Opportunities and challenges of new product development and testing for longevity in clothing

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Abstract: Many types of clothing are now seen as disposable by consumers in the UK even though durability is among the top criteria that consumers claim to use when buying garments (WRAP, 2012). Routine tests for clothing performance carried out by retailers are generally designed to ensure garments are 'fit for purpose', not to establish durability or longevity. Designing clothing that lasts longer is, however, key to reducing waste and has become a government policy objective (Defra, 2011).

This paper discusses the findings from a recent research project, carried out for WRAP (Waste and Resources Action Programme), that investigated the opportunities for measuring, specifying and communicating aspects of clothing longevity within a Longevity Protocol. The Protocol is intended to enable retailers to obtain a reliable indication of garment life expectancy and was piloted in conjunction with clothing industry practitioners. It incorporates recommendations for best practice in product development and a testing regime that provides an indication of garment life expectancy (WRAP, 2014).

Overall, the findings from the pilot suggest that it is possible to test for garment longevity, however, this process can be drawn-out and may not fit easily into the normal product development process. Furthermore, variations in consumer wearing patterns and laundering make it difficult for retailers to guarantee and communicate product lifetimes in absolute terms.

The research adds to a growing body of evidence that supports the concept of design for clothing longevity. The findings will help to inform strategies for the implementation of government policy on sustainable clothing, but point to the need for refined testing processes to support this agenda.

Introduction

Clothing products have an average lifetime of 3.3 years, although there is considerable variation between different types (WRAP, 2013). While many discarded items are reused, either in the UK or overseas, others are thrown away because they are damaged or worn out (Morley et al., 2009; Cooper et al., 2013). The Sustainable Clothing Action Plan (SCAP) seeks to reduce the environmental impacts of clothing supply, use and disposal by identifying good practice which could be adopted by retailers and their suppliers. An assumption is made that garment longevity ('keeping a garment looking good and in use for longer') need not impact on commercial returns and could contribute to increasing brand value. Furthermore, evidence suggests that over a third of the population would like to do more to buy clothes that are 'made to last' (WRAP, 2012, p.22).

A research team from Nottingham Trent University was commissioned by WRAP to develop an industry-supported approach to measuring, specifying and communicating aspects of clothing longevity to help to increase the active lifetime of clothing in the UK. The primary outcome took the form of a 'Longevity Protocol' for use by retailers who are stakeholders of the SCAP, and by the clothing sector more widely (WRAP, 2014). The Longevity Protocol combines a 'best practice' approach to product development with the appropriate physical performance and quality tests in the context of specific garment types, to provide an indication of life expectancy. The

Protocol is intended to serve as an aid to garment technologists and designers to ensure greater compatibility of performance standards, as failure will depend on the lowest common factor, and should enable retailers to communicate an indication of life expectancy to the consumer with confidence.

In order to be successful, it was necessary to gain sufficient industry consensus with regard to the testing and performance standards and product development processes that could result in longer garment lifetimes. This paper discusses a 'longevity testing' pilot that was carried out to inform the development of the final Protocol and concludes with an assessment of its feasibility in relation to replicating consumer behaviour in wearing and laundering practice..

Research methods

The Longevity Protocol was developed through a research process that included:

- A visual survey of 1,476 discarded garments viewed at textiles recovery centres to identify common causes of garment failure
- Approximately 30 interviews with industry practitioners to inform best practice in product development and testing regimes for clothing longevity, and
- A 'longevity testing' pilot to evaluate how well the lifetime of certain garment types could be assessed.

The research findings informed the development of a draft Longevity Protocol which was presented to key retailers and suppliers for feedback. The longevity testing element of the draft Protocol was then trialled as a working tool for clothing industry practitioners, and the results of this pilot were incorporated into the final version.

The longevity testing pilot

The initial research with clothing retailers and suppliers informed the development of the following elements of the Longevity Protocol:

- A 'best practice' approach to new product development in which garment longevity is considered from the initial design stage and involves input from designers, technologists, buyers and suppliers working together to ensure a cohesive and integrated approach
- a set of recommended physical performance and colour fastness tests based on a range of 'basic' or 'core' clothing products that give an indication of fitness for purpose, and
- a longevity testing regime that uses a combination of extended wearer trials and repeated care label wash cycles to give an indication of garment lifetime.

1.Identification of recommended physical performance and colour fastness tests

The recommended tests are based on existing British, European and International standards as applied to a range of generic core products. The pass/fail criteria for pilling and colour fastness is based on a scale of 1-5 with grade 5 being the highest level of performance and grade 1 the lowest. Dimensional stability standards are based on a percentage tolerance of shrinkage or extension. While the tests are already widely used in industry, the performance criteria has in some cases been set higher in the Protocol than is currently practiced. For instance, the pilling performance pass for knitwear is set at grade 4 for the Protocol, whereas it is often set at grade 3 in industry. Clothing companies are advised to interpret these tests within the context of the product to take account of variation in fibre use and fabric construction. The selected products and their testing criteria are shown in Figure 1.

