Standards selection approach for clothing longevity indicators

4th PLATE 2021 Virtual Conference
Limerick, Ireland - 26-28 May 2021

Standards Selection Approach for Clothing Longevity Indicators

Benkirane, R.[(a)], Thomassey, S.[(a)], Koehl, L.[(a)], Perwuelz, A.[(a)]
a) ENSAIT GEMTEX – Laboratoire de Génie et Matériaux Textiles, F-59000 Lille, France

Keywords: Longevity Indicator; Tests Selection; Robustness Analysis; Clothing.

Abstract: Given the diversity of textile products, their uses and also the reasons related to their end-of-life, it appears that estimating the effective lifespan of clothing items is unrealistic. To estimate a lifespan equivalent, a reasonable solution is to rely on standards commonly performed by the apparel industry. However, according to the international classification of standards, the textile and clothing sector benefits from more than 1.900 standards covering the aspects of processes, materials, semi-finished and finished products. Thus, this paper focuses on how to make the standard selection consistent to estimate the product in accordance with the end of life of apparel. First, a list of objective clothing disposal reasons is proposed and is to associate to a standards pre-screening that enable the assessment of the ability of a product to withstand the damage. Then, since a single aggregated score is desired, the tests results are aggregated into a single normative duration index. In a robustness analysis, the influence of the number of metrological tests constituting the score is investigated. It enables the identification of the most appropriated tests with the aim to rationalize the methodology regarding time and cost consideration. In a case study, 29 T-shirts were tested regarding five damage categories. Based on expert knowledge and literature review, the laboratory tests procedure involved a selection of ten tests, out of which the five providing the maximum explanation rates were investigated.

Introduction

In the framework of the Circular Economy Action Plan, manufacturers, retailers and consumers are encouraged to adopt a more responsible model by making and choosing sustainable products. To support this effort, to strengthen consumer protection against green washing and to meet the necessary transparency and communication requirements, the European Commission also propose that companies use Product Environmental Footprint methods to support their environmental claims (European Commission, 2020).

For now, the Fashion sector benefits from two methodological guidelines to assist in the assessment of the environmental impacts:

- the Product Environmental Footprint Category Rules: T-shirts, published by the European Commission as PEFCR – T-shirts (European Commission, Pesnel, & Payet, 2019)
- the French guideline published by ADEME as BP. X 30-323-23 (ADEME, 2016).

These two documents provide rules to standardise the environmental assessment method for labelling purposes, such as the functional unit, the system boundaries, the product's lifespan and the impact categories to be assessed. In both cases, a known limitation is that the lifespan is considered as a fixed value while it significantly influences the evaluation (De Saxce, Pesnel, & Perwuelz, 2012; Leffland, Kaersgaard, & Andersson, 1997; Sandin, Roos, Spak, Zamani, & Peters, 2019).

Given the diversity of textile products, their uses and also the reasons related to their end-of-life, it appears that estimating the effective lifespan of clothing items is unrealistic. To estimate a lifespan equivalent, a reasonable solution is to rely on standards commonly performed by the fashion industry as the concept of normative duration suggests: an average operating time is objectively measurable using tests (ADEME, Fangeat, Chauvin, & le pôle usage et durée de vie, 2016).

Scope of longevity

The standards selection first depends on the scope of the longevity: which criteria are to be assessed? What type of obsolescence should be considered?

The scientific literature distinguishes between two categories: absolute and relative obsolescence, corresponding to a technical and a premature end of life, respectively (Cooper, 2004; Granberg, 1997; Park, 2012). Both suggest that the product's lifespan highly depends on:

- its quality and ability to resist deterioration;
- the ability to produce with consistent quality;
- the ability to maintain and repair the product;
- its ability to evolve;
- its economic depreciation;
- changes in consumer needs.

A sectoral textile and clothing approach, is given by Klepp and Laitala et al. in (Laitala & Klepp, 2011): it mentions six types of obsolescence, from the technical and quality related, to the psychological, the situational, or sentimental and also provides seven grouping of disposal reasons, with about 60 listed causes. Some of these reflect objective ageing factors and perfectly fit with standards-based longevity estimation. Furthermore, given the abundance and coverage of standards in the textile and clothing sector, the normative duration framework appears meaningful when developing an objective and repeatable approach to estimate the longevity of products.

