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A Performance and Consumer-based Lifespan Evaluation for T-shirt Eco-design

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Abstract: Increasing clothing longevity is recognized as a promising lever to help in reducing apparel sector's environmental impacts. However, longevity evaluation of textile products remains complex and so tracking of longevity factors is needed. Current researches mainly focused on garment design to increase lifespan. Since, no researches involving fabric quality, raw material and technical performances were carried out in this sector, we defined a methodology to address the lack of performances-based approach to help in evaluating clothing longevity. We defined the consumer-oriented quality (COQ) score. Since it relies on both the consumer and the product knowledge it could be used as a normative duration index. Indeed it takes into account relative importance of material damage that lead to disposal, and products performances (i.e. their ability to withstand these damage). To assess COQ score's appropriateness as a lifespan index, products were truly aged through a wash and care procedure and were evaluated by a non-trained panel to determine whether or not they were still usable.

Introduction

The clothing sector is said to be responsible for 2% to 10% of private consumption's environmental impacts (Tukker et al., 2006). Design for longevity as recognized eco-design lever (ADEME, Fangeat, Chauvin, & le pôle usage et durée de vie, 2016; Cooper, 2010; De Saxce, Pesnel, & Perwuelz, 2012; Laitala & Klepp, 2011; UNEP, Bakker, & Schuit, 2017) could help in reducing such impacts. However since there is no consensual method to measure clothing longevity, identifying clothing longevity factors remains complex. Current "Design for longevity" researches mainly adopted an user-centered approach (Cooper, Hill, Kininmonth, Townsend, & Hughes, 2013; Laitala, Boks, & Klepp, 2015; Lilley, 2009; Maldini, Stappers, Gimeno-martinez, & Daanen, 2019; Niinimäki & Hassi, 2011) and revealed size and fit as a main reason for garment change. Garment's cut and shape is thus a first approach to increase lifespan. However and to the best of our knowledge, no researches involving fabric quality, raw material and technical performances were carried out in this sector. In this paper we defined a methodology to address the lack of performances-based approach to help in evaluating clothing longevity.

Methods

To help in framing this study, we first should sharpen product lifespan definition we have relied on. The French environmental agency, ADEME defined the "normative duration" as an average operating time, measured under specific test conditions (ADEME, 2016a). It is thus supposed to be measurable and objective however, since it is a cross-functional vocabulary, specific tests conditions should be specified.

Laboratory tests conditions are supposed to reflect objective use phase constraints such as material damage that lead to disposal. The consumer behavior has thus been surveyed to identify damage type and their importance in the disposal decision. More than 800 answers were collected and material damages of seven clothes categories were identified.

Calculated, relative importance of the consumer perception to deterioration, concerning T-Shirts, is deduced using multiple criteria decision-making method and fuzzy techniques, Fuzzy Analytic Hierarchy Process (Fuzzy AHP) (Chang, 1996; Saaty, 1980).

Damage type knowledge enables to set up a laboratory tests procedure to measure

product's performances, i.e. their ability to withstand to deterioration. It should involve standardized tests which selection is to reflect the use phase constraints. However such performances translate specific quality of product and not an overall quality. We therefore defined a Consumer Oriented Quality score (COQ). Since it combines product and consumer knowledge, it could be used as a normative duration index.

The COQ score was computed using a complete ranking method (Brans, 1982) such as the PROMETHEE II method (Preference Ranking Organization Method for Enrichment Evaluations), to minimize a compensating effect and not to blind products' weaknesses with a high strength.

To check the COQ score appropriateness as a normative duration index, we compared it to an evaluated product lifespan. Such an evaluation resulted from an ageing procedure and a sensory survey. We restricted the ageing procedure to product care making the procedure more replicable. Washing, drying and ironing parameters were selected in accordance to consumer practices. On a regular basis sensory survey sessions involving a non-trained panel were conducted. Consumers were asked:

"Given the state of wear of the product, would you continue to wear it?"

Three answers were accepted:

- Yes, to be worn under normal conditions;
- Yes to be worn under poor conditions (gardening, cleaning, etc.);
- Nor to be worn anymore.

Based on answers distribution, an actual lifespan value was attributed to product and compared to the COQ score.

We implemented such a methodology on the T-shirt case as it is the reference product in the Product Environmental Footprint (PEF) methodological frameworks (ADEME, 2016b; European Commission, Pesnel, & Payet, 2019).

Consumer perception to deterioration

Thus 29 T-shirts were bought from national and international retailers. Three samples of each were needed: one as control product, one for testing and one for ageing.

Based on the evocated consumer survey, we first identified T-shirt's material damages that lead to disposal. The disposal frequencies of five material damages were investigated:

- Loss of colour (MD1);
- Loss of shape (MD2);
- Opened/Torn seam (MD3);
- Hole(s) (MD4);
- Pilling (MD5).

Relative importance of each material damage in the disposal decision were computed from collected behavior using Fuzzy AHP method (Chang, 1996). It finally appears that T-shirts are more likely to be disposed of for hole(s) and loss of shape issues (Benkirane, Thomassey, Koehl, & Perwuelz, 2019) (Table 1).

