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Sustainable fashion tech innovation: A case study of Bolt Threads' redefinition of fashion systems, design activism and social entrepreneurship

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Abstract

This research article explores the transformative journey of Bolt Threads, a pioneering biomaterials firm operating at the intersection of biotechnology and fashion. First, the research paper sets the background and provides the research question. Second, the existing literature is reviewed to investigate sustainable entrepreneurship within the fashion industry, exploring sustainable fashion concepts and highlighting sustainable entrepreneurs' challenges. Third, the research paper examines Bolt Threads as a case study to redefine fashion systems, design activism, cultural sustainability, design for social change and social entrepreneurship. The case study thoroughly examines Bolt Threads' founding story, business model, innovative technologies and strategic initiatives, underscoring the company's dedication to sustainability and technological advancement. This case study analyses Bolt Threads collaborations with renowned fashion brands, financial strategies, the potential for industry-wide adoption and outlook. Bolt Threads demonstrates that sustainable innovation requires thinking beyond traditional materials and methods. This approach shows that transformative change in sustainability involves looking outside the industry's usual practices and integrating technology in unexpected ways, which can lead to groundbreaking materials that still align with fashion's functional and aesthetic standards. Partnerships with major players help start-ups accelerate market acceptance, increase consumer trust and create broader demand for sustainable products. These alliances demonstrate that aligning with influential brands can be a strategic move for sustainable companies seeking scalability and industry-wide adoption.

Keywords: Fashion design, Sustainability, Social awareness, Social responsibility, Biotechnology

Introduction

Mehta (2024) cites Deborah Golden, Deloitte's U.S. chief innovation officer, who said, "*Innovation readiness encompasses more than just adopting new technologies, tracking specific metrics, or embracing the latest buzzword."* In other words, innovation readiness goes beyond surface-level actions or superficial changes. This quote highlights that innovation readiness goes beyond adopting new technologies or following trends. Instead, it requires a more profound commitment and understanding of innovation. Bolt Threads, a company focused on sustainable materials, such as micro silk, Mylo™ and B-silk protein, aligns with this quote by demonstrating an integrated approach to innovation.

This research paper addresses the following research question: How do emerging sustainable fashion tech start-ups, exemplified by Bolt Threads, contribute to the redefinition of fashion systems, incorporating design activism, cultural sustainability and social entrepreneurship, and what role do designers play in navigating and influencing policy for sustainable fashion practices? By integrating design activism, cultural sustainability and social entrepreneurship concepts, this research offers a novel approach to understanding sustainable fashion systems beyond environmental considerations, encompassing broader societal impacts and ethical dimensions inherent in the fashion industry's evolution. The aim is to gain valuable insights to

effectively address the sustainability challenges in fashion and textiles. As an outstanding sustainable fashion tech start-up, Bolt Threads plays a crucial role in reshaping fashion systems, advocating design activism, promoting cultural sustainability, driving design for social change and embodying principles of social entrepreneurship. This research paper addresses the innovative technologies employed by Bolt Threads, such as the biofabrication of silk through the fermentation of yeast, which challenges traditional material production methods (Seltenrich, 2015).

Literature review

This literature review aims to provide a comprehensive understanding of the nuances within sustainable entrepreneurship in the fashion industry, exploring the concepts, trends and challenges that define this evolving landscape.

Sustainable fashion: Concepts, diverse perspectives and entrepreneurial influence

The fashion sector, with a global valuation of $1.3 trillion and employing over 300 million individuals, is a crucial economic force and a significant contributor to the global GDP (Amed & Berg, 2018; BCG, 2019). Amidst intense competition and growing uncertainty, firms within this vast industry must adapt swiftly to remain competitive, as highlighted in market analyses by prestigious consultancy firms such as McKinsey, Deloitte Group and BCG (Gazzola et al., 2020). Additionally, with advancements in medicine and other factors leading to a rise in global life expectancy, fashion brands have a unique opportunity to cater to both younger and older demographics simultaneously, emphasizing the need for diversified business strategies and marketing approaches (Gazzola et al., 2020).

