

Article

A Product Line Analysis for Eco-Designed Fashion Products: Evidence from an Outdoor Sportswear Brand

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Abstract: With the increasing awareness of sustainability, eco-design has been an important trend in the fashion industry. Many fashion brands such as Nike, Adidas, and The North Face have developed sustainable fashion by incorporating eco-design elements. Eco-design is an important part of sustainable supply chains. In this paper, we conducted a product line analysis of eco-designed products from a famous outdoor sportswear brand, Patagonia. We collected Patagonia's 2017 Spring Season product line data and analyzed the data through descriptive analysis, factor analysis and correlation analysis. We found that Patagonia mainly uses organic, recycled, and traceable materials in their eco-product line development. We identified that the usage of eco-materials may significantly affect the number of color choices and product weight as well as gender difference, pattern design, product fit and online reviewers' opinions at Patagonia. We argued that Patagonia should focus on functionality more than aesthetics in eco-design. We discussed how sustainable fashion firms should manage eco-design in the supply chain.

Keywords: eco-design; sustainable fashion; product line analysis; Patagonia; sustainable supply chain

1. Introduction

Fashion and textile is one of the most polluting industries in the world. Every stage of the fashion and textile supply chain threatens our planet and resources [1]. For example, more than 20,000 L of water are consumed to produce one kg of cotton, many chemicals are used in manufacturing fabric for dyeing and finishing processes, and large amounts of carbon dioxide are emitted to produce one t-shirt [2]. Consumers are aware of the importance of sustainability and are willing to purchase sustainable fashion products even though they are more expensive than conventional ones [3].

Sustainable fashion is developed through an eco-design approach. Eco-design is defined as a variety of design aspects that relate to a product's environmental impacts [4]. Eco-design is an important part of sustainable supply chains and significantly influences the entire supply chain processes, including eco-material selection, process design, production, distribution, and retail [1,5–7]. With the increasing awareness of sustainability, many fashion brands such as Nike, Adidas, and The North Face have incorporated eco-design elements into new products [8]. The global outdoor sportswear brand Patagonia develops its sustainable product line by using eco-friendly materials such as recycled down, organic cotton and traceable down [9]. Earlier studies have indicated that design processes influence decision-making in the fashion supply chain; as a result, eco-design is critically important for sustainable supply chains [10,11]. However, literature that examines the impact of eco-design on product line development is rare.

In this paper, we conducted a product line analysis for eco-designed products. Our aim was to explore the impact of eco-design on product line development. We collected product line data from a famous outdoor sportswear brand, Patagonia. Patagonia is an American outdoor sports brand founded in 1973 that mainly sells sustainable outdoor clothing. Patagonia enjoys a great reputation for selling sustainable fashion products [9]. Learning the practices of Patagonia is beneficial for providing managerial insights to other fashion firms and supplementing the theories of sustainability in terms of eco-design. In this paper, we attempted to answer the following questions:

- How does eco-material usage influence design elements such as product weight, product fit, pattern design and color choices?
- How do sustainable fashion firms manage eco-design in the supply chain?
- How will online consumers evaluate eco-design?

To address these questions, we collected the in-season product line data from Patagonia's official website. We analyzed data through descriptive analysis, factor analysis and correlation analysis to identify patterns regarding product weight, product fit, pattern design, color choices and online consumers' opinions in relation to fashion eco-design. The organization of the rest of this paper is given as follows. We first show the related literature in Section 2; Section 3 describes research methods; Section 4 summarizes our results; Section 5 discusses managerial insights; and Section 6 concludes the paper through providing limitation and future research.

2. Related Literature

Three streams of literature are reviewed in this section.

2.1. Eco-Design and Sustainable Fashion

Eco-design can refer to Design for Sustainability (DfS), Design for Environment (DfE), and Design for Recycle (DfR) in fashion [12–15]. Specifically, DfS relates to both social and economic elements of production through its Triple Bottom Line (i.e., people, profit, and planet) [16]. DfE implies that the product development process needs environmentally-conscious consideration [17]. DfR aims to extend products' lifetime by optimizing products for repair, refurbishment and the recovery of materials [4]. To realize the effectiveness of eco-design, designers implement proper eco-design strategies such as DfS, DfE and DfR to influence consumer habits, lifestyles and practices in terms of sustainability [18].

