycling potential, scored significantly lower than the other

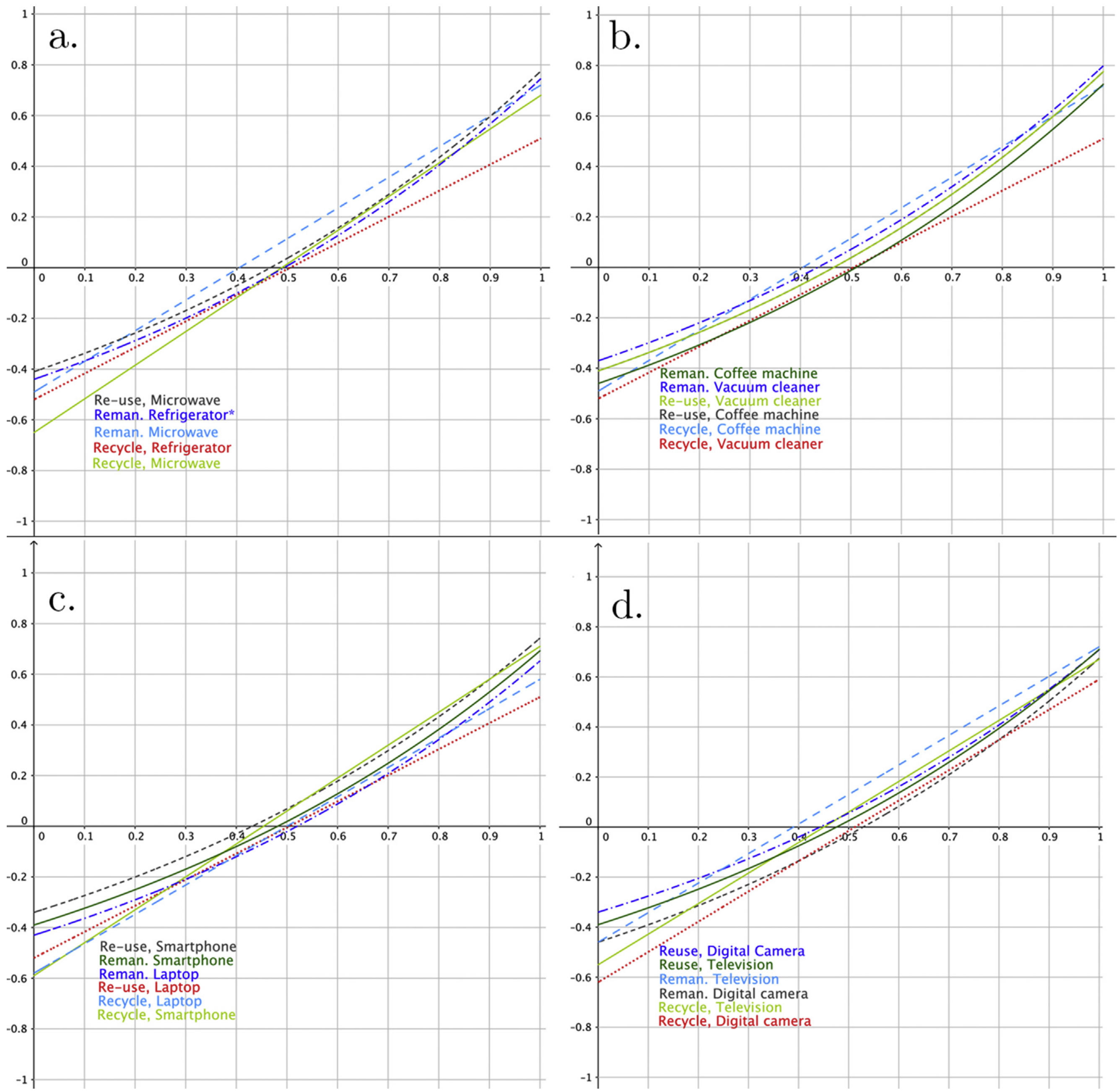

Fig. 3. Plotted functions from each product category; a) large appliances, b) small appliances, c) IT & Telecommunications equipment and d) consumer electronics. In each plot, the x-axis represents implementation of functional requirements (Design for EoL in this case) while the y-axis represent user satisfaction. *Reuse of microwaves has the same function.