However, according to the international classification of standards, the textile and clothing sector benefits from more than 1.900 standards covering the aspects of processes, materials, semi-finished and finished products.

Thus, this paper focuses on how to make the standard selection consistent to estimate the product longevity:

- How to select appropriate standards, both in terms of content and number?
- How many tests should be included?
- Are there tests combination more appropriated?

Methods

Considering, the investigated products' longevity is strongly connected to their ability to resist to measurable stresses. It thus requires a specific laboratory tests procedure that enables the products' performances to be assessed.

The proposed methodology integrates that the textile sector benefits from a large number of standards and that a pre-screening is necessary. Then, since the objective is to move towards a single value such as the lifespan, we propose the testing results to be aggregated into a single normative duration index. Finally, considering the number of tests as essential to widely implement the methodology, an optimization and rationalization of the tests number is considered.

Standards pre-screening

We suggest that the selected standards reflect the use phase. Thus, to help in the selection, the constraints of use must be known. Regardless the product category, a list of objective disposal reasons is proposed (Table 1). It is based on textile expertise, literature review (Cooper, Hill, Kininmonth, Townsend, & Hughes, 2013; Laitala, 2014; Laitala, Boks, & Klepp, 2015; Laitala & Klepp, 2011; Saville, 1999c) and on companies' experience.

Clothing disposal reasons	
Colour change	Coloration caused by bleeding
Yellowing	Dimensional change (loss of shape, shrinkage, spirality)
Hole(s)	Degradation of hand properties
Tear	Increase of product rigidity
Bagging	Functional degradation (loss of function)
Pilling	Degradation of customization elements
Fuzzing	Worn out specific area (collar, cuffs, …)
Felting	Loosening of elastic bands
Broken accessories	Increase of electrostaticity
Persistent stains	Persistent wrink
Persistent odour	Loss of inner filling material

Table 1: Clothing objective disposal reasons

Standards should be identified according to their ability to quantify the robustness of products against each disposal reasons. This identification should rely on textile expertise, scientific literature and companies' standards. Based on (Bide, 2012; Fulton, Rezazadeh, & Torvi, 2018; Nayak & Padhye, 2015; Ray, 2013; Saville, 1999c, 1999b, 1999a; Shaw, 2012), an example of standards pre-screening to address some common damage is given in Table 2.

Standard	Number
Color Change	
Color fastness to water	NF EN ISO 105 – E01; E02; E03
Color fastness to daylight	NF EN ISO 105 – B01
Color fastness to perspiration	NF EN ISO 105 – E04
Color fastness to domestic laudering	NF EN ISO 105 – C06
Color fastness to hot pressing	NF EN ISO 105 – X11
Color fastness to rubbing	NF EN ISO 105 – X12
Color fastness to weathering	NF EN ISO 105 – B03
Loss of shape (dimensional changes, spirality)	
Dimensional change in washing and drying	NF EN ISO 5077
Spirality after laundering	ISO 16322: 1, 2 and 3
Apparel appearance after domestic washing and drying	NF EN ISO 15487
Hole(s)	
Abrasion resistance of fabrics: Martindale method	NF EN ISO 12947:1 , 2, 3 and 4
Pilling	
Fabric propensity to surface pilling, fuzzing or matting	NF EN ISO 12945: 1, 2, 3

Table 2: Selection of relevant standards in compliance with product end-of-life

Single quality indicator: aggregation method

To compute a single quality score to be used as a normative duration index, we developed a single product- and consumer- dependent indicator, called Consumer-oriented Quality (CoQ) (Benkirane, Thomassey, Koehl, & Perwuelz, 2019a, 2019b). Based on a previous study, the concept is briefly described.

The proposed CoQ score aims at giving a better estimation of the clothing longevity from the knowledge of objective ageing factors. It enables multiple textile qualities to be aggregated according to the relative importance of each in the disposal decision. The aggregation process relies on the complete ranking PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluations) method. PROMETHEE II enables a finite set of objects to be ranked from a multi-criteria analysis (Brans, Vincke, & Mareschal, 1986). Based on a pairwise comparison along different criteria which have to be maximized or minimized, it allows the computation of a single net flow for each of these objects. This single net flow corresponds to the CoQ score.