Eco-design is more and more popular in the fashion industry due to consumers' increasing awareness of sustainability [7]. Fashion eco-design aims to develop products with a reduced impact on the environment and society while meeting consumer needs in terms of fashion trends [19]. Fashion eco-design focuses on eliminating harmful consequences in the supply chain and operations as well as optimizing raw-material selection by considering both green and aesthetic principles [4]. In other words, eco-design products should not only satisfy aesthetic demands and follow fashion trends, but also integrate the Triple Bottom Line elements into the design process throughout the life cycle [8].

Eco-design requires close collaboration within the fashion supply chain [7]. The extant literature shows that both producers and designers lack knowledge of what the consumer desires in the eco-fashion sector [20]. To develop sustainable fashion products, designers and manufacturers are encouraged to share resources for realizing eco-design. Gam [21] proposed a sustainable fashion design process model, which was called "Cradle to Cradle Fashion Design (C2CAD)". This model encourages designers and manufacturers to work together at the stage of sample making, and collaborate with manufacturers and other supply chain members in terms of fabric selection for eco-product development. Subic et al. [22] argued that the sustainability criteria should be integrated into product/process sustainability targets when designers develop new sportswear products.

The eco-labels with certified information are important to make consumers aware of the importance of sustainable products [23–25]. Etsy and Winston [26] argued that eco-labels are the best venue to show the elements of eco-design that are driving consumers to make purchase decisions

on eco-products. Clancy et al. [18] investigated three Sweden fashion companies and analyzed the relationship between eco-labels and fashion design. They found that eco-labels could guide the consumers to take care of their products and extend their lifespan. Moreover, some consumers believe that hand-made fashion products are more sustainable because of energy savings during the production process [26]. This implies that sustainable production process is one of the icons in eco-labels that show product sustainability. In this paper, we study eco-design in an outdoor sportswear company. We classify eco-design into aesthetic and functional aspects, since both aesthetic and functional aspects affect decisions in operations and supply chain management.

2.2. Eco-Design and Product Line Development

Eco-design is vital for sustainable fashion product line development, as many decisions in terms of sustainability are decided at the design stage [10,27]. According to the theory of the Triple Bottom Line, the impact of eco-design could be divided into three aspects: economic, social and environmental. Design includes developing manufacturing processes, selecting materials, managing transportation modes, and extending product life cycles [28]. Clark et al. [16] proposed four key approaches to eco-design in the real world of fashion: (1) new product design, (2) redesign, (3) incremental design, and (4) radical design. Lee [29] demonstrated that sustainable design and sustainable production means designing and producing products with less resource consumption and less impact on the environment. Köhler [4] argued that eco-design mainly addresses a variety of aspects in a product's environmental impacts such as material selection (e.g., non-toxic substances, organic materials, recyclable materials), choices of production processes (e.g., low-carbon emission and waste production), and end-of-life treatment (e.g., repair and recycle). Cimatti et al. [30] examined eco-design and sustainable manufacturing in luxury fashion. They argued that life-cycle assessments (LCAs) could enhance sustainability in fashion by describing the case of a prestigious Italian luxury fashion brand. De Angelis et al. [31] evaluated the impact of design on luxury fashion green products. They conducted three experiments and identified that the new green luxury product design is more similar to the luxury company's previous models instead of the similar models produced by green companies.

For eco-material selection, sustainable fabric choices are limited compared to the conventional options. It causes much difficulty for sustainable fashion designers when integrating function, aesthetic, and sustainability into product design [32]. Allwood et al. [33] compared the energy consumption for a cotton t-shirt and a viscose blouse. They found that producing a viscose blouse can save energy compared to producing a cotton t-shirt. This result implies that if the aim of a fashion designer is to develop a green product with low-energy consumption in the production stage, using viscose as the raw material is more desirable when compared with cotton.