Feedback from textile testing companies indicated that physical performance and colour fastness tests are designed to give an assessment of a product's fitness for purpose, and only represent the early stage of the garment lifetime. Retailers also reported using wearer trials to supplement the tests to achieve a more accurate representation of garment performance as a consumer would experience it. This normally involves assessing the product's performance during 50 hours of wear and 2-3 washes. However many industry interviewees found it challenging to factor this in to the product development process due to the short development lead times required for certain products.

Core Test	Knitwear	Shirt	Jeans	Socks	T-shirt
Dimensional Stability to washing/dry clean	+or- 5%	+or- 3%	+or- 3%	to fit sock boards or volumetric legs	+or- 5%
Pilling	Pass grade 4	n.a.	n.a.	Pass grade 4	Pass grade 4
Care Label Wash with visual assessment	expert judgement	expert judgement	expert judgement	expert judgement	expert judgement
Colour Fastness to: - Washing* / dry clean - Water or perspiration* - Light - Rubbing *(*includes shade change and staining)*	Pass grade: 4 4 4 4	Pass grade: 4 4 4 4	Pass grade 4 4 n.a. 4	Pass grade 4 4 n.a. 4	Pass grade 4 4 4 4
Spirality	3%	n.a.	n.a.	n.a.	3%
Seam slippage	n.a.	80N for 6mm opening	n.a.	n.a.	n.a.
Seam strength	n.a.	100N at breakdown	n.a.	n.a.	n.a.
Fusible lamination	n.a.	appearance after wash	n.a.	n.a.	n.a.

Figure 1. Table of recommended physical performance testing criteria for some core product types. Source: WRAP, 2014.

2. Product selection

The pilot was carried out on a range of core basic products identified as being the most appropriate for inclusion within the Longevity Protocol. The visual survey of discarded clothing had identified the key issues as being pilling of knitwear and jersey products, localised abrasion on woven trousers (especially jeans) and general colour fading across woven and knitted products (Cooper et al., 2013). Responses from UK clothing company participants had indicated that longevity is a challenging concept in an industry that is based on introducing new products each season in the context of the 'fast fashion' model that has seen prices reduce and volumes rise in recent years. However, durability (which can contribute to clothing longevity) is already being considered pro-actively by some retailers as part of a quality and value statement to the customer in certain product areas:

- 'Core basic' products in men's and womenswear (for example jeans, formal shirts, basic t-shirts and classic knitwear). Durability testing may be carried out on existing fabrics, and when new fabric bases are introduced, including those that have been engineered for durability and may be marketed as such. The product development process may have a longer cycle as these are not fashion items.
- School wear, which may undergo heavy daily wear and laundering. Improvements to fabric durability, seam strength and component attachment may be considered along with designing features to allow for growth such as expandable waists, and adjustable skirt and leg lengths.
- Risk assessed fashion products, for example where the performance of a new fashion fabric, print or embellishment is of potential concern and may undergo several washes or a durability test to assess its performance.

Due to the wide range of product types within the UK clothing industry, it is envisaged that retailers and brands will identify appropriate products to be considered suitable for the longevity approach. For the pilot, it was decided that a range of core basic adult clothing products would be used (Table 1). The products were donated by a 'value' clothing retailer and a knitwear supplier to a major UK clothing retailer.

Product	Fibre Composition	Colour
Women's crew neck jumper	100% cashmere	Light beige mix
Men's denim jeans	100% cotton	Dark blue
Men's formal shirt	65% polyester, 35% cotton	White
Men's crew neck t-shirt	100% cotton	White
Men's socks	78% cotton, 20% nylon, 2% elastane	Black

Table 1. Table of core products that underwent the longevity testing process.

3. Development of the longevity testing method

The aim of the pilot was to assess whether longevity testing could pinpoint possible areas of 'first fail' not identified by routine physical and colour fastness tests, and therefore be a valuable way of informing future product development where longevity is desirable.

In order to assess garment lifetimes it is appropriate to use a testing regime that is more

representative of lifetime wear. There is no formalised test method for clothing longevity, but retailers reported using a range of approaches to assess durability beyond the basic physical and colour fastness tests (which only give an indication of fitness for purpose rather than a representation of the garment lifetime). Methods are used individually or in combination with each other, and include the following:

- Extended wearer trials (of up to 200 hours or longer).
- Formal durability tests to replicate a number of multiple washes.
- Repeated care label wash cycles, where garments may or may not be dried in between each cycle. Products may be visually assessed at intervals.
- Extended abrasion / pilling tests.