features and therefore seems to be the least regarded by users. Some deviations for specific product categories and segments were also observed in Table 5. For example, in the case of IT & Telecommunications equipment and males, it can be seen that the highest user satisfaction would be obtained when the remanufacture potential is maximized. This is just to illustrate that individual segments may have different preferences regarding the EoL scenarios even though the reuse potential was generally favored, followed by remanufacture and recycling potential. Product developers can use the information provided in Table 6 to identify the right DfEoL strategies based on the preferences of a specific target segment. They should however be aware of that when segmenting the Kano results as is done in Table 6, each segment consists of fewer respondents which also makes the results for each segment less robust unless a rather large cohort of respondents is included in the study.

3.2. Disposal methods

Table 5 shows results concerning user preferences for disposal preferences for all products, whereas Table 7 contains segment-specific results. With regards to disposal methods, the results overall indicate that users prefer the option of large and small appliances along with IT & telecommunications equipments being collected at their residence. For consumer electronics, not much difference was found between collection methods (Table 7).

Again, differences between individual user segments were observed. For example, users with university education (of any

Table 6
Results from integration for all functional features among all segments between $x = 0$ and $x = 1$.

	Maximise reuse potential				Maximise remanufacture potential				Maximise recycling potential				Σ
	Consumer electronics	IT & Telecomm. equipm.	Large appliances	Small appliances	Consumer electronics	IT & Telecomm. equipm.	Large appliances	Small appliances	Consumer electronics	IT & Telecomm. equipm.	Large appliances	Small appliances	
Gender, Female	0.11	0.06	0.09	0.14	0.08	0.05	0.07	0.06	0.06	0.04	0.02	0.07	0.85
Gender, Male	0.04	0.01	0.14	0.09	0.06	0.12	0.1	0.05	−0.03	0.02	−0.04	−0.02	0.54
High sch. and lower ed. level	0.05	0.02	0.12	0.09	0	0.05	−0.02	0.06	−0.07	0.14	−0.04	0	0.40
Short higher education	0.17	0.07	0.17	0.11	0.08	0.09	0.1	0.15	0.11	0.05	0.08	0.09	1.27
Medium long higher education	0.05	0.12	0.16	0.1	0.09	0.08	0.06	0.11	0.02	0.06	−0.03	0.05	0.87
Long higher education	0.07	0.12	0.05	0.05	0.07	0.08	0.1	0	−0.04	−0.02	−0.06	−0.04	0.38
Age 19–29	0.11	0.06	0.05	0.08	0.02	0.05	0.1	0.09	0.03	0.017	−0.01	0.04	0.64
Age 30–49	0.05	0.11	0.17	0.16	0.1	0.12	0.15	0.14	0.05	0.08	−0.02	0	1.11
Age 50+	0.07	0.06	0.14	0.09	0.11	0.1	0.09	0.05	−0.02	0.05	0.04	0.04	0.82
Recycling behavior, u4,9	0.1	0.14	0.11	0.07	0.06	0.07	0.08	0.14	0.13	0	0.08	0.05	1.03
Recycling behavior, 4,9–5,9	0.09	0.13	0.08	0.08	0.07	0.09	0.16	0.1	0.12	0.08	−0.03	0.05	1.02
Recycling behavior, 5,9+	0.13	0.13	0.05	0.08	0.09	0.1	0.1	0.12	−0.07	−0.03	−0.06	−0.04	0.60
Σ	1.04	1.03	1.33	1.14	0.83	1.00	1.09	1.07	0.29	0.49	−0.07	0.29	

type) prefer to bring consumer electronics to the store for drop-off compared to users with lower education levels (Table 7). As in the case of EoL scenarios, the results show the need for designers and policy makers to consider individual users segments when evaluating different disposal methods. Females are again expected to regard these disposal methods more than men, but only marginally. The segment with the highest appreciation for the suggested disposal methods are people with long higher education, in the age groups 19–29 and 30–49. Information about disposal method preferences can be used in practice by firms accommodating recent EU regulations for collection of electronic waste, where collection methods can be based on customer base and type of appliances sold. Table 7 demonstrates the integrals for different segments towards appliance type and disposal method and can be used to look up potential user appreciation of disposal method with regard to different types of appliances.