Eco-design considers product life cycle and end-of-life treatment in product line development [34]. Armstrong and LeHew [35] argued that eco-design is different from traditional design because designers must reconcile conflicts between functional priorities. They summarized several sustainable product development approaches adopted in sustainable apparel product development, such as life-cycle assessment (LCA). In the textile and apparel industry, LCA is important to consider in the area of textile-related product design [36]. The well-known example of conducting LCA in product development is Patagonia [37]. Zamani et al. [38] evaluated a carbon footprint of textile recycling. They tested different textile recycling techniques with product life cycle assessment. As a result, designers selected the proper raw material in the product design stage and the suitable production process in the process design stage [32]. For example, the designers selected the degradable materials in raw-material selection if the used products collected from secondhand shops and charity systems were treated by landfill disposal [39]. Niinimäki and Hassi [7] argued that the sustainable fashion designers should consider the frequency of apparel wash in terms of product lifespan in the eco-design stage. If the product has a long lifespan, designers should pay attention to aesthetic longevity and consider classic styles and colors [34]. Moon et al. [40] developed guidelines for the design and production of sustainable energy-saving fashion products. They argued that fashion products can use eco-materials

through the manufacturing, utilization, and disposal stages. Consistent with Moon et al. [40], we considered various eco-materials in fashion product line development. The use of eco-materials is one of the indicators for sustainable fashion, i.e., the more eco-materials that are used, the higher the degree of sustainability for each product.

2.3. Sustainable Practices at Patagonia

Patagonia is an outdoor sportswear brand that has been greatly examined in the extant literature [9,41–45]. Patagonia was founded by Yvon Chouinard in California in 1973. Patagonia predominantly sells and showcases sustainable outdoor clothes for climbers, skiers, and other people engaging in outdoor activities [9,41]. Patagonia's mission statement is "build the best product, cause no unnecessary harm, use business to inspire and implement solutions to the environmental crisis". Patagonia admitted that its apparel production process may incur pollution. To reduce the negative impact, Patagonia launched "1% for the Planet", "Footprint Chronicles", and "Worn Wear" initiatives [46]. The "1% for the Planet" initiative contributes 1% of total annual sales to environmental organizations, "Footprint Chronicles" seeks to reduce adverse social and environmental impacts in the supply chain, and "Worn Wear" sells high-quality products that will last for years and be repaired easily [47]. The extant literature of has greatly examined Patagonia's sustainable practices; however, no previous study has investigated its eco-design practices. In this paper, we focused on examining its eco-design practices and identifying the impact of eco-design on its product lines.

Product line development follows company mission statements at Patagonia [42,48]. With rigorous attention to quality, Patagonia integrates the principles of industrial design into all aspects of clothing production [9]. Alongside quality, environmental concerns play an important role in eco-material selection and the manufacturing process [43]. Patagonia promotes sustainable manufacturing in several aspects, such as symbolic eco-labels, non-chemical print technology, transparent supply chains and detachable designs [49].

The literature has been shown that eco-labels enable consumers to receive product sustainability information and educate consumers' sustainability awareness [44]. Patagonia uses eco-labels such as Blue-sign and Fair Trade-certified in its product line development [50]. Eco-labels convey sustainability information to consumers and illustrate the company's efforts on sustainable product development [45]. Patagonia designers obey the requirements of eco-labels in product line development. For example, when the Blue-sign label is attached to new products, designers design the product with consideration of consumer safety, water emissions, occupational health and safety; when Fair Trade-certified is attached, designers may use recycled accessories, such as zips, buttons and waistbands, and attach the recycled heritage label to convey the sustainable consciousness [50]. In this paper, we focused on examining the case of Patagonia, whose eco-design is well-known and representative in the fashion company.

3. Research Method

The purpose of this study is not only to explain the eco-design practices of a particular company as a case study, but also to sharpen our understanding of eco-design in fashion product lines, especially how fashion firms should manage eco-design and further influence supply chain management.

3.1. Case Company Selection

In this paper, we examine the outdoor sportswear brand Patagonia. The case company is a leading global outdoor sportswear retailer that aims to provide consumers with high-quality, fashionable and sustainable outdoor sportswear [9]. There are several reasons that we have selected Patagonia as the investigated company. First, Patagonia emphasizes sustainability and social responsibility as its competitive advantage. The majority of Patagonia's products are made by at least one eco-material. For the other responsible retailers such as H&M, the North Face, etc., a part of their product line is produced by eco-materials. We admit that only analyzing Patagonia's product line has limitations. However, Patagonia is representative of the impacts of eco-design in sustainable fashion companies.