	MD1	MD2	MD2	MD4	MD5
Consumer perception to deterioration (%)	15	26	18	27	14

Table 1. Consumer perception to deterioration (Benkirane et al., 2019).

Consumer-oriented quality score computation

The COQ score relies on the product and consumer knowledge. Thus, we set up a laboratory tests procedure regarding material damage's nature. T-shirts abilities to withstand material damage were finally tested through ten standardized tests specifically identified to reflect the use phase constraints (Table 2).

Damage category	Test	Standard
Loss of colour	Colour fastness to domestic laundering	NF EN ISO 105 - C06
	Colour fastness to water	NF EN ISO 105 - E01
	Colour fastness to hot pressing	NF EN ISO 105 - X11
	Colour fastness to rubbing	NF EN ISO 105 - X12
Loss of shape	Dimensional change in washing and drying	NF EN ISO 5077
	Spirality after laundering	ISO 16322-3
Opened/Torn seam	Seam tensile properties (Grab method)	NF EN ISO 13935-2
Hole(s)	Bursting properties of fabrics (Pneumatic method)	NF EN ISO 13938-2
Pilling	Surface fuzzing and pilling (Pilling box)	NF EN ISO 12945-1
	Surface fuzzing and pilling (Martindale)	NF EN ISO 12945-2

Table 2. Conducted standardized tests.

Tests results corresponding to T-shirts performances were measured and combined to the consumer perception to deterioration using the PROMETHEE II method to get one unique score [19].

As illustrated in figure 1, each T-shirt is thus given a single score going from -1 (for lower quality) to +1 (for higher quality). Combining both product and consumer knowledge, the COQ score aims to predict product quality as it should be perceived and could be used as a normative duration index.

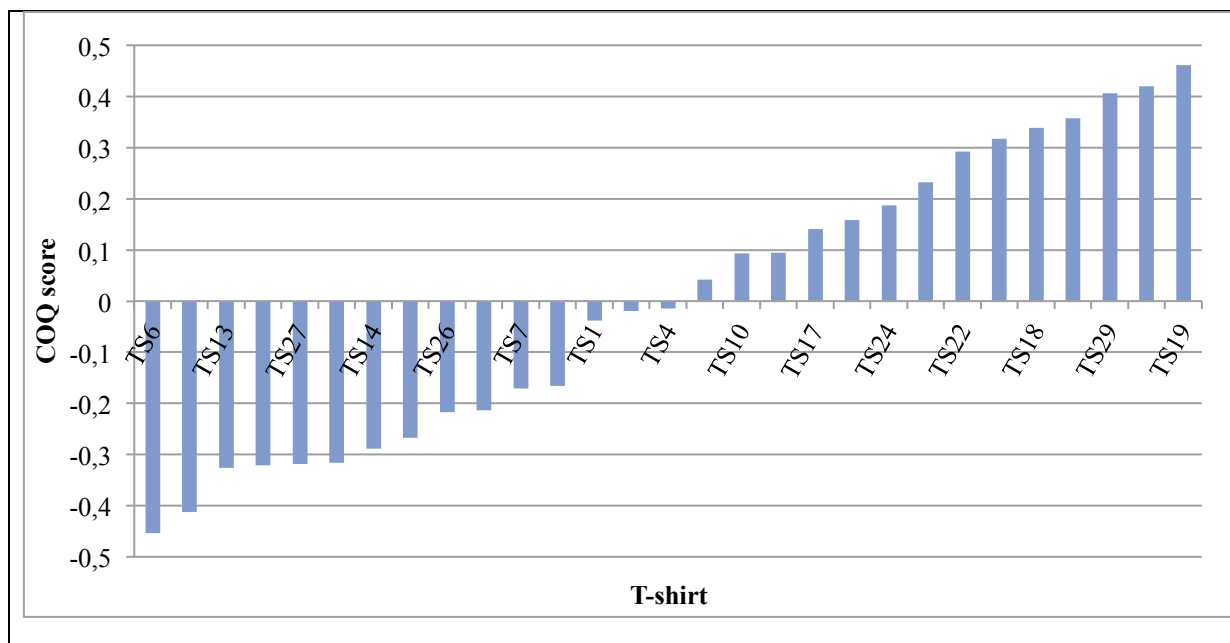


Figure 1. T-shirts' COQ score.

COQ score and panel evaluation

To check appropriateness of the COQ score as normative duration index, T-shirts lifespan were evaluated through repeated washes. According to surveyed practices, all T-shirts were thus washed to 40 °C, air dried and not ironed.

Three sensory evaluation sessions were held after 15, 30 and 50 washes respectively. Each involved about 30 people. An example of response rate after 15 washes is given in figure 2.