The pilot assumed that the selected core products had already passed the basic performance tests in line with normal industry practice. A longevity testing regime was then devised based on extended wearer trials and a number of repeated care label wash cycles. As actual usage environments and behaviour by individual consumers may vary considerably, this would allow companies to specify and communicate lifetimes in terms of 'wear and wash' cycles rather than years. An attempt was firstly made to calculate the lifetime of each garment in terms of the number of hours of wear and number of washes a consumer would experience. In each case, the estimated lifetime was increased by around one third in comparison to data on current garment lifetimes (WRAP, 2013), in line with the SCAP proposals to increase clothing lifetimes (WRAP, 2012). However, it became clear that due to insufficient time within retailers' product development cycles it would be virtually impossible to accurately test garment longevity by replicating lifetime consumer wear through extended wearer trials and repeated wash cycles (Table 2).

Longevity factors	Knit-wear	Shirt	Jeans	Socks	T-shirt
Current lifetime estimate (years)	3.7	3.6	3.1	1.8	3.3
Target lifetime (years)	5	5	4	2.5	4.5
Hours of wear for the target lifetime	**1,800**	**960**	**3,600**	**1,500**	**1,350**
Hours of wear per wash	60	24	120	24	24
Average number of washes for the target lifetime	**30**	**40**	**30**	**62**	**56**

Table 2. Estimates of clothing lifetimes expressed in number of hours wear and number of washes. Source: adapted from WRAP, 2014.

Extended wearer trial procedure

Feedback from industry had confirmed that wearer trials provide valuable insights into effects of the wearing process on garments to complement insights from wash cycle tests.

The extended wearer trials were designed to be conducted for substantially longer than the 50 hour trials commonly used by many retailers and brands, in order to assess if this procedure could contribute to estimating the 'normal' life-expectancy of a garment. The trials undertaken in the pilot were intended to last for 200 hours. Used products were compared against a control garment at the end of the trial.

Wearers were issued with garments and supporting documentation to complete, which included specified care label instructions to follow. Wearers were required to complete information on hours of wear each day, method of washing and drying and frequency of washes, together with descriptions of the condition of the garment before washing, after the first wash and after each 50 hours of wear. Garments were returned to the research team at 50 hour intervals, whenever possible, and visual assessments against a control garment and dimensional checks undertaken.

Repeated wash cycle procedure

The repeated wash cycle tests were undertaken by a leading textile testing company where identical garments of the five product types underwent extended wash testing. The aim was to see if garment failure might occur before the 'lifetime' estimate used for the product category in the draft protocol. Each product was washed according to the care label either 20, 40 or 50 times depending on the product category, fibre composition and care instructions. The total number of cycles was

based on researchers' knowledge of the likely frequency of wash and wear of the specified products (Table 3). They were compared with a control garment at intervals during the process and assessed against the relevant testing criteria for that product.

The tests produced objective measurable data on the key aspects of physical performance (such as pilling, abrasion and dimensional stability) and colour fastness, enabling comparison with the wearer trial results. After the wash tests the garments were inspected by both test house and NTU staff.

Test / Trial	Knit-wear	Shirt	Jeans	Socks	T-Shirt
Number of repeated wash/dry cycles	20 (cash-mere)	40	40	50	50
Target wearer trial hours	200	200	200	200	200

Table 3. Number of repeated wash cycles and target wearer trial hours by product. Source: adapted from WRAP, 2014.

Findings of the longevity testing pilot

Extended wearer trials

A total of 12 garments across the 5 product types completed around 200 hours of wear each (2 knitwear, 2 shirts, 2 jeans, 3 socks and 3 t-shirts). The extended wearer trials proved complex and time consuming, reinforcing a concern that they may be considered unrealistic by some companies due to the time taken to complete (except for classic styles where there may be a longer lead time to market).

A higher number of trials had been attempted but some wearers abandoned the trial early due to a range of problems resulting in non-completion. These included seasonal weather and wearers becoming bored with a garment because they needed to wear it more often than normal. There also proved to be difficulty in finding reliable wearers who were able to provide constructive feedback.
Failure to complete the trial period reflected the significant commitment involved. A further concern was that it is uncertain whether triallists behaved as they would with their other clothes; for example, the cashmere jumper may have been washed more carefully if the wearer had paid for it themselves.

Wearer trial evaluation

The trials demonstrated that garments subject to an average 200 hours of wear show some signs of deterioration, although this was mostly insubstantial except in the case of cashmere knitwear and socks. The cashmere knitwear suffered from pilling and dimensional stability problems and although the garments remained within the retailer's tolerances for shrinkage, one sample (which had been washed at too high a temperature) was outside the tighter tolerances advised by the Protocol. The socks were affected by significant pilling and colour fading to a level that did not meet the test pass/fail criteria. The level of colour loss in two of the sock samples was thought to have been caused by using an inappropriate detergent that contained optical brighteners.

