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Design of resilient consumer products

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Abstract: Consumer product sustainability is a topic that has been of increasing interest to practice and academia in recent decades. In this context, a widely discussed means of achieving sustainability is to design more durable products, thereby reducing the need for the production of new products. In particular, the emotional perspective on product durability has received attention in recent design literature, since consumer products are often replaced long before they become physically non-functioning. However, the literature does not provide a full account of the causes of product replacement or of the means for making products more durable. This paper addresses these issues by defining the concept of 'resilient product design', providing a detailed classification of causes of product replacement, and organising means to extend product longevity. Hereby, the paper provides a more structured basis for designers to design resilient consumer products and for researchers to engage in further studies.

Keywords: product resilience; emotional durability; sustainability; consumer product design

1. Introduction

Given the increasing awareness of the environmental problems we face, sustainability has become a much-debated topic in both practice and academia. One of the means of sustainability that is often mentioned is making products more durable, thereby minimising the need for new products. Since consumer products are often replaced long before they become physically non-functioning, the emotional durability aspect in particular has received increased attention in recent design literature (Cooper, 2004; van Nes and Cramer, 2005; Mugge et al. 2005; Chapman, 2009; Fletcher, 2012). The literature includes several explanations of why well-functioning consumer products are replaced as well as a range of design strategies to increase product longevity. There are, however, still no exhaustive answers to these questions (van Nes and Cramer, 2005; Chapman, 2009).



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In relation to the discussion above, this paper argues that there is a need for more complete descriptions of the causes of product replacement and the means of increasing product longevity. This is reflected in existing classifications, which, although they provide good understandings of what the phenomenon concerns, may not have sufficient structure and detail if designers are to grasp the full range of potential issues when they attempt to design more durable consumer products — and from a research perspective, there is a need for a clear understanding of the problem at hand in order to be able to address it efficiently. This paper does not claim to provide the final answer to these issues, but by employing a somewhat different approach to the topic, as compared to the existing literature, the paper sheds new light on the issue. More specifically, the paper addresses two overall questions:

1. What are the causes for consumer product replacement?
2. What are the design strategies for increasing consumer product longevity?

The two questions are addressed through discussions of the existing literature, on which basis the paper defines the concept of ‘resilient product design’, clarifies its dimensions, and organises strategies for designing resilient consumer products.

The paper focuses on durable ‘consumer products’, i.e., tangible products sold for non-business purposes, excluding convenience goods. This focus was chosen to limit the extent of the topic. However, the paper’s contributions may also be relevant for many types of business products, in particular the ones most likely to be replaced while still being physically functioning.

2. Literature review

To understand consumer product durability, a basic distinction may be employed between absolute and relative obsolescence (Granberg as cited in Cooper, 2004). Discussing absolute obsolescence, Granberg (as cited in Cooper, 2004) describes intrinsic durability as referring to 1) the ability to withstand ‘wear and tear’ and material degradation; 2) process quality (i.e., product consistency in manufacturing); and 3) factors relating to maintenance (i.e., ease of repair, availability of parts). This kind of durability is therefore, to a large extent, a topic related to engineering research. On the other hand, from an industrial and fashion design perspective, relative product obsolescence (i.e., factors other than physical functioning) is often particularly interesting. The literature contains several classifications of causes of product replacement within these two dimensions. A selection of these is shown in Table 1, where it should be noted that all the identified causes do not apply to all kinds of products.

Table 1 Identified classifications for causes of product replacement.

Source	Dimensions
Bayus (1991, p. 43)	1) Style; 2) Features and technological advantages; 3) Price and sales promotions; 4) Changed family circumstances; 5) Improved financial situation
Mowen (1995)	1) Technical condition; 2) Style; 3) Price and sales promotions; 4) Previous

	decision; 5) Changed circumstances and aspirations; 6) Changes in financial situation; 7) Aging; 8) Physical or psychological changes
Heiskanen (1996)	1) Failure; 2) Dissatisfaction; 3) Change in consumer needs
Creusen (1998)	1) Practical function; 2) Ergonomic function; 3) Hedonic function; 4) Symbolic function.
Van Nes et al. (1999)	1) Technical obsolescence; 2) Economic obsolescence; 3) Ecological obsolescence; 4) Aesthetic obsolescence; 5) Feature obsolescence; 6) Psychological obsolescence
Cooper (2004)	1) Absolute obsolescence; 2) Relative obsolescence: 2a) Psychological obsolescence; 2b) Economic obsolescence; 2c) Technological obsolescence
Van Nes and Cramer (2005)	1) Wear and tear; 2) Improved utility; 3) Improved expression; 4) New desires
Mugge et al., 2005	1) Performance decrease (function and appearance); 2) Technological obsolescence; 3) Legislation change; 4) New features/technology; 5) Fashion; 6) Family/financial circumstances
Burns (2010, p. 45)	1) Aesthetic; 2) Social; 3) Technological; 4) Economic