In this study, the objects and criteria represent the clothing and damage categories. Also, since the method requires the use of weights (Brans et al., 1986) the relative importance of each of these category in the disposal decision is considered.

Appropriateness of the tests: model optimization

Considering the aggregation process results in a single CoQ score for each evaluated product, it enables to rank them.

To help in determining the right number of tests and the most appropriate ones, the proposed approach is based on a robustness analysis of the CoQ computation model. The aim is to assess the intensity of the disturbance in response to a variable number of tests. The process consists in:

- computing the reference CoQ score values for an exhaustive list of tests (reference scenario = scenario 1);
- computing alternative CoQ score values for a reduced list of tests (considering different combinations of tests: scenario 2 to scenario n);
- comparing each alternative scenario with the reference one using the Pearson correlation coefficient r.

Results: implementation on the T-shirt case

This methodology was implemented in a T-shirt case study involving 29 products. The T-shirts' performances were evaluated with respect to five damage types out of the 22 mentioned in (Table 1): loss of colour, loss of shape, broken seam, hole(s) and pilling.

In response a specific laboratory tests procedure was set up, it integrates ten standardized tests and since three of them results in two evaluations, the whole procedure results in 13 evaluations (Table 3).

Damage category	Standard	Number evaluation
Loss of colour	NF EN ISO 105 - C06	1
	NF EN ISO 105 - E01	1
	NF EN ISO 105 - X11	1
	NF EN ISO 105 - X12	2
Loss of shape	NF EN ISO 5077	2
	ISO 16322-3	1
Opened / Torn seam	NF EN ISO 13935-2	2
Hole(s)	NF EN ISO 13938-2	1
Pilling	NF EN ISO 12945-1	1
	NF EN ISO 12945-2	1

Table 3: Selected standards in the T-shirt case study

Aggregating tests' results, a single quality score was computed for each T-shirt (

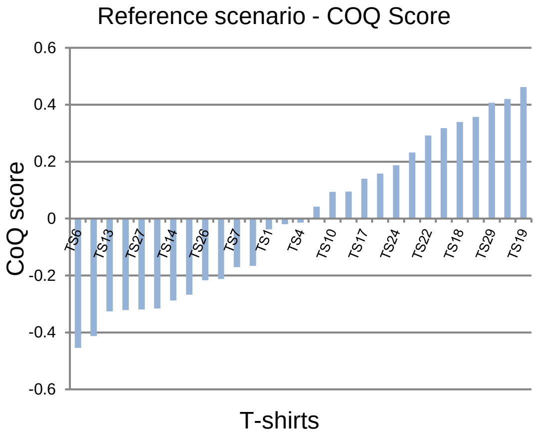

Figure 1). Being based on the whole set of tests; this score varies from -0.45 and 0.46 and represents the reference scenario's score i.e. scenario 1.

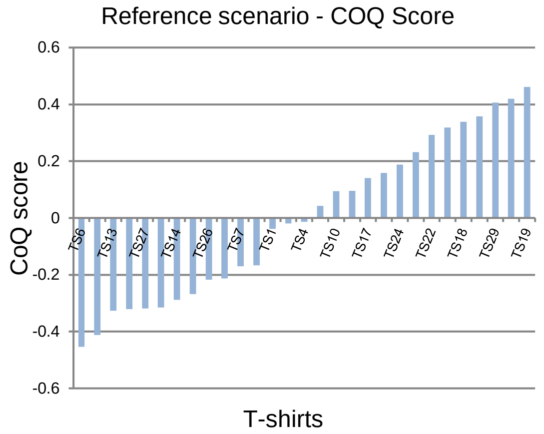

Figure 1: Computed CoQ score for reference scenario

More than 70 alternative scenarios were then computed considering different combination of the 13 tests (Table 4):

- in the first 12 alternative scenarios, the influence of excluding one measure at a time is evaluated;
- then, 60 more extreme scenarios are considered keeping only one test per damage category, i.e. five tests per scenario.

