



# Are second-hand shell jackets better than users think? A comparison of perceived, assessed and measured functionality throughout lifespans

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## ABSTRACT

Using the case of outdoor shell jackets, this research studies obsolescence and potential lifespan extension by re-examining how product functionality, objectively and subjectively, develops over the course of product lifespans. In particular, the study focuses on second-hand stores for outdoor products. Functionality is indicated by user perceptions, visual assessments, laboratory measurements and price data, collected at first use, second-hand resale and end-of-life. Perceived functionality and price decline more rapidly (5–6 % per year) than assessed and measured functionality (around 3 % per year). This could be explained by properties related to appearance, which are not assessed nor measured but influence user perceptions and price. Discontentment regarding such properties appears more relevant for obsolescence than inadequate performance, suggesting the potential for design for attachment and timeless design. The relative stability of measured functionality over time suggests that a barrier for second-hand sales, concern about performance, could be ameliorated by a potential functionality-label.

## 1. Introduction and aim

The concept of a circular economy revolves around the idea of reducing the environmental impact of consumption by avoiding or reversing obsolescence to extend product lifespans. The term “obsolescence” is used here to describe a state at which one use span of a product ends, after which it is either discarded, and hence reaches end-of-life, or is used for an additional use span through circular economy measures such as reuse or repair (den Hollander et al., 2017; Proske and Finkbeiner, 2019).

There are various reasons why products become obsolete to users, including emotional, psychological, functional and economic (Cooper, 2004). Regardless of the type, obsolescence can be understood as to occur as a result of misalignments between user requirements and the state of product properties (André and Björklund, 2023; Van Nes, 2016). For instance, functional obsolescence occurs when the state of the performance of a product no longer fulfils the user's performance requirements. This can result from either an increase in the user's requirements or a decline in the product's performance since acquisition. In the literature, this is often described as a distinction between objective and subjective obsolescence (Cooper, 2004; Proske and

Finkbeiner, 2019). In addition to objective and subjective reasons, obsolescence can concern any given product property which users consider relevant. Thereby, reasons for obsolescence are diverse and dynamic. Understanding the reasons for obsolescence, encompassing both states of product properties and user requirements on product properties, is crucial for extending product lifespans through circular economy measures (Van Nes, 2016). Such knowledge can be used, on one hand, to inform design strategies to avoid obsolescence in the first place (Van Nes, 2016), and on the other hand, to match states of obsolete products with requirements of potential second-hand users (i.e. reversing obsolescence). As yet, there is a lack of research that aims to contribute to such knowledge (Cooper and Claxton, 2022).

The European Union's Circular Economy Action Plan (European Commission, 2020) has identified textiles as a priority sector due to its significant environmental impact and potential for increased circularity. Shell jackets used in outdoor recreational activities, such as hiking and skiing, are interesting textile products in the context of obsolescence and circularity considering that their obsolescence is commonly linked to both objective and subjective reasons. To illustrate, users typically have high requirements and expectations on objectively measurable performance-related product properties such as water penetration

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resistance and repellency, breathability and air permeability (European Outdoor Group, 2015) and many users also have high requirements on more subjective properties, such as appearance (André and Björklund, 2023).

Previous research has found that reluctance to buying shell jackets second-hand is often connected to a lack of knowledge about the level of performance and quality, since these properties may have declined during the first use span (André and Björklund, 2023). The same concerns are also relevant for other, non-technical, clothing (Gullstrand Edbring et al., 2016; Hur, 2020; Laitala and Klepp, 2018). For such reasons, it has been discussed that making information about functionality and expected longevity available to potential second-hand users, for instance, through digital product passports (European Commission, 2023) could help increase the circularity of clothing (Cooper and Claxton, 2022). Users typically expect price to be indicative of functionality but the strength of this relationship has been questioned (Cooper and Claxton, 2022; Rao, 2005). To the best of our knowledge, no previous research has investigated this relationship in the context of second-hand products, nor compared how functionality, in terms of both objective and subjective properties, changes over the course of product lifespans.

This study aims to address these research gaps to contribute to knowledge that can help inform strategy and policy to extend lifespans of shell jackets and potentially, other technical textile products. The study investigates and compares objective and subjective functionality of shell jackets throughout their lifespans, more specifically, in terms of user perceptions, visual assessments performed by researchers, laboratory measurements (of e.g. water repellency) and price. In addition, this article discusses the limitations and opportunities of addressing obsolescence of shell jackets through, for instance, a product functionality-label, building and expanding on an article published in the proceedings of the PLATE 2023 Conference (André and Swenne, 2023).