Repeated wash cycle tests

The wash tests proved very useful for showing the point at which garments failed against aspects of the Protocol performance criteria. The testing took around four weeks to complete for the products able to be tumble dried; the cashmere knitwear took longer due to having to be dried flat after each wash.

Particular areas of first failure were socks and jeans colour fading, cashmere shrinkage and pilling, t-shirt dimensional stability and sock pilling (Table 4).

Repeated wash cycle evaluation

An advantage of wash tests revealed by the study was that they appear more realistic than extended wearer trials given short product lead times. The number of tests ranged from 20 to 50, depending on the type of product, significantly more than the norm, which is often five care label washes carried out as a durability test by some retailers. The increased number was beneficial as certain problems were not evident until later washes. In the case of knitwear, for example, significant pilling was only evident by the 10th wash and in the case of jeans significant colour loss was only apparent after the 20th wash. With socks, pilling was evident after the 5th wash, but the rate of deterioration was only apparent after the 20th wash and colour loss was only significant after the 30th wash.

Product	Pilling Test	Dimensional stability Test	Colour change/loss assessmernt
	Pass/fail criteria: **grade 4 or better**	**Pass/fail criteria:** **knitwear and t-shirt+/- 5%** **shirt and jeans +/- 3%**	**Pass/fail criteria:** **grade 4 or better**
Knitwear 20 wash cycles (cashmere)	Grade 3 by 5th wash, grade 1-2 by 10th wash	Width shrinkage is out of tolerance by 10th wash. Whole garment shrinkage is out of tolerance by 15th wash. Shrinkage is progressive	No issues
Shirt 40 wash cycles	n/a	No issues	No issues (white shirt)
Jeans 40 wash cycles	**n/a**	Shrinkage is slightly outside tolerance from the 10th wash, but is not progressive	Grade 3 by 20th wash, grade 2 by 30th wash
Socks 50 wash cycles	Grade 3 by 5th wash, grade 2 by 30th wash	Unsatisfactory shrinkage by 40th wash	Grade 3 by 30th wash
T-Shirt 50 wash cycles	Grade 3-4 by 40th wash	Length shrinkage out of tolerance by 5th wash. Garments become progressively shorter and wider.	No issues (white t-shirt)

Table 4. Physical performance of products undergoing repeated wash cycle tests. Source: adapted from WRAP, 2014.

Conclusions

The longevity testing pilot demonstrated that carrying out a series of care label washes representing a lifetime's laundering of a garment is effective in showing a level of durability beyond that revealed through current tests. Even so, in seeking to measure longevity of clothing it is difficult to give a definitive quantified guideline for the recommended number of hours for extended wearer trials and the number of wash test cycles. Longer wearer trials (perhaps 500 hours) would be needed in order to obtain conclusive data: the 200 hour trials did not result in enough washes to allow for comparison with results from the repeated wash tests, and different drying methods were a further complicating factor. The number of wash cycles used in these tests broadly reflected the number anticipated during the lifetime of the selected garments, but the wearer trials indicated that there is considerable variation in the frequency of washes per hours of wear.

The longevity testing element within the final version of the Protocol therefore proposes a basic framework that includes wearer trials of up to 200 hours and a series of repeated wash cycle tests based on a range of generic core products. Users are advised to interpret these in the context of their own products, considering end use and fibre composition.

The potential benefit of the Protocol to companies is that a minimum standard of good practice can be embedded across the product range, reinforcing brand value. It provides a structured approach for development teams to ensure that good practice is achieved for all garments, minimising the potential cost of discovering poor quality at a later stage. It also offers workable regimes for garment testing that build the knowledge and experience necessary to predict, identify and avoid sub-standard performance and premature failure.

Further research would be needed to give more accurate recommendations for testing clothing longevity based on a specified number of wash tests and wearer trial hours. Guidelines would need to be specific in terms of fibre, fabric and garment type and could take the form of a range to allow for different user behaviour (i.e. wear frequency, user environment and laundering). This project did not directly address the context of consumer behaviour but future studies could investigate consumers' understanding of fibres, fabrics and care labels as well as patterns of wearing and washing of clothing. This could inform the development of more accurate longevity testing regimes and influence the communication of care instructions. In addition, the need for a more standardised approach to testing for longevity was highlighted by retailers; currently there is no formal test method that represents more than five care label washes.

Future research could consider opportunities to develop a new test that combines the lifetime wearing and washing impact on clothing in order to give an accurate estimate of garment lifetime. Developing an accelerated method that is more representative of the range of consumer behaviour could also be effective in reducing the time taken to carry out longevity

testing compared to the extended wearer trials and repeated wash cycle tests used in the development of the Longevity Protocol.

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