3.3. Willingness to pay

Willingness to pay for e-products with more environmentally friendly EoL scenarios gave mixed results. In total, 20% of the users reported that they would willing to pay 10–50 DKK (for an hypothetical e-product costing 1000 DKK), 27% would pay pay between 50 and 100 DKK, 22% would pay between 100 and 200, 7% would pay more than 200 DKK. Only 23% of the users reported that would not pay anything extra for a more environmentally friendly product.

When looking at the results by key demographics, some interesting patterns emerged. Both gender and age significantly affected the frequency of willingness to pay responses (Gender: $\chi^2_{(4)} = 12.9; p = 0.011$; Age: $\chi^2_{(8)} = 39.2; p < 0.001$). With respect to gender, consistently with the indications of the Kano results, females were more prone than males to pay a premium price for the environmental advantage (Fig. 4). Both genders had similar willingness to pay results for the lowest premium prices (up to 100 DKK), but females were also much more willing to pay between 100 and 200 DKK (29% females and 13% males, $p = 0.002$, *two −tailed*). In addition, almost 30% of men did not want to pay extra for environmentally friendly products, whereas less than 20% of female users checked that option (Fig. 4).

With respect to age, the segment 30–49 old was the most willing to pay extra for environmentally friendly e-products. Users older than 50 were also more likely to be willing to pay between 100 and 200 DKK. Amongst users aged between 19 and 29, 31% were found to be willing to pay between 50 and 100 DKK (Fig. 5).

4. Discussion

The overall aim of this work was to investigate users' preferences for different EoL scenarios and disposal methods across a wide range of electrical and electronic household appliances.

Our results revealed that the majority of EoL scenarios were actually regarded as *attractive* features in the Kano (Kano et al.,) framework, suggesting that users do not currently hold strong expectations regarding the EoL of their e-products, but would be very satisfied with a product that has a more favorable EoL scenarios.

Among the three EoL options surveyed, maximization of reuse potential was regarded as the most attractive among the participants of this study. Interestingly, this finding is at odds with to the general consumption trends as well as the 'linear' industrial model that does not prioritizes reuse. On the contrary, it suggests that first users' preferences are largely aligned with the concept of circular economy, and it is therefore a welcome finding for all environmentally concerned stakeholders. Our study did however not

Table 7
Disposal preferences of users. Kano results are viewed as integrals as demonstrated in Table 6.

	Consumer electronics		IT & Telecomm. Equip.		Small appliances		Large appliances		Σ
	Collect at house	Nearest store for free	Collect at house	Nearest store for free	Collect at house	Nearest store for free	Collect at house	Nearest store for free	
Gender, Female	0.01	0.1	0.1	0.12	0.1	0.1	0.1	0.03	0.66
Gender, Male	0.07	−0.08	0.12	0.01	0.16	0.1	0.1	0.09	0.57
High sch. and lower ed.	0.02	−0.01	0.07	0	0.02	0.02	0.07	0	0.19
Short higher education	0.1	0.13	0.14	0.07	0.16	0.1	0.1	0.05	0.85
Medium long higher education	0.05	0.07	0.09	0.1	0.12	0.07	0.08	0.04	0.62
Long higher education	0.12	0.12	0.13	0.15	0.17	0.14	0.1	0.13	1.06
Age 19–29	0.09	0.12	0.12	0.13	0.16	0.12	0.12	0.08	0.94
Age 30–49	0.14	0.16	0.18	0.13	0.15	0.13	0.09	0.07	1.05
Age 50+	0.09	0.05	0.1	0.08	0.13	0.07	0.13	0.1	0.75
Recycling behavior, u4,9	0.1	0.13	0.11	0.05	0.1	0.1	0.04	0.07	0.7
Recycling behavior, 4,9 –5,9	0.02	0.07	0.1	0.1	0.13	0.08	0.07	0.04	0.61
Recycling behavior, 5,9+	0.13	0.1	0.14	0.13	0.15	0.11	0.15	0.09	1
Σ	0.94	0.96	1.4	1.07	1.55	1.14	1.15	0.79	