## 2. Research background

This study was conducted in the context of the research and

collaboration program Mistra Sport and Outdoors. A central theme within this program is environmental sustainability of equipment for sport and outdoor recreational activities. This study encompasses and combines the knowledge from two principal research areas: life cycle assessment (LCA) of circular economy measures (CE LCA) and material testing within the sport and outdoor sector (Fig. 1). Data from material tests on functionality are valuable to LCAs, inter alia, because deterioration of functionality over lifespans is recommended to be accounted for in LCAs (European Commission, 2011) but in practice, this is rarely done (presumably due to lack of data). Conversely, a life cycle perspective is beneficial to material testing within the sport and outdoor sector because it opens new research avenues (for instance, second-hand products have been less researched) and contexts where results can have valuable utility.

With this in mind, it was decided that research in both areas would be connected to the same case study. The case study included three second-hand stores in Sweden focused on resale of used outdoor clothing and equipment such as skis, backpacks and shell jackets (Fig. 1): Tracks Recycle, Re-Adventure and Mountain Recycle located in Gothenburg, Stockholm and Åre respectively. Shell jackets were chosen as a suitable product since they are used for a variety of sports and outdoor activities, their initial high economic value means that they are frequently sold second-hand (both online and in the studied second-hand stores) and because their obsolescence is dependant on both objective and subjective reasons.

Fig. 1 presents an overview of the research connected to this paper. The analysis in this paper synthesizes knowledge from, most directly, André and Swenne (2023) and André and Björklund (2023), and, additionally, other forthcoming publications (see Fig. 1). An initial research effort was the development of a framework designed to improve the inventory of the use phase in CE LCAs (André and Björklund, 2022, 2023). More specifically, the purpose of this framework was to facilitate accounting for influential, but commonly overlooked aspects, such as differences in functionality between compared alternatives (Kjaer et al., 2016) such as new and second-hand products,

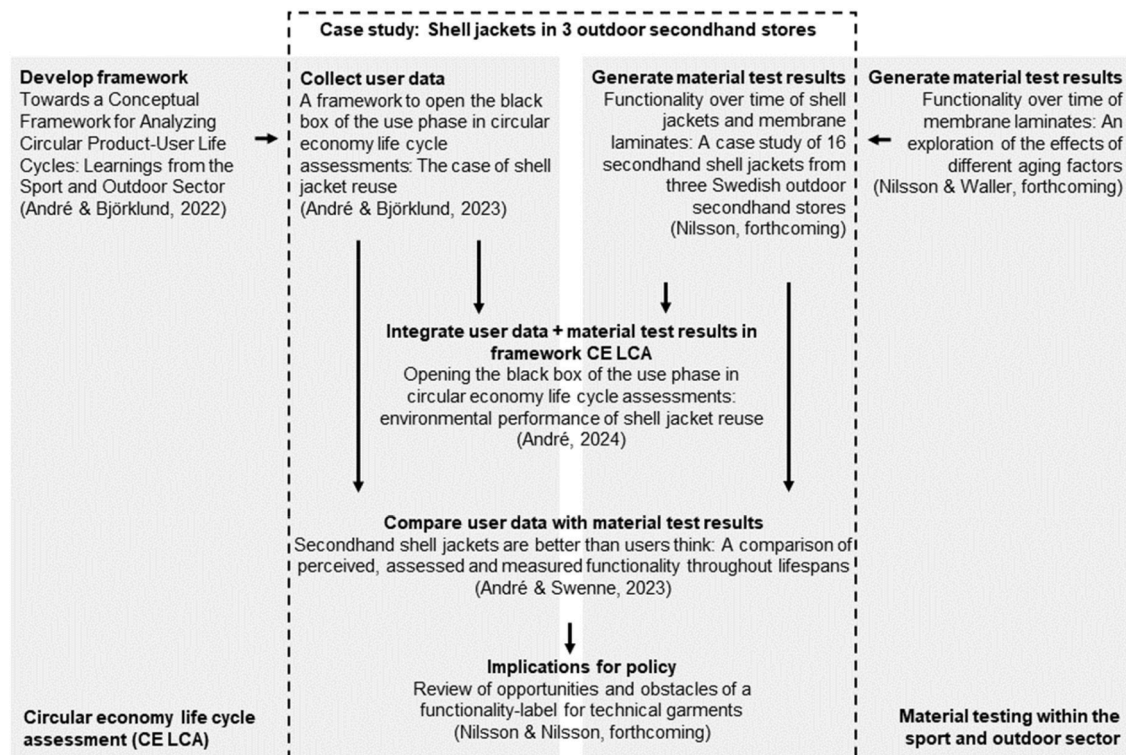


Fig. 1. Overview of the research context and the previous studies on which this study is based.