Sustainability is emerging as a prominent concept in the fashion industry, aiming to address its shortcomings. While academic groundwork in this area has been established by scholars such as de Brito et al. (2008) and Fletcher (2010), there remains a lack of consensus on the definition of sustainability, which can be interpreted differently based on various perspectives and contexts (Henninger et al., 2016). Multiple approaches representing a comprehensive range of sustainability considerations in the fashion industry have been proposed, encompassing both environmental and social dimensions (Henninger et al., 2016; Köksal et al., 2017; Mukendi et al., 2020).

Concepts such as eco-fashion, slow fashion, green fashion, ethical fashion and sustainable fashion have emerged as prominent approaches to addressing these concerns (Mukendi et al., 2020; Thomas, 2008). According to Hofman et al. (2022, p. 4), citing Kozlowski et al. (2018, p. 183), entrepreneurs, particularly fashion designers and founders, play an essential role in promoting sustainability within the fashion industry. Many of these entrepreneurs are driven by personal beliefs and values, aiming to provide alternatives to the mass market and challenge the practices of fast fashion players (Kozlowski et al., 2018, p. 183), as highlighted by (Hofman et al., 2022, p. 4). This underscores the importance of individual commitment and values in propelling the sustainable fashion movement (Hofman et al., 2022, p. 4).

Textile consumption trends

From 1990 to 2018, the data indicate that the actual prices of footwear and clothing in the United States plummeted by half (Ryan, 2021). Moreover, a recent report from the European Union (EU) has underscored the significant environmental and climate change impact of textile consumption, ranking it as the fourth-highest contributor, following food, housing and mobility (Glasner, 2023). Textiles also represent the third-highest water and land-use consumption category (Glasner, 2023).

In response to these challenges, the EU has introduced a sustainable and circular textiles strategy, aiming for all textile products introduced to the market by 2030 to possess the qualities of being "durable, repairable, and recyclable" (Glasner, 2023). Additionally, these products should consist of recycled fibres, be free of hazardous substances and be manufactured in adherence to social rights and environmental considerations (Glasner, 2023). Highlighting the environmental and climate change repercussions of textiles, particularly their standing as the fourth-largest contributor (Glasner, 2023), underscores the urgent need for innovative solutions. In this context, Bolt Threads' biofabrication of silk and unwavering dedication to sustainability (Seltenrich, 2015) seamlessly align with the imperative to address these challenges.

Challenges faced by sustainable entrepreneurs

Sustainable entrepreneurs and small businesses encounter significant customer interaction challenges (Hofman et al., 2022). Given the diverse forms and approaches of sustainable fashion, entrepreneurs and small business managers struggle to predict and align customer and stakeholder expectations with their ideas and concepts (Kozlowski et al., 2018; Todeschini et al., 2017; Štefko & Steffek, 2018).

This complexity within sustainable fashion makes it challenging for businesses to anticipate consumer preferences accurately. Moreover, sustainable fashion companies face a continuous demand from the market for new products featuring innovative design elements (Hofman et al., 2022). Discovering innovative aspects of sustainable materials, functions or production methods for each new fashion season poses a difficulty (Rindova et al., 2005). However, effectively addressing this challenge can enhance a company's reputation and create new value propositions (Rindova et al., 2005). Ultimately, successfully managing the quest for innovation in sustainability can provide a competitive advantage for fashion companies (Rindova et al., 2005).

Golden, as cited by Mehta (2024), underscores the current era in which various technologies, industries and ideas converge, emphasizing the value of diversity in thought and expertise (Mehta, 2024). Organizations can access a more comprehensive range of ideas and resources by engaging with a broader ecosystem that includes internal resources and external partners, such as start-ups, academic institutions and competitors (Mehta, 2024). Recognizing the importance of incorporating social aspects of sustainability into business models is fundamentally a cultural factor (Hristov et al., 2022). However, a significant challenge to effectively integrating social dimensions into business models is the prevailing managerial focus on short-term economic and financial outcomes, which undermines adopting sustainable values offering long-term benefits (Hristov et al., 2022). Achieving sustainability requires ongoing investments and a consistent focus on product and service quality, worker health and safety and equity and climate change (Hristov et al., 2022).