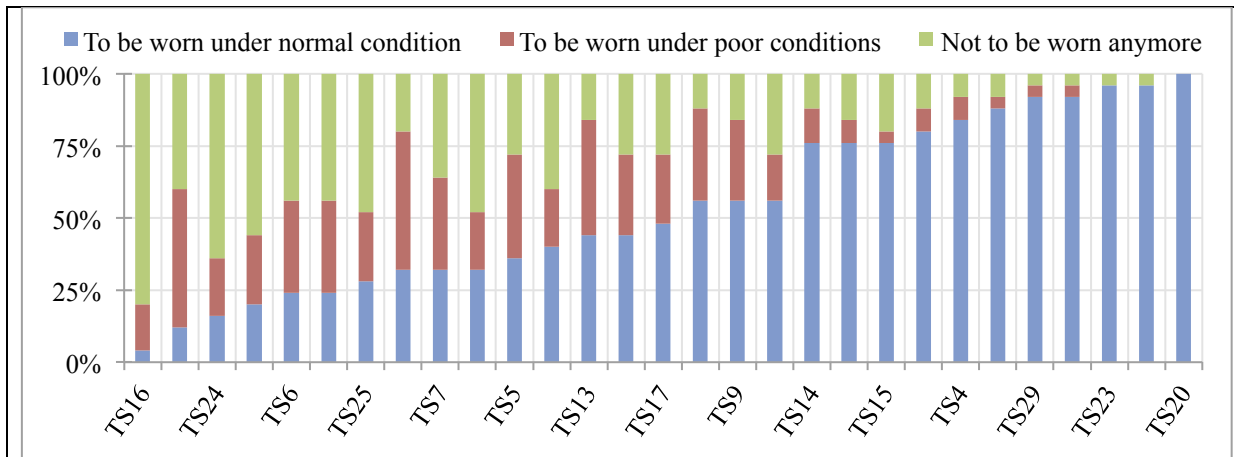


Figure 2. Panel Response rate to the question:” Given the state of wear of the product, would you continue to wear it” after 15 washes.

Cumulative wear and tear after 15 washes appears to be sufficient to affect normal conditions usability of half of the 29 T-shirts as 50% of surveyed consumers won't wear these products under normal conditions anymore.

To go further and to evaluate T-shirts lifespan, we focused on answers evolution over washes, with a particular interest in the first answer (i.e. “to be worn under normal conditions”) (figure 3). For a better graphical visualization, only six T-shirts are illustrated depicting major evolutionary patterns.

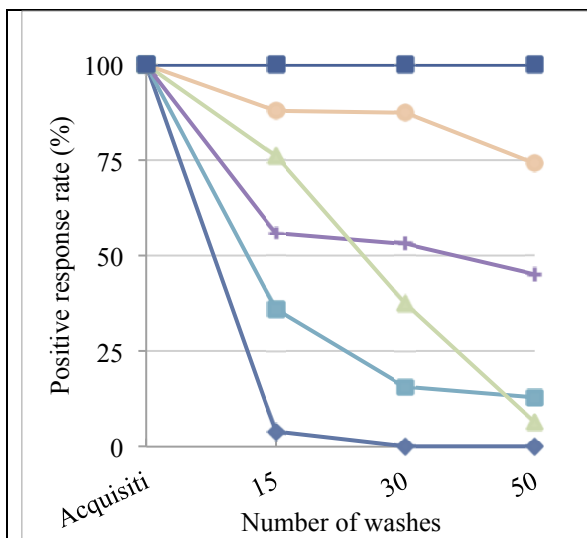


Figure 3. Panel response rate evolution over washes.

Two types of evolutionary patterns were distinguished:

- A progressive response rate evolution which could be assimilated to a progressive ageing. Here represented by T-shirts TS15, TS19 and TS20. 8 of 29 T-shirts follow such a pattern and reach a lifespan of 15 washes, 6 reach 30 washes and only 4 reach 50 washes;
- A decreasing exponential pattern, here represented by TS3, TS5 and TS16. It concerns 21 T-shirts of which only 6 reach 15 washes.

Based on these results, an evaluated lifespan was assigned to each T-shirts and compared to the COQ score (figure 4).

Finally, good correspondence is to observe between the computed COQ score and an actual lifespan for 12 T-shirts and a promising correspondence for 4 others. COQ score currently covers five material damages.

Discussion

In this paper, we discussed about a methodology proposal to compute a consumer-oriented quality score. Since its uniqueness comes from the consumer integration through its perception of material damage, we consider it could be used as a normative duration index. Our findings revealed a promising but partial correspondence between the COQ score and an evaluated lifespan.

However, computed COQ score currently covers five material damages. Based on an existing consumer survey which main advantage was number of answers, we actually restricted our study on loss of colour, loss of

shape, seam, hole(s) and pilling issues. To go deeper and to better conform to consumer we should consider more damages, including more subjective ones.

Finally, to assess the appropriateness of COQ score we conducted a product care-based ageing procedure set up to conform consumer practices: washing to 40 °C, air dry and no ironing. 3 sensory evaluations sessions followed, after 15, 30 and 50 washes respectively. This could be improved in two ways:

- First, we should refine number of sensory evaluation sessions by conducting more at the beginning as more of the T-shirts do not reach 15 washes;
- Secondly, we should also conduct a parallel wear study to check our ageing procedure validity.

Acknowledgments

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