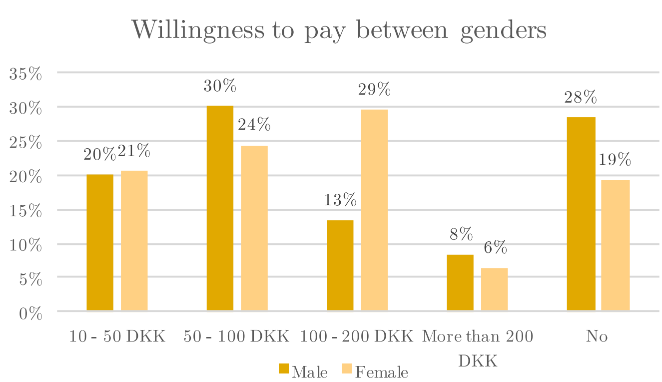

Fig. 4. Users' willingness to pay a premium for an environmentally friendly product: breakdown by gender.

include the second user perception of EoL scenarios. This means that even though a first user may find reusability an attractive feature of a product, the second user may not necessarily find such reused product attractive. This alignment between EoL from the first user perspective, and eventual acceptance by second users has been suggested in previous literature. As for smartphones, if properly treated with battery upgrades and software updates, second users are likely to accept them to some extent, creating a continuous flow between first and second user (Mugge et al., 2017; van Weelden et al., 2016). It is therefore important for future research to further investigate second users' perspective. Another

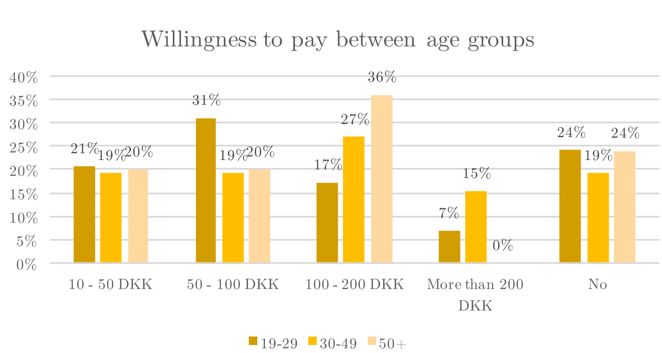

Fig. 5. Users' willingness to pay a premium for an environmentally friendly product: breakdown by age.

important issue is the mobility between user segments during ownership of products. A user purchasing electronics that have a relatively long lifetime, such as a refrigerator, are likely to move between segments in the time they possess the item. This needs to be taken into account when the product is designed, as preferences between segments are different. One way designers can account for this, is to estimate to which segment the user will belong to at the end of the products lifetime, rather than at its beginning. This may however not hold true for electronics with shorter lifetime, such as smart phones where the user is less likely to move between segments during the products lifetime.

Although all users generally showed a positive attitude towards the EoL scenarios, the Kano analysis expanded to individual user segments revealed that some differences in how the different options were weighted. In the light of previous literature with regards to refurbished mobile phones, it is interesting to note that for IT & telecommunications, the reuse of smartphones was regarded as an attractive attribute with the highest CS value of all possible devices and EoL scenarios within that category (Mugge et al., 2017). Females were in most cases found to favor all EoL scenarios more than men, and were also more willing to pay a premium price for environmentally friendly e-products. Taken collectively, these results indicate that products targeted towards females are more likely to enter favorable EoL scenarios. Our findings regarding gender differences are somewhat inconsistent with previous research reporting that men follow recycling science more closely than women, and are therefore more up to date (see e.g., (Miller and Buys, 2008)). A possible explanation for this difference in attitude towards EoL treatment between genders is that previous results were specific to the product categories investigated (smartphones in (Mugge et al., 2017) and with regards to water recycling in (Miller and Buys, 2008)). The underlying factors driving this gender difference should be further studied in a larger (sample-wise) study, and possibly including a larger geographical area.

The effect of gender on attitudes towards environmental impact and energy use has been studied to some extent (Clancy et al., 2004). It is therefore surprising that most previous studies looking at user perception of environmental impacts of products, or packaging have not focused on gender in some way. Our results suggest that gender may be an important basis for user segmentation in the context of product development for e-products. Gender preferences towards EoL scenarios may also have implication to product design and marketing. It may improve the likelihood of products to enter favorable EoL stream if marketed towards the gender that favors EoL treatment more. Such results can be extracted from the results in the paper. In fact, Tables 5–7 tell several stories about which EoL scenarios are favored by different segments. The tables can therefore be used by product developers when looking at which EoL scenario would be more likely to be adopted by different user groups.