It should be noted that it is not always desirable for products to have as long a lifetime as possible. To underline this point, some literature uses the term ‘lifetime optimisation’ instead of terms such as ‘lifetime extension’ (Charter and Tischner, 2001). More specifically, there are situations in which extended lifetime does not imply an environmental improvement — for example, if a new product is significantly more energy-efficient than an existing one. It should also be noted that some would argue that longer product lifespans could have a negative impact on economic development (van Nes and Cramer, 2005). For most products, however, lifetime extension is desirable from an environmental point of view (van Nes and Cramer, 2005), which is the focus of this paper.

Several streams of literature related to strategies for increasing product longevity exist. Such literature is, however, scattered across different areas of research (i.e., engineering design, industrial design, fashion design, and marketing). The literature review conducted for this paper identified five streams of research involving strategies for enabling increased product longevity (others may exist):

1. Adaptation focus
2. Timelessness focus
3. Exclusivity focus
4. Emotional focus
5. Design process focus

The adaptation approach concerns providing consumers with possibilities for maintaining, altering, and repairing products to extend product lifetime. In this vein, van Nes et al. (1999) defined five approaches related to the physical adaptability of products: reparability; element replacement for economic benefits; element replacement for ecological benefits; element replacement for aesthetic benefits; and adding new features through modules. In a

similar manner, van Nes and Cramer (2005) identified five design strategies for improving product longevity, of which four have a product adaptability focus: design for reliability and robustness; design for repair and maintenance; design for upgradability; design for product attachment (personalisation); and design for variability (reconfiguration). Focusing on electronic products, Walker (2011) defined five means of promoting longer product lifetime, four of which have an adaptation focus: continuous product evolution; accommodation of component change; local maintenance, repair, and upgrade; and internalising impacts through new enterprise models (e.g., by including repair and upgrade services). Another type of focus in relation to the adaptation approach is offering complementary products to ensure a constant level of functionality for the core product (e.g., razor blades) (Claussen et al., 2015). More specifically, in the case of a razor, as compared to disposable razors, the handle of a removable-blade razor is to be reused with new blades, as opposed to being disposed when the blade stops being useful. This approach is often used as a means of making a profit by demanding relatively high prices for complementary products of which the producer is the only supplier (Claussen et al., 2015). However, offering complementary products for products where certain parts are subjected to more stress than others can also be used as a means of extending product longevity to achieve environmental benefits.

The timelessness approach is about making designs that are resistant to changes in consumer taste and preferences. In this context, the studies by Mugge et al. (2006) suggest that an emotional bond to a product does not necessarily result in a long-lasting relationship with the product, which they explain as being related to fashion trends that may be short or long-lived and thus cause consumers to be attached to products for shorter or longer periods of time. Another type of explanation for certain products being more timeless was provided by Aaker (1999) and Govers and Schoormans (2005) who, with a basis in the theory of self-congruity, found that consumers prefer products and brands with personality characteristics that are congruent to their own, since these products can help to maintain and express their identity. Because people strive to maintain a positive view of the self, an old-fashioned product is typically less valuable for maintaining a person's self, and therefore, the product attachment will decrease. One of the approaches towards more timeless designs involves diverting attention away from the moment of product realisation or purchase, but instead trace the usage of products with references to 'product careers' and wider cultural consumption trends (van Hinte, 2004; Cooper, 2005). Another timelessness approach is to focus more on biological factors that produce an aesthetic experience (e.g., Hekkert, 2006; Norman, 2004). It could be hypothesised that drawing on inherent tendencies to find objects beautiful would make products more resistant to changing fashions, as compared to products whose perceived beauty is a more cultural phenomenon.