	Loss of colour				Loss of shape		Open seam	Hole(s)	Pilling box	
	NF EN ISO 105 C06	NF EN ISO 105 E01	NF EN ISO 105 X11	NF EN ISO 105 X12	NF EN ISO 5077	ISO 16322 - 3	NF EN ISO 13935 - 2	NF EN ISO 13938 - 2	NF EN ISO 12945 - 1	NF EN ISO 12945 - 2
Reference Scenario 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alternatives Scenario 2 to n		✓	✓	✓	✓	✓	✓	✓	✓	✓
	✓		✓	✓	✓	✓	✓	✓	✓	✓
					…					
	✓	✓	✓	✓	✓	✓	✓	✓	✓	
					…					
	✓				✓		✓	✓	✓	
					…					

			✓		✓	✓	✓		✓

Table 4: Standards selection per scenario

Based on the Pearson correlation coefficient r, each new scenario is compared to the reference one to measure the linear correlation: a value close to 1 indicating a higher correspondence.

When excluding only one measure at a time, the calculated r show little disturbance on the initial ranking (Table 5). The least correlated scenario obtains an r of 0.98 (Figure 2) and corresponds to the exclusion of the Pilling box results. In terms of pilling, this test is the one that we noted as distinguishing the least between T-shirts. We also notice that the five best coefficients are obtained with the exclusion of the color fastness tests. Since five tests are involved in the laboratory tests procedure, a compensation effect appears.

Scenario	1 (ref)	2	3	4	5	6	7	8	9	10	11	12	13
r	1	0.999	0.999	0.998	0.999	0.999	0.986	0.982	0.985	0.985	0.983	0.978	0.983

Table 5: Correlation coefficient for scenario 1 to 13

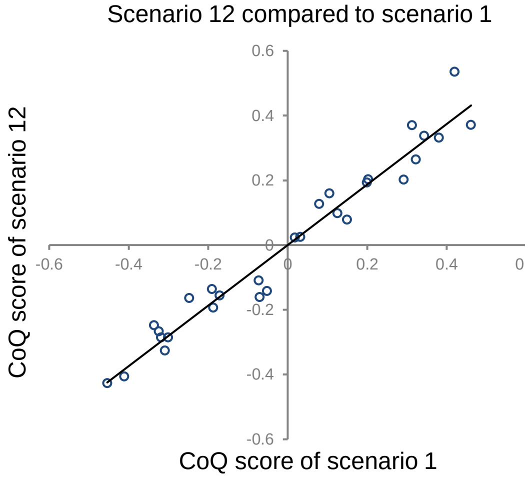

Figure 2: Comparison of the computed score in scenario 12 and 1

In scenarios 14 to 74, each damage category is represented by one single test. Given the high number of r values, we present their dispersion (

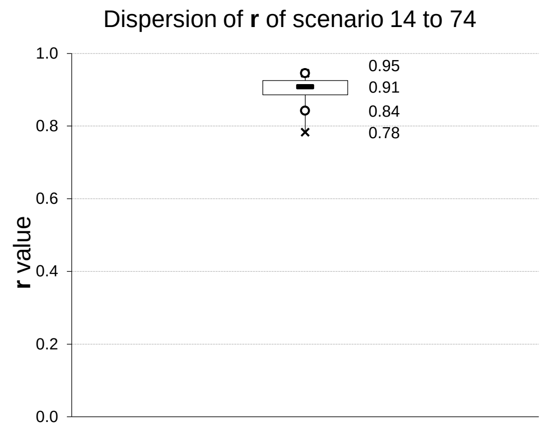

Figure 3). We observe a maximum value of 0.95 and a minimum value of 0.78, with a median of 0.91.