and connected to such functional non-equivalence, potential rebound effects (Harris et al., 2021; Zink and Geyer, 2017). The framework was thereafter used to collect data concerning, inter alia, how users perceive the functionality of shell jackets throughout their lifespans (André and Björklund, 2023). The methods for this data collection were mainly surveys distributed to shell jacket users, and additionally, interviews with store managers of the outdoor second-hand stores. The paper by André and Björklund (2023) contributed significantly to the current paper with, firstly, data on perceived functionality over time, and secondly, data that help interpret differences between the functionality indicators, for instance, user requirements and reasons for product replacement. From the material testing perspective, the functionality of shell jackets throughout their lifespans was explored from a more objective standpoint. Studies investigated the influence of ageing stressors on functionality and how the functionality of shell jackets developed over time in terms of four performance-related properties: water penetration resistance and repellency, breathability and air permeability (see Fig. 1).

### 3. Material and methods

The following sections describe the material, methods and assumptions regarding the functionality indicators: perceived, assessed and measured functionality, and price. Following these descriptions, Table 1 provides an overview of the product properties and shell jacket components each functionality indicator encompasses.

#### 3.1. Perceived functionality and price

Data on perceived functionality were collected through surveys targeting users from two of the three second-hand stores (Tracks Recycle and Re-Adventure) and five conventional stores for outdoor clothing and equipment (André and Björklund, 2023). The users who either sold or bought jackets at the second-hand stores rated the condition of the jackets according to the scale "New-Excellent-Good-Decent-Poor" at the time of second-hand resale. They also reported on original and second-hand sales price. Purchasers of shell jackets reported on how long they expected to use the shell jackets and what condition they expected them to be in, or alternatively, what they expected to do with them at the end of use (used as a proxy for expected condition at

end-of-life). In the conventional stores, users reported on price, expected lifespan and expected condition at end-of-life. The surveys were distributed through QR-codes in the conventional and second-hand stores, as well through the communication channels of the second-hand stores. In total, the surveys had 71 respondents, 51 from the second-hand stores and 20 from the conventional stores. (André and Björklund, 2023)

The pricing of shell jackets in the second-hand stores generally involves a 50 % reduction from the original retail price. Then, additional reductions are applied depending on the age and condition (e.g. wear, defects and stains) of the jacket. This assessment is done mainly through visual inspection, relying on the knowledge and experience of the staff (i.e. a structured protocol is not used). In addition to the visual inspection, the operability of components is tested, e.g. zippers, hook and loop tapes and cords (J. Oxling, personal communication, April 4, 2023; K. Olivensjö, personal communication, April 19, 2023). Jackets in new condition and from popular brands can be exempt from the standard 50% reduction from the original retail price, whereas jackets that remain unsold undergo further price deductions (J. Oxling, personal communication, April 4, 2023; K. Olivensjö, personal communication, April 19, 2023). Due to the lack of access to material testing equipment to measure performance-related properties, e.g. water repellency, the second-hand stores cannot provide warranty for second-hand shell jackets (K. Olivensjö, personal communication, April 19, 2023).

#### 3.2. Assessed and measured functionality

Data on assessed and measured functionality were collected from 16 second-hand shell jackets and 10 end-of-life shell jackets. The sample of shell jackets included a variety of technologies, materials, pricing and age. The second-hand shell jackets were bought from the outdoor second-hand stores. The end-of-life jackets were received from friends and colleagues from the Sports Tech Research Centre at Mid Sweden University. The end-of-life jackets were no longer used due to their poor condition (e.g. wear and tear) and were deemed to have no monetary value.

To conduct a structured assessment of functionality of the second-hand and end-of-life jackets, a visual inspection protocol was established. The protocol focused on 14 main shell jacket components: zippers (front, ventilation, outer and inner pockets), cuff hook and loop tapes, bottom and hood cords, hood cap, hanger loop, fabrics (outside, inside, cuff, bottom), and sealed seams. All components were assessed in accordance with the inspection protocol, using the same rating scale as in the user survey: "New-Excellent-Good-Decent-Poor". The assessed functionality for each jacket was calculated as an unweighted average of all component ratings.

Measured functionality includes four performance-related properties related to the fabric: water penetration resistance and repellency, breathability and air permeability. To evaluate the measured functionality of the second-hand and end-of-life shell jackets, six samples in total were cut from each jacket: two from the hood (left and right), two from the shoulders (left and right) and two from the back (upper and lower) (see Fig. 2). Water repellency and air permeability were tested on all six samples while water penetration resistance and breathability were tested on two samples each. Water penetration resistance was tested on the left shoulder and lower back, and breathability on the right shoulder and upper back. Water penetration resistance and breathability were not tested on the hood due to the presence of seams on some of the hood test samples. However, the seams did not influence the air permeability and water repellency test results, which could be tested on all six samples.