The exclusivity approach is about making products appear as scarce resources and thereby making consumers treasure them more (Brown 2001). One way of doing this is through limited editions, which many brands are currently introducing as part of their product lines (e.g., pianos, cars, and fashion goods) (Balachander and Stock, 2009). The scarcity of such products also implies that getting a similar object could be extremely difficult, for which

reason the owners take better care of the products and hold on to them for longer. Another exclusivity approach is to design luxury products. Such products typically have a higher quality and higher prices than non-luxury products of the same type. Also, luxury products are generally more closely associated with style than with fads, and many of them never go completely out of fashion (e.g., watches, jewellery, furniture, bags, certain cars, etc.) (Wolny and Hansen, 2011). Thus, luxury products are often kept for longer, and when replaced, they are often sold to other consumers rather than being discarded. Therefore, affecting consumer behaviour towards purchasing fewer products but ones that are more expensive and of higher quality could have a positive environmental effect.

The emotional approach is about designing products that produce an emotional attachment. Emotional attachment implies that the owner is more likely to handle the product with care, to repair it when it breaks down, and to postpone its replacement (Belk 1991). In the context of emotionally durable design, Chapman's (2005) ideas have received much attention. Based on a survey of product relationships of over 2,000 users of domestic electronic products, Chapman (2009, p. 33) distilled a six-point experiential framework to provide product designers with a pathway for designing more emotionally durable products. The six points are narrative, detachment, surface, attachment, fiction, and consciousness.

The design process approach involves having a strong user focus in the design processes. This may involve giving extensive attention to user needs, wants, and limitations at each stage of the design process in order to design products that fit users better and, thus, are more likely to create emotional attachment — i.e., 'user-centred design' (or 'human-centred design') (Sanders, 1998). Another possibility is to involve users in the design process, which, besides implying more personalised products, may also promote attachment to the product, because the user has been involved of the design process. Terms used to describe such approaches include 'participatory design', 'co-creation', and 'co-design' (Sanders and Stappers, 2008).

It should be noted that outside a product design perspective, the issue of product lifetime extension has also been addressed from a government perspective in the form of demands or incentives aimed at product manufacturers. In this context, the UK government's environment department, Defra (Department for Environment, Food & Rural Affairs), commissioned ERM (Environmental Resources Management) to conduct a major study of product lifetimes (ERM, 2011). The report from this study mentions 13 possible initiatives in the form of business-led voluntary measures and government-led voluntary and mandatory initiatives.

As mentioned in the Introduction, the identified classifications of causes of product replacement may have some limitations if they are to be applied as analytical tools for designers to increase product longevity, or if they are to provide a clear basis for future research. First, the identified classifications include factors related to appearance, function, and/or communication dimensions. The lack of clarity about which of these dimensions the factors refer to may cause confusion. For example, in some of the identified classifications,

‘aesthetics’ is seemingly used to refer exclusively to the product’s appearance, although use processes and marketing messages may also carry important aesthetic qualities. Second, the classifications may be too general to be applied as analytical tools for designers. In other words, using a more detailed list of dimensions as a basis for analysis could make the task easier, more efficient and help to avoid neglecting important aspects. As discussed above, since the possible means of increasing product longevity focus on different aspects, there is a need for further organisation in order to provide a more complete picture. These issues are therefore the focus of the remainder of this paper.

3. A framework of product design resilience

The term ‘resilience’ refers to the quality of “being able to recover quickly or easily from, or resist being affected by, a misfortune, shock, illness, etc.; robustness; adaptability” (OED, 2015). Thus, as compared to the term ‘durability’, ‘resilience’ has stronger connotations to a capacity for ‘recovering’ or ‘adapting’, as opposed to being mainly associated with ‘robustness’. In relation to product longevity, this double meaning is particularly relevant. For example, when a piece of furniture develops appreciated patina because its environment affects it, this is a quality of ‘adaptability’ rather than an ability to withstand use and decay. Another example is an old T-shirt for sale in an exclusive second-hand store. In many cases, the T-shirt will have been out of fashion for years, but it now re-emerges as another type of product, i.e., ‘a fashionable second-hand T-shirt’. Another example is vinyl records, which for many years were a rare encounter, but which have received renewed interest in recent years (Stanley, 2015). In relation to furniture and graphic design, today, more than ever, the mid-century modern look (roughly 1933 to 1965) has re-emerged (Fenton, 2015). Most of the furniture designs from the mid-century had gone out of fashion by the late 1960s, but in the 1980s, interest in the period began to return, and by the mid-1990s, a niche collectors’ market had already driven up prices of the original mid-century designs (Fenton, 2015). In this manner, product designs can go out of fashion and later re-emerge with new cultural meanings. Thus, when focusing on product designs with a long lifetime, the key consideration is not just how long the product can last before becoming physically dysfunctional or losing its emotional appeal but also its ability to adapt its physical characteristics and social meaning. Based on these arguments, the term ‘resilience’ is applied in this paper.