Also, as products are generally not designed for a single country market, but rather regions, this study may have limited application in regions that differ culturally and economically from Denmark. The method of analysis can however be applied within various regions in order to design products according to user preferences within a given region. Therefore, even though the results may perhaps not apply to certain regions (developing countries for example), the method of analysis can be used within such regions.

It should be noted that the Kano method adopted in this study does not in and of itself provide an explanation of why specific user groups evaluated EoL scenarios differently. Further research is advised to elucidate why, for example, females appreciated EoL scenarios to a higher extent than males. This could include, among others, in-depth interviews with a smaller subset of each individual segments to get a deeper understanding of the underlying reasons, which should prove useful for any initiative targeted to change their behavior. It should also be noted that, given the topic investigated, social desirability bias in users' responses could have been an issue. This seems likely in particular for the willingness to pay results, for which only 23% of the users reported *not* to be willing to pay a premium for more environmentally friendly e-products. This result appears to be too good to be true and therefore future studies including actual marketplace behavior are advised to ascertain the possible gap between stated intentions and actual willingness to pay. Finally, future investigations are also advised to confirm the generalizability of the findings by replicating this study in different geographical locations, as Danish users may perceive EoL scenarios differently than in countries with different cultural backgrounds and socio-economic conditions. Also, as this study took place in Denmark, institutional settings may differ from other regions or countries. For instance, Denmark is a part of the European Union, and follows European regulations. In other regions, where institutional settings may differ, EoL treatment of electronics may be have less (or more) emphasis among regulatory bodies, potentially leading to different preferences among users. Economic factors may also affect user preferences, where rich users may be more willing to pay a premium for a new product, where in poorer countries, this willingness to pay is less. Also, in richer countries, users may be more willing to pay a premium for an environmentally friendly product, while again in poorer countries this will not be considered. However, as we did not attempt in this work to conduct a causal analysis looking into which factors drive the willingness to pay per se, the issue may be addressed in future research.

The Kano model is sensitive to the way functional requirements are classified. The classification system used is based on a classification table for each combination of questions. Also, a functional requirement is classified based on the mode of classified combination of answers. In short, one can argue that the method of classifying functional requirements (as attractive, must-be and so on) is one of the method's biggest shortcoming. This has however been addressed by various researchers (MacDonald et al., 2006). Our study follows the classification system provided by Clegg et al. and Xu et al., (Clegg et al., 2010; Xu et al., 2009).

Although we covered the three preferred EoL options (reuse, remanufacturing and recycling) considering a classic product-sales type business as a reference, it would be of interest to extend this line of research into how product-service systems are perceived by the users. Product-service systems provide a platform that has been found to increase the probability of products entering favorable EoL scenarios (Lindahl et al., 2014). Therefore, we recommend future research to address the user acceptance of product-service systems (at least for some of the product categories considered in this research) and investigate how EoL scenarios are regarded to the providers of product service systems.

In addition to studying EoL scenarios, this study also addressed users' perceptions of disposal methods. This aspect was found to be of relevance because of recent regulations with regards to retailers' obligation to collect EoL appliances. In that case, we demonstrate which disposal methods are most favored by different segments. Taken collectively, our findings indicate that users highly favor the option of appliances being collected at their residence, with some differences between the four product categories. The information provided in this paper may assist retailers to use the recent regulations in their favor, for example by emphasizing a regulated feature as an attractive one. This study does, however, not include analysis of alternative behavior because these possible disposal methods, how users would react if disposal will come with economic burden or if the collection would be conducted using any alternative method. Alternatively designed regulations for collection may, and is potentially likely to have, an effect on the user behavior and should be studied carefully.

5. Conclusion

This research has investigated users' perception on EoL scenarios of household appliances and different methods for disposal of products. To this end, a quantitative Kano analysis was used where 146 users were surveyed. Findings show that people with medium to long higher education and older than 50 years old seem to favor the integration of EoL in product design. Females were found to favor EoL scenarios more. Our results can be used by product developers to integrate relevant EoL scenario within the development process. Including a relevant EoL scenario into the product design depending on which segment is targeted by developers should increase the likelihood of products entering favorable EoL stream.

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