All test methods were based on ISO (International Organization for Standardization) standards, except the test for air permeability, which was tested with an Akustron air permeability tester (Rycobel, 2023). The water repellency and breathability test methods were based on ISO 4920:2012 (ISO, 2012) and ISO 15496:2018 (ISO, 2018b). Water repellency was determined by spraying 250 millilitres of water on a

**Table 1**

Overview of product properties and components included in the four functionality indicators: perceived, assessed and measured functionality and price.

Product property	Perceived	Assessed	Measured	Price
Performance:	Yes,	No	Yes	No
- Water penetration resistance	implicitly through use <sup>a</sup>			
- Water repellency				
- Breathability				
- Air permeability				
Quality	Yes	Yes	No	Yes
Appearance:				
- Wear and tear, stains etc.	Yes	Yes	No	Yes
- Fashion	Yes	No	No	Yes
<b>Components</b>	All	14 main components (specified in the text)	Fabric (hood, shoulders and back)	All

<sup>a</sup> Except for the small share of users who responded to the survey directly in the stores at the time of purchasing a second-hand shell jacket. Most responses were received after communication about the survey through the digital channels of the second-hand stores. This implies that most respondents had used the shell jackets before answering the survey.



Fig. 2. Marked positions of the samples that were cut and tested for measured functionality.

mounted test sample positioned at a specified distance and an angle of 45° below a spray nozzle (ISO, 2012). A rating (ISO 5-0) was attained by comparing the appearance of the test sample after being sprayed with descriptive standards and photographs. Breathability was determined by mounting a test sample together with a membrane on a ring holder submerged in a water bath (ISO, 2018b). A cup with saturated potassium acetate covered with a second piece of the same membrane was then weighed and inverted above the test sample in the ring holder. After 15 min, the cup was removed and re-weighed. Based on the difference in weight and by using the result of a control test without a test sample, the breathability of the test sample was calculated and corrected for the influence of the two membranes. The test methods for water repellency and breathability were not fully compliant with the ISO standards since the temperature ( $20.0 \pm 2.0$  °C) and relative humidity ( $65.0 \pm 4.0$  %) requirements of ISO 139 (ISO, 2005) were not met during testing. The test laboratory had a constant temperature of 23 °C and relative humidity of 28%. The water penetration test method based on ISO 811:2018 (ISO, 2018a) was performed in a conditioned textile lab. In accordance with ISO 811:2018, water penetration resistance was determined by subjecting the outer surface of the test sample to a steadily increasing water pressure until penetration occurred in three places (ISO, 2018a). The pressure at which the water penetrated the test sample at the third place was noted as the water penetration resistance. However, the test method used was not fully compliant since the test method endpoint included not only three drops but also full surface perspiration and leakage due to fabric failure.

### 3.3. Assumptions and calculations

To plot functionality over time, data on perceived, assessed and measured functionality, all expressed on a scale of 0–1, were combined with data on use span and lifespan (or age as a proxy). The plot of measured functionality over time consisted of the average values obtained from the tested samples as well as from assumptions on original performance (=1). New jackets were assumed to resist 20000 mmH<sub>2</sub>O, have a breathability of 17,857 g/m<sup>2</sup>/24 h and be fully windproof (0 mm/s) and water repellent (ISO 5). The assumption on water penetration resistance was set by the capacity of the test equipment, at 20000 mmH<sub>2</sub>O. Breathability data was not available for all jackets, so where missing, the average data from the jackets with existing data was used. For breathability, three jackets were excluded due to unreasonably high results, for instance, due to broken fabric. Similarly, one jacket was excluded from the results on water penetration resistance due to test

failure.

To plot perceived and assessed functionality, the following rating was used: New = 1; Excellent = 0.8; Good = 0.6; Decent = 0.4; Poor = 0.2. In addition, since price may be perceived as an indicator of functionality (Rao, 2005; Cooper and Claxton, 2022), price was compared to the other functionality indicators. The plot of price over time consisted of price data at the point of second-hand resale, normalized to the average original sales price of the jackets (3942 SEK). The properties and components included in the measured and assessed functionality were weighted equally.

Missing data points regarding the age of second-hand and end-of-life jackets, were replaced by average values from each jacket group. For price however, data were missing for too many of the jackets in the user survey to be replaced by an average value. These jackets were instead excluded from the analysis of price over time.

The results (Section 4) are presented as linear representations and data points. The use of linear representations is for the purpose of facilitating comparison between the functionality indicators, and they should not be regarded as accurate representations of the data points. However, they are deemed adequate for the purpose of visualizing key result patterns.