The resilience of a product may be defined as involving two overall dimensions:

1. Intrinsic resilience: resilience against product-devaluing product changes (certain decay, defects, etc.)
2. Extrinsic resilience: resilience against product-devaluing environmental changes (fashion trends, new technologies, etc.)

As mentioned earlier, in the identified classifications in the literature, the causes of product replacement refer to three product dimensions: appearance, function, and communication (e.g., marketing messages). By combining these three dimensions with the distinction

between intrinsic and extrinsic resilience, the model in Figure 1 is constructed as a frame of reference for the subsequent discussions. In the figure, it should be noted that symbolic meanings could emerge from all three design dimensions: appearance, functionality, and communication.

		Design dimension		
		Appearance	Functionality	Communication
Resilience dimension	Intrinsic product resilience	Intrinsic appearance resilience	Intrinsic functionality resilience	Intrinsic communication resilience
	Extrinsic product resilience	Extrinsic appearance resilience	Extrinsic functionality resilience	Extrinsic communication resilience

Figure 1 Product design resilience

3.1 Intrinsic product resilience

As mentioned previously, intrinsic product resilience refers to how well a product holds up physically to use and other sources of decay. In relation to intrinsic product resilience, a set of states and processes can be described, as done in Figure 2. The premise of Figure 2 is that once a product is put into use there is an initial period during which the product seems ‘as good as new’. How long this phase lasts, obviously, depends on the product type and how it is treated. After this initial phase, there is a decay phase, during which a decrease in quality occurs, as compared to the original level. However, as shown in the top-left model in Figure 2, in some cases the decay phase actually produces an increased level of perceived quality for a period of time. For example, a leather sofa may develop appreciated patina, and a pair of jeans may become more comfortable with use. The top-right model in Figure 2 illustrates how product maintenance may both increase the duration of the ‘non-decay phase’ and decrease the intensity of decay in the ‘decay phase’. For example, maintaining a coffee machine or a car properly may postpone the onset of decay. The middle-left model in Figure 2 illustrates how the ability to replace product elements may restore product quality. For example, replacing a battery in a laptop or replacing a chair seat cover can restore the level of quality. The middle-right model in Figure 2 illustrates how a product upgrade may raise quality beyond the original level. This includes, for example, a laptop that has additional memory inserted or a rack system that has additional modules added. The bottom-left model in Figure 2 illustrates how repairs can restore the quality of a defective or damaged product. For example, if the recharge function of a smartphone stops working it may be repaired, and a tabletop that has become too scratched, in the owner’s opinion, can be repainted. The bottom-right model in Figure 2 illustrates how reconfiguring a product can

restore its quality. For example, a children’s chair may be height-adjustable, and a laptop may allow for the adjustment of various settings.