Second, to the best of our knowledge, it is rare for fashion retailers to share product line information online with consumers, except in the case of Patagonia. We collected Patagonia's product line data from its official website (www.patagonia.com). This product line analysis is an instrument that enables us to assess all impacts and identify insights on the Patagonia's production processes [51].

3.2. Data Collection

In this study, we collected information on the 2017 Spring Season product line from Patagonia's website in February 2017. A total of 456 products were collected from the 2017 Spring Season product line at Patagonia, in which 260 products are menswear and the other 196 are womenswear. Each product has various sizes and colors. The clothing product types include jackets and vests, fleeces, sweatshirts and hoodies, shirts, t-shirts, pants and jeans, etc. An example of a Patagonia product (<http://www.patagonia.com/product/womens-pastel-p-6-label-midweight-full-zip-hoody/39507.html>): the Women's Pastel P-6 Label Midweight Full-Zip Hoody is regular fit, has three color choices (red, blue, and black), weighs 566 grams, costs USD \$99, and is comprised of 84% organic cotton (i.e., one eco-material is used). In terms of the aesthetics of its products, Patagonia aims to develop classic products with an emphasis on graceful functionality and authenticity [9]. In this paper, we conducted a product line analysis on the number of color choices, product fit (regular or slim), pattern design (with or without), product weight, and number of eco-materials used at Patagonia. The multiple color choices and pattern decisions refer to product aesthetics, while the product fit and weight refer to product functionality in eco-product development [35].

3.3. Data Analysis Method

In this paper, the data analysis can be classified into three steps. First, we conducted a descriptive analysis on the usage of various eco-materials in product line development at Patagonia in terms of different genders. The descriptive analysis includes the number of eco-materials used for different gender, patterns and product fit. This step helps us to identify which eco-materials are the most frequently used at Patagonia. Second, we conducted a factor analysis on gender difference, pattern design and product fit in terms of eco-material usage at Patagonia. This method provides a deeper analysis on eco-design in various sectors (i.e., different gender, pattern design and product fit); as a result we can have a clearer picture of eco-design practices at Patagonia. Third, we conducted a correlation analysis and explored the statistical relationship between the number of eco-materials used and design elements (i.e., gender difference, pattern design and product fit), and the relationship between the number of eco-materials and online reviewers' opinions. This method provides strong evidence on how eco-design influences design decisions and consumers' opinions at Patagonia. More managerial insights are derived. Figure 1 shows the three steps of data analysis in this paper.

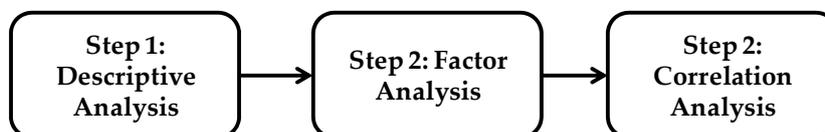


Figure 1. Three steps of data analysis in this paper.

4. Results

Based on the collected data, it is found that six types of eco-materials (i.e., organic cotton, recycled cotton, recycled nylon, recycled polyester, recycled down, and traceable down) are used at Patagonia. The outcome of selected eco-material is consistent with Patagonia's mission, i.e., reducing the environment impact in the material selection stage [9]. Eco-material selection is the beginning of the sustainable supply chain management [16]. Designers select eco-materials to convey the design philosophy and optimize the consumers' sustainable, aesthetic and functional needs.

Table 1 shows the descriptive analysis results in terms of the number of eco-materials used in both menswear and womenswear at Patagonia. It indicates that the eco-materials include organic materials, recycled materials and traceable materials. Recycled polyester is the most widely used for both menswear and womenswear development (29.0% and 19.5%, respectively), followed by organic cotton (19.5% and 15.1%, respectively), and recycled nylon (5.6% and 3.1%, respectively) at Patagonia. Recycled polyester can be easily re-melted or reshaped in order to make new products [43], rendering it a popular choice in new product development [52].