## 4. Results and analysis

This section demonstrates how the functionality of shell jackets develops over time. We first focus on the three main indicators of functionality: perceived, assessed and measured (Fig. 3). Thereafter, results on measured functionality are disaggregated into the constituent properties: water penetration resistance, water repellency, breathability and air permeability over time (Fig. 4). Lastly, the comparison is broadened to also include price (Fig. 5).

Comparing the three main functionality indicators, perceived functionality decreases most rapidly over time, at around 6% per year. Assessed and measured functionality decrease at a slower rate, both around 3 % per year.

Fig. 4 presents measured functionality over time, together with the constituent properties: water penetration resistance, water repellency, breathability and air permeability. Air permeability remains stable over time while water repellency decreases at a rate of approximately 2.5 % per year. The most significant functionality deterioration is observed in breathability and water penetration resistance, which decrease at around 5% per year.

In Fig. 5, perceived, assessed and measured functionality over time is

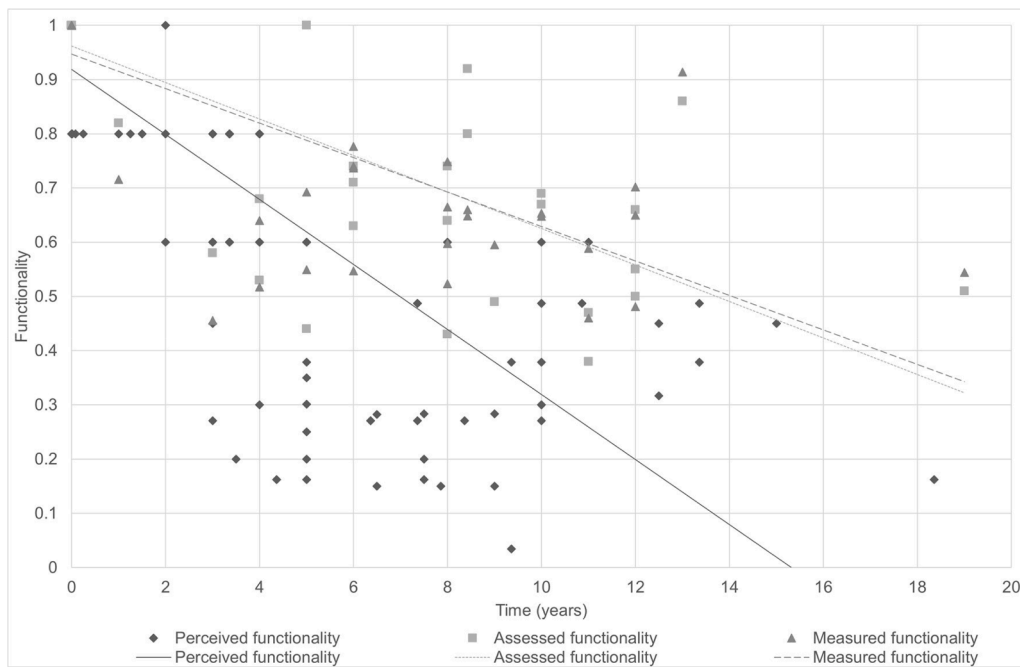


Fig. 3. Perceived, assessed and measured functionality (on a scale of 1–0) over time.