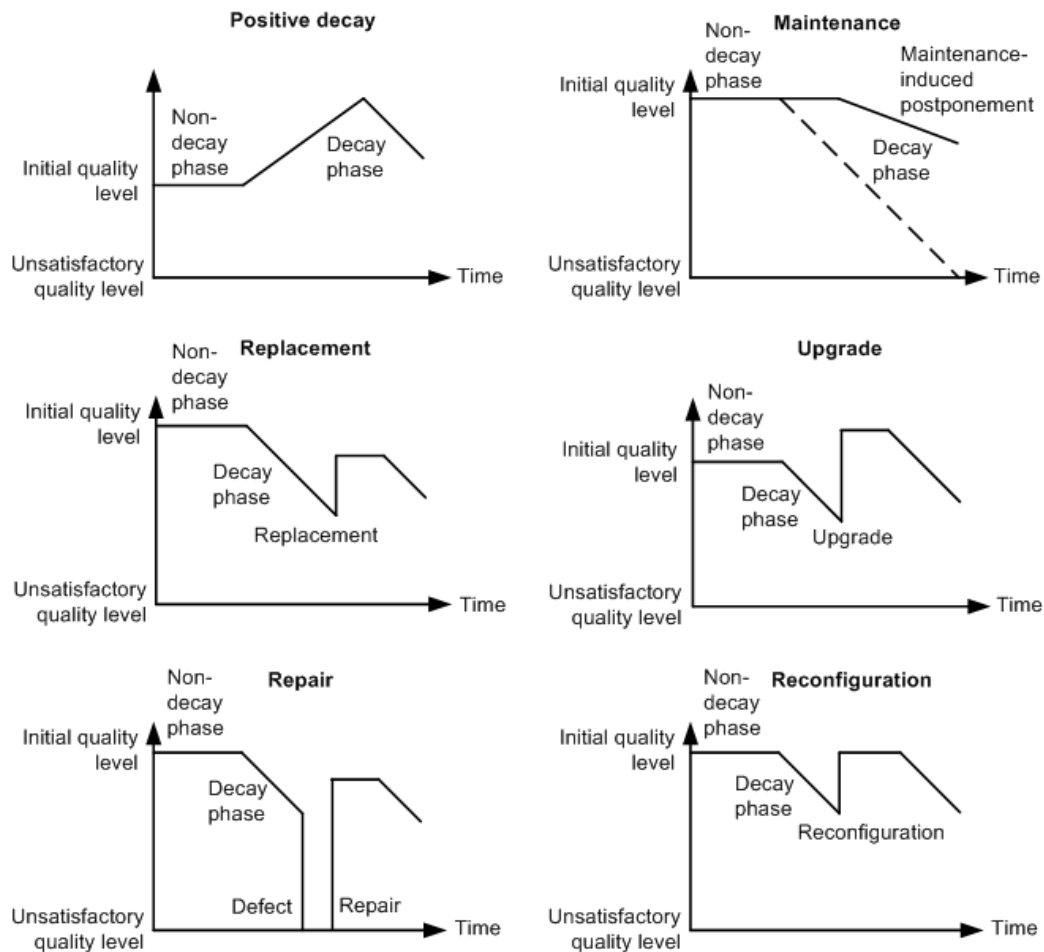


Figure 2 Intrinsic product resilience

To summarise the discussion above, the sum of the durations of three phases determines the total duration of a product’s lifetime with a satisfactory quality:

- Non-decay phase: i.e., time until the onset of noticeable decay
- Negative decay phase: i.e., from the onset of decay to an unacceptable level of decay
- Positive decay phase: i.e., period of positive decay (if any)

Five types of lifetime extension measures may extend these three phases:

- Maintenance
- Replacement
- Upgrade
- Repair
- Reconfiguration

In relation to the five types of lifetime-increasing actions, they obviously need to be sufficiently attractive for consumers to employ in order to be relevant. This includes providing adequate information about these options, making them convenient enough, and making sure they are not too pricy.

As argued earlier, the factors associated with intrinsic product longevity are relevant in relation to all three design aspects: appearance, function, and communication. Table 2 provides a set of examples to support this point.

Table 2 Examples of intrinsic product resilience

	Appearance	Function	Communication
Decay resilience	A car with scratch-resistant surfaces.	A vinyl record player that maintains its sound quality.	A brand that launches a commercial that sticks in the mind.
Positive decay features	A leather sofa that develops appreciated patina.	A chair that adapts to the user's body over time.	A brand that launches a commercial that acquires nostalgic qualities over time.
Maintenance quality	Easily understandable instructions for how to maintain a woollen sofa.	A coffee machine that is easy to clean.	A brand that continuously promotes itself in a consistent way.
Replace quality	A chair with an easily replaceable seat cover.	A laptop with an affordable and easily replaceable battery.	A brand that repositions a product when it is criticised.
Upgrade quality	New attractive covers for a smartphone.	A laptop that allows the addition of extra memory modules.	A brand that improves its image over time.
Repair quality	Shoes with an affordable sole repair service.	A smartphone with a warranty that covers malfunctions.	A brand that rebuilds its image when faced with criticism.
Reconfiguration quality	A sofa with modules that can be reorganised.	A laptop where the settings can be individualised.	A brand that positions a product in different ways to address different target groups.