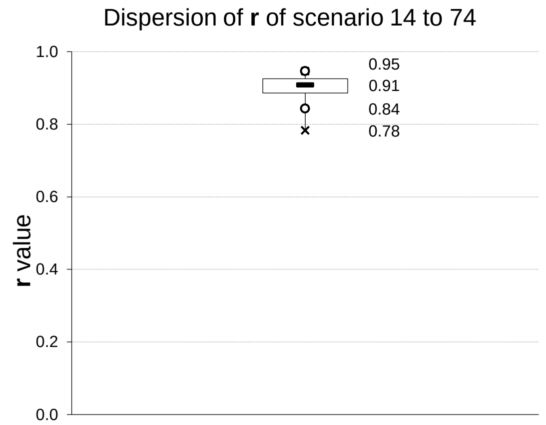

Figure 3: Correlation coefficients r for scenarios 14 to 74

Discussion

The robustness analysis finally results in r values varying from 0.78 to 0.99. This approach suggests that reducing the laboratory tests procedure is possible to meet cost and time issues. Although the lowest values reveal a certain complexity of the single quality scoring model, the highest values computed from five-test based scenarios are up to 0.95 and are of clear interest. The threshold r value remains to be determined however, arbitrarily considering 0,93 is acceptable, there are still 18 five-test based scenarios that enable combinations of tests to be identified to retain maximum information.

Based on these 18 best scenarios, the following observations can be formulated:

- None of the colour fastness tests stand out for the *loss of colour* category. The colour fastness to washing (NF EN ISO

105 C06) is slightly ahead with only five out ot 18 occurrences;

- The determination of spirality (ISO 16322 – 3) clearly emerges as representative for the *loss of shape*, with 16 out of 18 occurrences;
- For the *opened seam* category, only one test was involved however, one of the two measures seems more significant, the one in the row direction, with 11 out of 18 occurrences;
- The pilling box test (NF EN ISO 12945 – 1) appears more appropriate for the *pilling* category with 11 out of 18 occurrences.

To go further in this analysis, 8, 7 or 6 tests-based scenarios could be considered with the aim to find a suitable compromise between the number of tests and the model quality. In addition, to confirm the study results, other statistic methods, such as the Mean Squared Error, the Mean Absolute Error or the Root Mean Squared Error could complete the computed r values.

Conclusions

In this study, a standards selection approach is proposed with the objective to assist in the development and optimization of a clothing longevity indicator.

Considering the complexity of evaluating the effective lifespan of clothing items, a solution is to rely on a standards-based indicator. However, given their high number, a specific selection must be provided. To frame this process, we thus propose that the selected standards reflect the constraints of use. Relying on textile expertise and literature review a list of objective clothing disposal reasons is proposed and is to be refined according to the product considered.

Each disposal reason is to associate to a standards pre-screening that enable the assessment of the ability of a product to withstand the damage. Also, since a single quality value is desired, the tests results are aggregated into a single normative duration index (CoQ score).

In a robustness analysis, the influence of the number of tests constituting the score is investigated. Such approach is to conduct in early stages and offers the opportunity to identify the most appropriated combination and number of tests with the aim to rationalize the methodology regarding time and cost consideration.

In the proposed case study, 29 T-shirts were tested regarding five damage category. While the laboratory tests procedure involved ten tests, the robustness analysis highlighted that five tests could maintain satisfactory result.

Acknowledgments

This article is based on research undertaken with funding from the French region Hauts de France and ECOTLC. Its publication is supported by the EcyTwin project, the Interreg V FWVL program and the FEDER.

References

ADEME. (2016). *Principes généraux pour l'affichage environnemental des produits de grande consommation - Partie 23 : méthodologie d'évaluation des impacts environnementaux des articles d'habillement.*

ADEME, Fangeat, E., Chauvin, C., & le pôle usage et durée de vie. (2016). *Allongement de la durée de vie des produits*. Angers.

Benkirane, R., Thomassey, S., Koehl, L., & Perwuelz, A. (2019a). A consumer-based textile quality scoring model using multi-criteria decision making. *Journal of Engineered Fibers and Fabrics*, *14*, 1–12. https://doi.org/10.1177/1558925019854773

Benkirane, R., Thomassey, S., Koehl, L., & Perwuelz, A. (2019b). A performance and consumer-based lifespan evaluation for T-shirt eco-design. In N. F. Nissen & M. Jaeger-Erben (Eds.), *PLATE Product Lifetimes And The Environment 2019 – Conference Proceedings*. TU Berlin University Press. https://doi.org/ISBN 978-3-7983-3125-9

Bide, M. (2012). Testing textile durability. In P. A. Annis (Ed.), *Understanding and improving the durability of textiles* (pp. 126–142). Woodhead Publishing Limited.