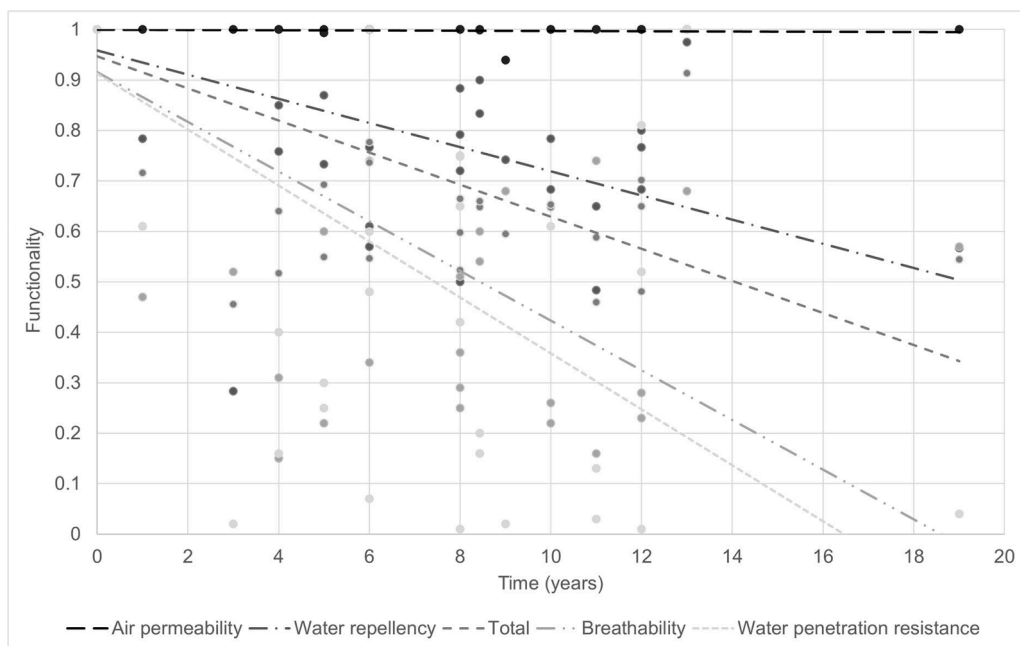


Fig. 4. Measured functionality and the four fabric properties it comprises, water penetration resistance, water repellency, breathability and air permeability, over time.

presented together with price. Price decreases more rapidly than assessed and measured functionality but more slowly than perceived functionality, at a rate of approximately 5% per year. Regarding the potential user expectation of price being an indicator of functionality (Cooper and Claxton, 2022; Rao, 2005) the study indicates a closer relationship to perceived, than to assessed and measured functionality.

The overall pattern of these results, that perceived functionality and price decrease more rapidly than assessed and measured functionality, can be explained, in part, by the difference in terms of what properties are included in the respective functionality indicators (Table 1). Since perceived functionality includes more properties than measured

functionality, for instance related to appearance, the results do not necessarily mean that users perceive the performance-related properties to be worse than they really are. On the contrary, users' survey responses regarding motivations to sell shell jackets suggest that sellers perceive the performance-related properties to be highly functional (André and Björklund, 2023). In other words, according to the sellers at least, the perceived functionality seems to be somewhat aligned with measured functionality. Unfortunately, there is no data on how the buyers of second-hand shell jackets perceived the state of the performance-related properties alone. However, users who bought shell jackets in conventional stores reported that the main reason why they do not buy shell

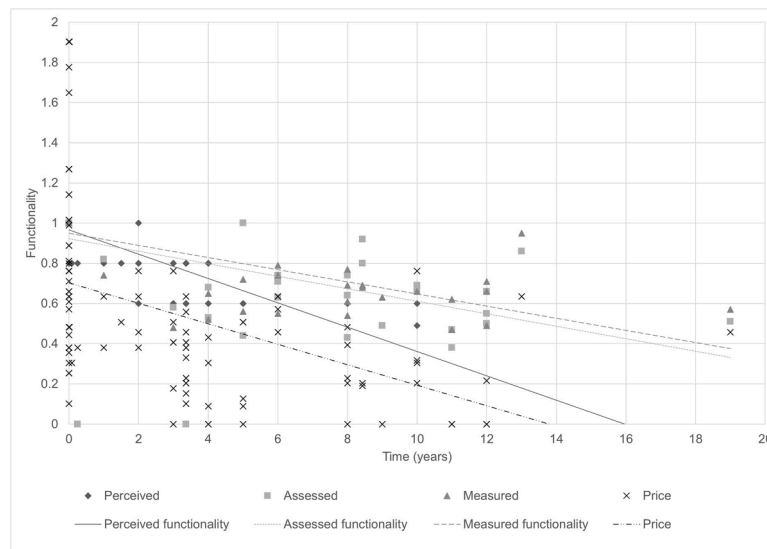


Fig. 5. Perceived, assessed and measured functionality as well as price over time.

jackets second-hand is because they are concerned with performance-related properties and quality (André and Björklund, 2023), corroborating previous findings on clothing (Hur, 2020). If buyers of second-hand shell jackets can be assumed to share such concerns but value the upside (high-quality products from reputable brands at a significantly lower price (Machado et al., 2019)), it is plausible that they suspect performance-related properties to be worse than they really are but are willing to accept it. In summary, some of the differences between perceived functionality compared to assessed and measured functionality are due to users perceiving performance-related properties to be worse than they are and some of the differences are due to the differences in included properties in the functionality indicators.