3.2 Extrinsic product design resilience

Extrinsic product design resilience refers to how well a product can maintain an adequate appeal to avoid being discarded while it is still physically functional or while it is possible to 'revitalise' the product by replacing elements or upgrading, repairing or reconfiguring the product. As shown, the literature contains several classifications of factors that cause products to be discarded although they are still physically functioning or could be repaired. However, existing classifications seem far from exhaustive. In order to broaden the understanding of such causes, Porter's 'five forces model' (Porter, 1980) can be brought into play. Porter's five forces include: 1) bargaining power of customers (buyers); 2) bargaining power of suppliers; 3) threat of substitute products or services; 4) threat of new entrants; and 5) intensity of competitive rivalry. The five forces model is a standard tool used by both

academics and practitioners in connection with strategic management studies (Rugman and Verbeke, 2000; Bose, 2008). According to Grundy (2008), the unique quality of this model is that it distilled “the complex micro-economic literature into five explanatory or causal variables to explain superior and inferior performance”.

Given that the focus of this paper is not rivalry between companies but product resilience, some adaptations of the five forces are needed. More specifically, the five actor/object types are used, but given a product design resilience focus. Furthermore, to make the focus clearer, the category ‘substitute products or services’ is changed to (new) ‘technology’, which is in fact a part of what ‘substitute products or services’ refers to. The five derived dimensions of extrinsic product resilience are shown in Figure 3, in which each dimension is subdivided into two subtypes to explain their scope. This scope is further clarified in Table 3, in which the derived five types of extrinsic product design resilience are combined with the three aforementioned design dimensions, i.e., appearance, function, and communication. This produces thirty distinct extrinsic design resilience dimensions, which are all relevant when designing resilient products, although they are rarely all relevant for the same product.

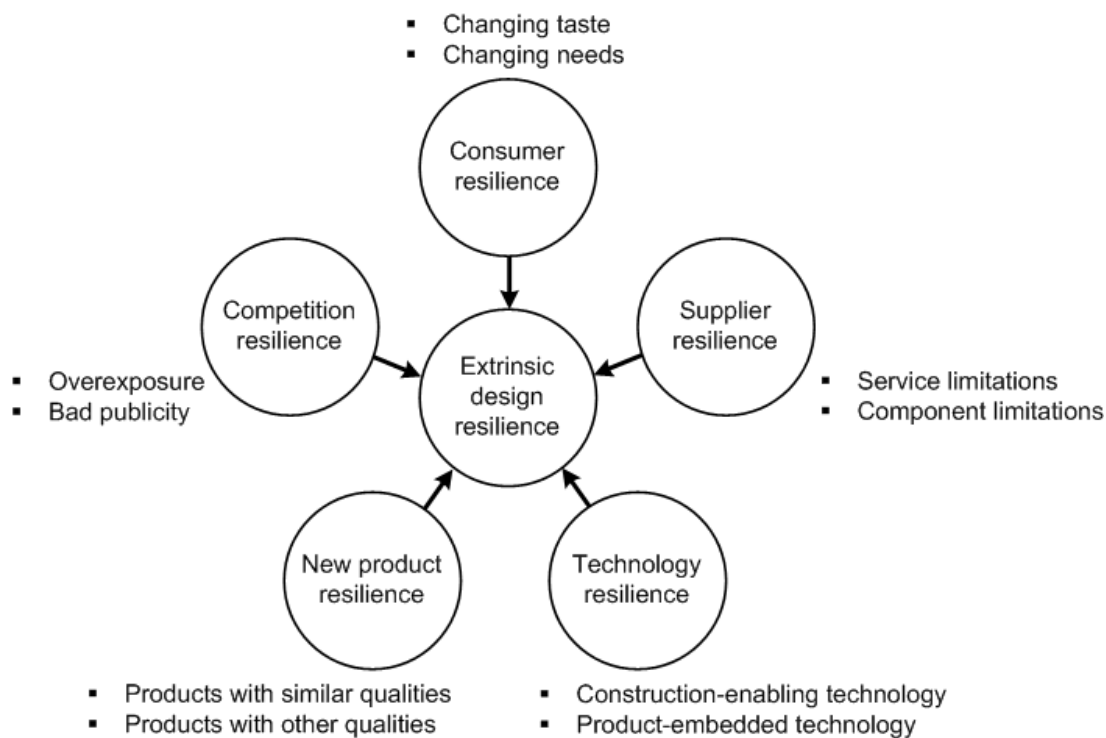


Figure 3 Dimensions of extrinsic product design resilience

Table 3 Examples of needs for extrinsic product design resilience

Resilience		Appearance	Function	Communication
Consumer resilience	Changing tastes	A product’s appearance becoming unfashionable.	A product’s operating principle becoming unfashionable.	A product’s brand messages becoming unfashionable.