Brans, J. P., Vincke, P., & Mareschal, B. (1986). How to select and how to rank projects : The PROMETHEE method. *European Journal of Operational Research*, *24*, 228–238. https://doi.org/10.1016/0377-2217(86)90044-5

Cooper, T. (2004). Inadequate Life ? Evidence of Consumer Attitudes to Product Obsolescence. *Journal of Consumer Policy*, *27*, 421–449. https://doi.org/10.1007/s10603-004-2284-6

Cooper, T., Hill, H., Kininmonth, J., Townsend, K., & Hughes, M. (2013). *Design for Longevity: Guidance on increasing the active life of clothing*.

De Saxce, M., Pesnel, S., & Perwuelz, A. (2012). LCA of bed sheets - Some relevant parameters for lifetime assessment. *Journal of Cleaner Production*, *37*, 221–228. https://doi.org/10.1016/j.jclepro.2012.07.012

European Commission. (2020). *Circular economy action plan: For a cleaner and more competitive Europe*. https://doi.org/10.2779/11035

European Commission, Pesnel, S., & Payet, J. (2019). *Product environmental footpring category rules (PEFCR): T-shirts*.

Fulton, M., Rezazadeh, M., & Torvi, D. (2018). Tests for evaluating textile aging. In D. Jackson & S. Webber (Eds.), *Advanced Characterization and Testing of Textiles* (1st ed., pp. 93–125). Woodhead Publishing.

Granberg, B. (1997). *The quality re-evaluation process: Product obsolescence in a consumer-producer interaction framework*.

Laitala, K. (2014). Consumers' clothing disposal behaviour - a synthesis of research results. *International Journal of Consumer Studies*, *38*, 444–457. https://doi.org/10.1111/ijcs.12088

Laitala, K., Boks, C., & Klepp, I. G. (2015). Making Clothing Last : A Design Approach for Reducing the Environmental Impacts. *International Journal of Design*, *9*(2), 93–107.

Laitala, K., & Klepp, I. G. (2011). Environmental improvement by prolonging clothing use period. In *Towards sustainability in the textile and Fashion industry* (pp. 1–22). Copenhagen.

Leffland, K., Kaersgaard, H., & Andersson, I. (1997). *Comparing environmental impact data on cleaner technologies*.

Nayak, R. K., & Padhye, R. (2015). The care of apparel products. In R. Sinclair (Ed.), *Textiles and Fashion: Materials , Design and Technology* (pp. 799–822). Elsevier Ltd. https://doi.org/10.1016/B978-1-84569-931-4.00031-3

Park, M. (2012). Defying obsolescence. In *Longer Lasting Products: Alternatives to the Throwaway Society* (pp. 77–106). Gower Publishing.

Ray, S. C. (2013). Process control in knitting. In *Process control in textile manufacturing* (pp. 243–264). Woodhead Publishing Limited. https://doi.org/10.1533/9780857095633.3.243

Sandin, G., Roos, S., Spak, B., Zamani, B., & Peters, G. (2019). *Environmental assessment of Swedish clothing consumption: Six garments – sustainable futures.* https://doi.org/10.13140/RG.2.2.30502.27205

Saville, B. P. (1999a). Colour fastness testing. In B. P. Saville (Ed.), *Physical testing of textiles* (1st ed., pp. 244–255). Woodhead Publishing Limited; The Textile Institute.

Saville, B. P. (1999b). Dimensional stability. In B. P. Saville (Ed.), *Physical testing of textiles* (1st ed., pp. 168–183). Woodhead Publishing Limited; The Textile Institute.

Saville, B. P. (1999c). Serviceability. In B. P. Saville (Ed.), *Physical testing of textiles* (1st ed., pp. 184–208). Woodhead Publishing Limited; The Textile Institute.

Shaw, A. (2012). Durability of protective clothing. In P. A. Annis (Ed.), *Understanding and improving the durability of textiles* (pp. 174–183). Woodhead Publishing Limited.