As regards the latter, properties included in perceived functionality and price, but excluded in assessed and measured functionality, such as appearance, are likely to contribute to the overall pattern of perceived functionality and price declining at a higher rate than measured and assessed functionality. Discontentment with the appearance of shell jackets is a somewhat more relevant reason for obsolescence compared to discontentment with performance-related properties (André and Björklund, 2023). In addition, according to the in-store visual inspection conducted as part of the price setting, 16% of the shell jackets had stains (A. Mangs Bergmark, personal communication, August 24, 2021), which further supports that discontentment with appearance could be influential for the differences between the mentioned functionality indicators. The most relevant reason for obsolescence was that users had bought or planned to buy another shell jacket which, combined with other data, could be connected to a desire for novelty (André and Björklund, 2023). The relevance of discontentment with appearance (except in the cases of stains) and the desire for novelty points to the potential for producers to adopt design strategies such as timeless design and design for attachment (Mugge et al., 2015; Van Nes, 2016) to increase the willingness of users to use shell jackets for longer periods of time and thus avoid obsolescence. Design for attachment aims to strengthen the person-product relationship (Mugge et al., 2015). This could mean designing products that “age with dignity”, as e.g. jeans and leather jackets (Mugge et al., 2015), which, in addition, could strengthen person-product relationships by enhancing “symbolic meaning attribution” (Casais et al., 2018), e.g. reminding users of memories of past use such as outdoor adventures (Mugge et al., 2015).

The finding that measured functionality of performance-related properties decreases rather slowly, combined with the survey responses indicating that users’ concerns about performance are a key barrier to second-hand sales (André and Björklund, 2023), suggests that

providing information about shell jackets’ performance could be effective as a means to increase second-hand sales and thus reverse obsolescence of shell jackets. Implementing control measures to ensure performance and quality has been highlighted as an essential strategy to increase the second-hand sales of clothing in general, and particularly, for quality-sensitive users (Hur, 2020), which many shell jacket users are (André and Björklund, 2023; European Outdoor Group, 2015). Accordingly, studying the feasibility and effectiveness of implementing a functionality-label for second-hand products based on measured or assessed functionality is identified as a topic for future research.

As a first step in this research, opportunities and obstacles with implementing such a functionality-label have been identified. A functionality-label would require development of a standardized protocol comprising new material test methods that are non-destructive. Furthermore, it needs to be possible to conduct the testing in-store, which implies additional requirements on time, expertise and equipment. Amongst the test methods used in this study, only the air permeability test currently fulfils these criteria. Considering that we have shown that air permeability remains stable over time, this property may not even require testing. As regards the other performance-related properties, there are only non-standardized or “homemade” methods, such as “shower-tests”, used internally by outdoor companies working with used garments. To be used for functionality-labelling, the reliability of these methods needs evaluation, or new testing methods and protocols will need to be developed. If no new test methods can be identified that fulfil these criteria, an alternative could be to use a structured visual test protocol given the demonstrated correlation between measured and assessed functionality.

There are a variety of product labels for new textile products that concern, for instance, environmental and social performance, but there are none for second-hand products and none that concern functionality. There are however initiatives spanning more sectors than textile that aim to collect and provide lifecycle information, for instance, the EU Digital Product Passport and the French reparability and durability labels. The EU Digital Product Passport intends to make available a set of digital data linked to a product, e.g. composition, reparability, disassembly and recycling options (European Commission, 2023). The French reparability label is set to be replaced by a durability label in 2024 (Right to Repair, 2021). Research on durability labels suggests they can be effective in influencing consumer decisions but there is also a risk that too many labels could cause confusion (Milios and Dalhammer, 2023). A functionality-label for second-hand products seems to be well aligned with initiatives such as the EU Digital Product Passport

and the French durability-label in the sense that they all aim to provide information that is useful for extending product lifespans. This alignment could imply a potential for streamlining information to support effective consumer decision-making while minimizing the number of labels.

## 5. Discussion

Because of limitations in sample size, both for jackets and survey respondents, which were in turn limited by the total number of shell jackets in the studied second-hand stores, the results of this study are only indicative. Nonetheless, the overall result pattern, that perceived functionality and price decrease more rapidly than assessed and measured functionality, is considered reliable since it is supported by data from the user surveys (André and Björklund, 2023). The result is also supported by a larger survey to shell jacket users and manufacturers, which shows a noticeable discrepancy between technical lifespans, and how long users expect to use them, which relates to measured and perceived functionality respectively (European Outdoor Group, 2015). Still, future research could investigate the robustness of this pattern by obtaining an increased sample size of shell jackets. Such a validation could be part of the future research that will study the implementation of the proposed functionality-label, which, in addition to the studied second-hand outdoor stores, could include stores that sell both new and second-hand outdoor products as well as circular initiatives from outdoor product manufacturers.