Table 1. The number of eco-materials used in product line development at Patagonia.

| Eco-Materials Category | Menswear | Womenswear | Total | Product Line Used |
|------------------------|-------------|------------|-------------|--|
| Organic cotton | 80 (19.5%) | 62 (15.1%) | 142 (34.6%) | Sweatshirts & Hoodies/Shirts/T-shirts/Pants & Jeans/Shorts/ |
| Recycled cotton | 7 (1.7%) | 2 (0.5%) | 9 (2.2%) | |
| Recycled polyester | 119 (29.0%) | 80 (19.5%) | 199 (48.5%) | Jackets & Vests/Fleece/Sweatshirts & Hoodies/Sweaters/Shirts/T-shirts/Pants & Jeans/Shorts |
| Recycled nylon | 23 (5.6%) | 13 (3.1%) | 36 (8.7%) | Jackets & Vests |
| Recycled down | 2 (0.5%) | 2 (0.5%) | 4 (1.0%) | |
| Traceable down | 10 (2.5%) | 10 (2.4%) | 20 (5.0%) | |

Remarks: Total eco-materials used is 410 (241 for menswear and 169 for womenswear) in this season collection at Patagonia.

From Table 1, it shows that Patagonia has frequently used organic cotton in its product line. As a matter of fact, the quality of organic cotton is equal to or even better than conventional cotton [9]. Organic cotton is cultivated without harmful chemicals and the farming methods used to produce it support biodiversity and healthy ecosystems, which can enhance soil quality and reduce water usage [1]. Sustainable fashion designers use organic cotton based on the style and characteristic of the apparel. As organic cotton is soft and healthy, sustainable fashion designers apply this material to products that directly adhere to the skin (e.g., hoodies and shirts) [20].

Recycled materials in Patagonia's product line include recycled polyester, nylon, cotton, and down. The collection line of jackets, vests, and pants is not 100% made from recycled materials, but it is close [53]. Recycled polyester is the most used material at Patagonia (as shown in Table 1). Based on the information on recycled polyester on the Patagonia website, soda bottles, unusable manufacturing waste and worn-out garments are used in producing recycled polyester. Recycled polyester is used to develop shell jackets, board shorts and fleeces. Using recycled polyester helps prolong landfill life and reduce toxic emission from incinerators. It is beneficial to build up a more sustainable ecosystem.

Traceable material is an innovative practice at Patagonia [50]. Transparency is an important part of the sustainable supply chain [54]. Traceable down helps assure animal welfare by tracing the source of down from parent farm to apparel factory. Using traceable materials hence encourages fashion designers to develop products in a more transparent way at Patagonia.

We separated the product line analysis into three categories: gender difference, pattern design, and product fit, as shown in Table 2. We concluded that on average less than one eco-material is used in Patagonia's products except for the products with pattern design. Specifically, we find that menswear uses more eco-materials than womenswear (0.85 vs. 0.78). It implies that Patagonia uses more eco-materials in menswear products. The reason might be because of gender differences in sustainable consumer behavior [55]. Menswear generally has a simple silhouette, which implies more basic products and leads to a higher use of sustainable material. Moreover, we find that products with pattern design are more likely to use eco-materials (1.04 vs. 0.74). The pattern printing process potentially generates a significant amount of pollution in the textile supply chain [56]. Using more eco-materials in patterned products can balance sustainability factors. Furthermore, we see that the number of eco-material usage for product fit is similar between regular and slim fit (0.76 vs. 0.76). This implies that both regular and slim fits products are made by a similar number of eco-materials.

Table 2. Number of eco-materials used for different categories at Patagonia.

| | Category | Numbers | Mean | Standard Deviation |
|-------------------|------------|---------|------|--------------------|
| Gender Difference | Menswear | 260 | 0.85 | 0.653 |
| | Womenswear | 196 | 0.78 | 0.655 |
| Pattern Design | With | 129 | 1.04 | 0.594 |
| | Without | 327 | 0.74 | 0.657 |
| Product Fit | Regular | 302 | 0.76 | 0.568 |
| | Slim | 154 | 0.76 | 0.560 |

Table 3 indicates the regression results of eco-materials used in product line and color choices/product weight at Patagonia. First, we found that for womenswear at Patagonia, products containing more eco-materials are heavier, even if the products do not include patterns or are slim fit; for the regular fit products, products containing more eco-materials have more color choices.