	Changing needs	Desires for appearances that better match new lifestyles.	Needs for new functions or better performance.	Desires for branding that better match new lifestyles.
Supplier resilience	Service limitations	Poor possibilities for getting a product surface repaired.	Poor possibilities for getting product functions repaired.	Poor possibilities for getting information about repair.
	Component limitations	Complementary visual parts being/becoming unavailable.	Complementary functional parts being/becoming unavailable.	Complementary product information being/becoming unavailable.
Technology resilience	Construction-enabling technology	New technology allowing slimmer constructions and novel shapes.	New technology allowing lighter and handier constructions.	Product branding focusing on advanced production techniques becoming outdated.
	Product embedded technology	New technology allowing new ways for a product to display information.	New technology allowing new functions and better performance	Branding highlighting a product as high-tech becoming outdated
New product resilience	Products with similar qualities	Products with a similar appearance making a product less exclusive.	Products with a similar functionality making a product less exclusive.	Products with similar branding making a product less exclusive.
	Products with other qualities	Products with other appearance qualities.	Products with other (non-technology-related) functional qualities.	Products with other branding qualities.
Competition resilience	Overexposure	Frequent exposure making a product's appearance less exclusive or interesting.	Frequent exposure making a product's functionality less exclusive or interesting.	Frequent exposure making a product's marketing messages less exclusive or interesting.
	Bad publicity	Attention being drawn to negative aspects of a product's appearance.	Attention being drawn to negative aspects of a product's functions, e.g. energy consumption.	Attention being drawn to negative aspects of a product's marketing.

3.3 Ensuring product design resilience

As mentioned earlier, the literature review identified five streams of research that may be relevant in relation to increasing consumer product longevity. As described, these streams include a multitude of different approaches that can improve a product's resilience. Besides the five streams, four approaches outside these streams were identified: sharing products, consumer communities, product advice, and making social connections (Fuad-Luke, 2010, p. 147; ERM, 2011). In different ways, these four approaches focus on ways to affect use processes positively through product-related services. Thus, they are grouped into a sixth category labelled 'use service'. On this basis, twenty distinct design aspects can be distilled and organised into six themes, as shown in Table 4.

Table 4 Product resilience-building means

Theme	Design consideration	Examples
Adaptation	Repair	Offering a repair service period for an coffee maker
	Maintenance	Offering leather care products/instructions for a sofa
	Element replacement	Offering replacement cartridges for a printer
	Element upgrade	Offering memory units for upgrading a laptop
	Reconfiguration	A height-adjustable children's chair
Timelessness	Long-lasting fashions/styles	Designing furniture in fashion neutral colours
	Inherent aesthetic focus	Designing furniture using gestalt principles
Exclusivity	Limited editions	Offering limited editions of a wrist watch
	Luxury	Using exclusive materials and manufacturing for a handbag
Emotional durability	Aging well	Using wood that develops appreciated patina for a table
	Having 'personality'	Designing a smartphone's user interaction to stand out
	Stimulating curiosity	Designing a table lamp that produces fictional associations
	Increasing sensorial variety	Designing a toaster to highlight look, feel, and sound (rather than merely focus on visual appearance)
Design process	User-centred design	Using extensive user studies for designing an injection pen
	User involvement in the design process	Letting users provide content for a website
	Pre-purchase personalisation	Allowing for the personal configuration of car elements
Use service	Sharing products	Offering car sharing services
	Consumer communities	Creating a web forum for discussions about wristwatches
	Product advice	Providing bicycle buyers with maintenance information
	Making social connections	Connecting a running tracker with social media

3.4 A process model for designing resilient consumer products

Having identified potential causes of product replacement (Table 3) and a set of potential means for avoiding such replacements (Table 4), a process for designing resilient products may be defined, as done in Figure 4. The idea of the process is first to consider the potential needs for resilience for the particular design problem. For example, if the product is a dress, the three types of 'product-embedded technology' in Table 3 would not be relevant (unless it is 'intelligent clothing'), while the appearance and communication dimension of 'changing tastes' typically would be. In this manner, the thirty 'potential resilience needs types' listed in Table 3 can serve as a basis for defining a list of relevant resilience needs associated with the given design problem. Next, relevant means for addressing the design problem at hand are considered. For example, if the product is a smartphone 'for the mass market', the 'limited edition' dimension would not be relevant, while, on the other hand, 'upgrade options/instructions', could be. In this manner, the twenty 'product resilience-building

means' listed in Table 4 may serve as a basis for defining a set of relevant means for the given design problem and developing a design proposal. Such a set could, for example, consist of 'element upgrade', 'aging well', and 'user involvement in the design process', which would thus form three main focuses of the design process. The resulting proposal is then compared to the derived list of resilience needs, and if the design adequately addresses these concerns, a satisfactory solution has been achieved. If the proposal fails to address the resilience concerns in a satisfactory manner, the proposal needs to be revised or redone, based on the derived list of relevant means. This iterative process may continue until a satisfactory solution has been obtained.