The generalizability of the result to other product types could also be studied. Since concern about quality and performance is a barrier to second-hand sales of clothing (see e.g. Hur (2020)), and specifically for technical products such as shell jackets (André and Björklund, 2023), it is likely that concerns about performance is a relevant barrier to second-hand sales of other technical outdoor products such as tents and backpacks. If so, the discussed functionality-label could be a relevant measure to reverse obsolescence of such products as well. However, perceived functionality of such products is hypothesized to be less influenced by subjective properties such as appearance compared to technical clothing, such as shell jackets. Hence, timeless design could be less relevant for such products. Design for attachment, on the other hand, has been discussed as potentially suitable strategy for products such as tents (Mugge et al., 2015).

Data on the original performance of the fabric-related properties could not be found for all jackets, despite that this is normally stated in the product specification. Assumptions were therefore used for original water penetration resistance and breathability. The original breathability assumption of 17,857 g/m<sup>2</sup>/24 h was based on the average of the available data. The assumption for original water penetration resistance was limited by the test equipment capacity of 20000 mmH<sub>2</sub>O and the average (25000 mmH<sub>2</sub>O) could therefore not be used. However, the use of 25000 mmH<sub>2</sub>O as original water penetration resistance would only change measured functionality slightly, decreasing at 3.1% instead of 3.2% per year (assuming all test samples that reached the test equipment limit of 20000 mmH<sub>2</sub>O would reach 25000 mmH<sub>2</sub>O).

A key topic of discussion is that perceived, assessed and measured functionality of shell jackets are compared although these functionality indicators do not include the same components and properties (Table 1). Perceived functionality includes all shell jacket components and properties, including appearance, while assessed functionality includes 14 components and measured functionality only includes the fabric. This could be viewed as a comparison of “apples and pears”, in other words, a comparison of alternatives that are too different to be compared. However, such a comparison is indeed valuable if the limitations of the comparison are kept in mind. To illustrate, apples and pears can be compared on the basis of being fruits (c.f. functionality indicators) while bearing in mind that apples are not pears (e.g. perceived and measured functionality do not include the same product properties). Accordingly, it is not possible to conclude that shell jackets are perceived to be worse

than they are in terms of performance-related properties, based solely on the quantitative results (Figs. 2 & 4). Using additional data from user surveys (André and Björklund, 2023) for interpreting the quantitative results does however provide support for this conclusion (discussed in Section 4 and the next paragraph).

It is important to note that shell jacket components and fabric properties included in assessed and measured functionality were weighted equally, and that alternative weightings reflecting their respective importance could influence the results. Concerning assessed functionality, the functionality of the front zipper and fabric may be considered more important than, for instance, the inner pocket zipper. Since the fabric components were rated low compared to the other shell jacket components, such a weighting would imply a more rapid deterioration of assessed functionality. Similarly, for measured functionality, water penetration resistance could be argued to be more important to the overall functionality than breathability. Since water penetration resistance is the performance-related property that deteriorates most rapidly over time, such a weighting would imply a more rapid deterioration of measured functionality. For perceived functionality, weighting properties in this way may be done unconsciously by users. For instance, when asked about the importance of the respective product properties essentially all users considered performance (e.g. water penetration resistance) and quality to be “very important” and appearance was on average considered “moderately important” (André and Björklund, 2023). The result that users have high requirements on performance-related properties is further supported by another survey (European Outdoor Group, 2015). Thus, when asked about the condition of shell jackets (i.e. perceived functionality) it is conceivable that users gave higher weights to performance and quality than appearance. This would imply that perceived functionality and measured functionality are more comparable in terms of what properties they concern and that users consider the performance-related properties to be worse than they really are. On the other hand, users may have underestimated the importance of appearance in their responses to this question due to social desirability bias (Stocké and Hunkler, 2016).

## 6. Conclusion

To our knowledge, this study is the first investigation of how functionality, as indicated by perceptions, assessments, measurements and price, changes over the course of product lifespans. The key finding is that perceived functionality and price both decline more rapidly than assessed and measured functionality. This result is explained by the fact that subjective properties such as appearance are included in perceived functionality and price but not in measured and assessed functionality, and that users seem to perceive performance-related properties to be worse than they are.

Our results point to the potential of product design and information policy to, respectively, avoid and reverse obsolescence, and to extend product lifespans of shell jackets and potentially to other technical textile products. The indication that relevant causes of obsolescence are related to discontentment with appearance and desire for novelty, suggests that design strategies such as design for attachment and timeless design could help avoid obsolescence. Furthermore, a functionality-label has been identified as a strategy to help break down an important barrier to second-hand sales, namely that users are concerned and lack information about the functionality of second-hand technical garments. However, implementation of a functionality-label requires further research to develop reliable material test methods which, amongst other criteria, need to be non-destructive, in contrast to most of the material test methods used in this study.

## CRedit authorship contribution statement

**Hampus André:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data

curation, Conceptualization. **Louisa Nilsson:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

Data will be made available on request.

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