Table 3. Statistical results of product line analysis at Patagonia.

| Dependent Variables | Independent Variables | | |
|--|-----------------------|----------------------|-------------------|
| | | No. of Color Choices | Weight (g) |
| Gender Difference | Menswear | 0.073 (0.234) | 0.030 (0.622) |
| | Womenswear | 0.016 (0.822) | 0.195 (0.006) ** |
| No. of eco-materials usage in product line | With pattern | −0.152 (0.259) | 0.017 (0.900) |
| | Without pattern | 0.091 (0.282) | 0.287 (0.001) *** |
| Product Fit | Regular fit | 0.157 (0.082) * | 0.122 (0.176) |
| | Slim fit | −0.144 (0.216) | 0.299 (0.009) ** |

Remarks: Pearson correlation is reported outside parentheses and sig. (2-tailed) is reported in parentheses. *** $p < 0.005$, ** $p < 0.01$, * $p < 0.1$.

From Table 3, we see that designers do not use more eco-materials when developing products with more color choices for both menswear and womenswear product lines at Patagonia. Moreover, designing patterns in new products is an important strategy for fashion designers in new product line development. However, based on the statistical results in Table 3, we see that it has no statistical effect on the number of eco-materials used or the number of color choices except for the regular fit products. This implies that when Patagonia designers develop a new product with more color choices, they might not be likely to use more eco-materials except for regular fit products. At Patagonia, product fit is critically important for eco-design. We observed that for the regular fit product development, the more sustainable products have more color choices, but for the slim fit products, the more sustainable products have less color choices. For the slim fit product development, products containing more eco-materials are heavier, but for the regular fit products, products containing more eco-materials are lighter. These results could provide many important insights on supply chain management because multiple color choices imply maintaining more stock keeping units (SKUs) in inventory and heavy product weights require extra attention during transportation and distribution.

Table 4 shows the relationship between eco-materials used and online reviewers' opinions. The reviewers' opinions include the number of reviews and reviewer scores. The number of reviews refers to how many discussions are online (the comments may be positive or negative). The reviewer scores imply the reviewers' acceptance, i.e., a higher score implies the consumers have higher product acceptance. Thus, Table 4 implies whether more eco-materials can increase online discussion and reviewers' acceptance. We found that the menswear eco-designed products, the eco-designed products with patterns, and the slim fit eco-designed products have less online consumers' acceptance, respectively.

Table 4. Statistical results of eco-materials with online reviewers' opinions at Patagonia.

| Dependent Variables | | Independent Variables | | |
|--|-------------|-----------------------|-----------------|-------------------|
| | | No. of Reviews | Reviewer Scores | |
| No. of eco-materials usage in product line | Gender | Menswear | 0.022 (0.719) | −0.152 (0.014) * |
| | Difference | Womenswear | 0.032 (0.655) | 0.006 (0.932) |
| | | Pattern Design | With pattern | 0.003 (0.978) |
| | | Without pattern | 0.014 (0.804) | −0.012 (0.824) |
| | Product Fit | Regular fit | 0.079 (0.171) | 0.008 (0.886) |
| | | Slim fit | −0.046 (0.576) | −0.230 (0.004) ** |

Remarks: Pearson correlation is reported outside parentheses and sig. (2-tailed) is reported in parentheses.
 ** $p < 0.005$, * $p < 0.1$.

5. Discussion and Managerial Insights

Through data analysis of Patagonia's product line, the following four important insights (i.e., eco-material selection, eco-design for functionality, eco-design for aesthetics in product line development, and eco-design and online reviewers' opinions) are valuable to discuss and summarize for both practitioners and scholars.

● Eco-material selection in product line development

Eco-material selection is the first stage of the sustainable supply chain. Eco-materials mainly include recyclable, recycled and low environmental impact materials [6]. At Patagonia, designers select organic, recycled and traceable materials in sustainable product line development. Using such eco-materials can lower environmental impact. Recycled materials (e.g., recycled polyester, recycled nylon, recycled cotton, and recycled down) have been greatly used in Patagonia's product line development. In particular, recycled polyester is popular. This can be potentially explained by polyester materials' simple adoption in fashion design and that recycled polyester can be reshaped according to new product designs. Eco-material selection is not only critically important for eco-design, but also beneficial for establishing a more sustainable supply chain.