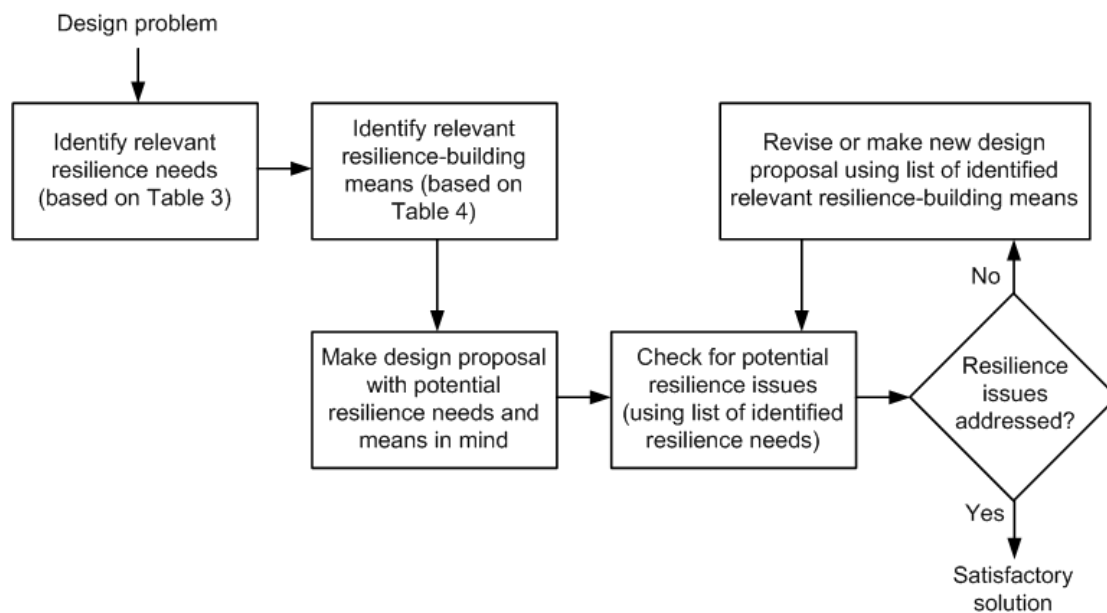


Figure 4 A process for designing resilient products

4. Conclusions

This paper argued that the existing classifications of factors leading to the replacement of physically functioning consumer products in some respects lack structure and detail. This could imply that designers would find it difficult to utilise such classifications for making more durable products. Also, from an academic perspective, a clearer understanding of the problem at hand may be a necessary condition for addressing it. The same types of problems exist in relation to the identified classifications of means of increasing product longevity. On this basis, the paper formulated two questions: 'What are the causes of consumer product replacement?' and 'What are the design strategies for increasing consumer product longevity?'

First, the paper argued for the usefulness of the concept of 'product resilience', as opposed to 'durability', in order to emphasise that product longevity is a matter of being able to both 'withstand' and 'adapt to' external physical, psychological, and social forces. On this basis, the first question was addressed by adapting Porter's (1980) 'five forces model' for use in product resilience analysis. Each of the derived five 'resilience needs' was divided into two

subtypes and combined with the three design dimensions: appearance, function, and communication, resulting in thirty distinct causes of product replacement. Compared to the classifications in the existing literature, this classification represents a far more detailed description of such causes. The second question was addressed by distilling twenty product resilience-building means from the classifications found in the literature. This classification also represents a more detailed perspective, compared to the ones identified in the literature. Using the thirty types of potential resilience needs and the twenty means of addressing such issues, a process model for designing resilient products was constructed.

For design practitioners, the extensiveness and the level of detail of the classifications in this paper provide a more structured and nuanced basis for the design of resilient consumer products. For future research purposes, the classifications presented in this paper may indicate new areas of product resilience to be explored and also provide a stronger basis for studying the effects of different types of product resilience means.

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