● Eco-design for functionality in product line development

Eco-design for functionality is critically important in product line development. Fashion functionality can refer to product weight, as the more functional products such as outdoor clothing are heavier than less functional products such as t-shirts. We found that for the basic products (without pattern design) at Patagonia, the functional products are more likely to be made by eco-materials. This result provides significant practical insights on eco-design for functional products, which should be promoted by the concepts of sustainability in marketing and distributed in environmentally efficient ways, even though the products are relatively heavy.

● Eco-design for aesthetics in product line development

Aesthetics is now the primary reason that consumers choose to purchase fashion products. In this paper, aesthetics refer to the choices of color and product fit (regular or slim) at Patagonia. Product fits are important for outlook and style. We found that for the regular fit product development, the products containing more eco-materials have more choices of color, but this does not apply to slim fit products. For the slim fit product development, the products containing more eco-materials are heavier, but for the regular fit products, products containing more eco-materials are lighter. This finding provides an important insight to sustainable fashion designers who should implement different eco-design strategies in terms of product fits for color choices and weight. Moreover, regarding product weight, this finding provides insights on logistics and distribution. If the product is aesthetics oriented (e.g., slim fit), logistics incur a higher cost because they are heavier, whereas if the product is not aesthetic oriented (e.g., regular fit), logistics may incur a lower cost because they are lighter.

● Eco-design and online reviewers' opinions

When online consumers purchase eco-designed products, they might leave comments on purchased websites and give a score to identify how they like the product. We found that the menswear eco-designed products, the eco-designed products with patterns, and the slim fit eco-designed products have less online consumers' acceptance. Both pattern and slim fit refer to aesthetics in fashion products. Thus, these results imply that when consumers purchase eco-designed products for aesthetics, patterns and slim fit would reduce the consumers' acceptance. In other words, the consumers may not be satisfied with the aesthetics of eco-design at Patagonia. This may further imply that Patagonia should focus on developing products for functionality instead of aesthetics when developing eco-designed products.

In the product development stage, designers determine how many colors will be available in each product. We find that for the regular fit products, designers are more willing to use eco-materials with more choices of color. This may be due to the following two reasons: (1) eco-materials may not be uniform, which can present multiple color choices after recycling [42], allowing designers to have more color choices in product design; (2) consumers may be more willing to select products among multiple color choices when they purchase sustainable products [55]. These results provide important insights on eco-product inventory management. When the eco-products have more choices of color, it implies that the eco-products have more SKUs for each product. More SKUs lead to a higher chance of overstocking for certain colors and sizes [57]. As a result, more choices of color in eco-products may increase the overstocking risk in the supply chain. Based on these results, we argue that better managing inventory for eco-products is critically important because the regular fit eco-products have more color choices, and consequently more SKUs to manage, which drive the inventory management to be more complex.

6. Conclusions, Limitation, and Future Research

In order to satisfy consumer needs and social development, eco-design is quite popular at present. In this paper, we collected product line data from the famous outdoor sportswear brand Patagonia. We analyzed Patagonia's product line in terms of eco-design and found that Patagonia mainly uses organic, recycled, and traceable materials in product line design. Moreover, we identified that the number of eco-materials used significantly affects the number of color choices and product weight as well as gender difference, pattern design and product fit. We find that menswear products use more eco-materials than womenswear at Patagonia. This result can be potentially explained by gender differences in sustainable consumer behavior. Furthermore, we identified the relationship between product weight, fit and patterns for eco-design at Patagonia. These statistical results provide many important managerial insights on eco-design in product line and eco-product supply chain management.

Our study is subject to two main limitations. First, we cannot say whether our findings at Patagonia can be completely generalized to other fashion firms. However, our findings can provide some partial managerial insights to other firms and the entire supply chain. In future research, it would be interesting to compare eco-design practices among different fashion brands [58]. Second, fashion design and product development processes are dependent on other supply chain factors, such as supplier selection process [59–61]. In future research, it would be significant to evaluate Patagonia's sustainable supply chain. Third, various eco-design approaches may influence consumer intentions when purchasing products [62]. It would be valuable to examine efficient eco-design elements in sustainable fashion for consumers.

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