Methodology

A case study approach allows for a detailed and comprehensive analysis of a real-world example within the context of sustainable entrepreneurship in the fashion industry (Yin, 2009). The case study approach was chosen for two main reasons. First, it allows for an in-depth examination of a real-world example, providing rich and detailed insights (Yin, 2009) into the complexities of sustainable entrepreneurship in the fashion industry. Second, it enables researchers to explore the dynamic interactions between several factors (Priya, 2021) within a specific organizational context, such as business models, technologies and strategic initiatives.

Data collection methods: Online web publications

The chosen sources provide a comprehensive and diverse understanding of Bolt Threads, its founding story and the impact of its innovative technologies on the fashion and sustainability industries. Bolt Threads' official website, notably the "Bolt's Founding Story" and "Bolt Impact" pages, offers insights into the company's background, values and contribution to sustainability, as seen in Table 1. News articles from reputable sources, such as *Fortune*, *Business Insider* and *Forbes*, were included to provide external perspectives on Bolt Threads' breakthroughs, collaborations and industry influence and are also included in Table 1. Table 1 also includes articles from *Vogue*, *W Magazine* and *Business of Fashion*, which explore the broader impact of Bolt Threads' technologies on the fashion world, especially in collaborations with renowned brands such as Stella McCartney, Adidas, Patagonia and Lululemon. This research paper aims to draw on these varied sources to present a well-rounded analysis of Bolt Threads' trajectory and influence.

Rationale for chosen sources.

The chosen sources collectively provide a comprehensive overview of Bolt Threads' history, technological innovations, collaborations, industry impact and outlook. These diverse perspectives enable a well-rounded analysis of the company's role in the intersection of biotechnology and sustainable fashion.

Table 1: Identification and description of sources.

Source	**Description**
Bolt Threads' Founding Story	Insights into the company's origins, initial challenges and milestones, offering a foundational understanding of Bolt Threads' journey.
Fortune Article on Synthetic DNA	Explores potential technological breakthroughs, specifically synthetic DNA, providing insights into the broader technological landscape and its relevance to Bolt Threads' innovative processes.
W Magazine on Mushrooms in Fashion	Investigates the spread of mushrooms in fashion, offering a unique perspective on the sustainable future of the fashion industry, focusing on the role of mushrooms, an essential aspect of Bolt Threads' materials.
Business Insider on Spider Silk Necktie	Highlights a specific product, a spider silk necktie, shedding light on Bolt Threads' early ventures into creating commercially available products and its impact on the market.
Bolt Threads' Impact Page	Provides valuable information about the company's broader impact, including its sustainability initiatives and contributions to the industry.
TechCrunch on Fundraising and Patagonia Deal	Investigating the fundraising and dealing with Patagonia, this source provides insights into the financial and strategic aspects of Bolt Threads, which are crucial for understanding its growth and partnerships.
Vogue on Stella McCartney's Mushroom Leather Bag	Examines Stella McCartney's collaboration with Bolt Threads, providing insights into high-profile partnerships and integrating Bolt Threads' materials into renowned fashion brands.
Source	**Description**
Forbes Article on Mushroom Leather and Spider Silk	Investigates the broader implications of mushroom leather and spider silk in the fashion industry, providing a macro-level perspective on the industry trends that Bolt Threads contributes to.
Business Insider on Adidas' Mushroom Leather Shoe	Focusing on Adidas' collaboration with Bolt Threads on a mushroom leather shoe, this source offers insights into the adoption of Bolt Threads' materials by major brands and the potential market impact.

WWD on Mushroom Fashion Moment at Stella McCartney Store	Provides real-world examples of the application of Bolt Threads' materials in a retail setting, offering insights into consumer reception and the practicality of these materials.
Forbes Article on Bolt Threads' SPAC Deal	Discusses the recent financial move of Bolt Threads, offering insights into its valuation, financial strategies and future.
Business of Fashion on Lululemon's Mushroom-Based Yoga Accessories	Examining Lululemon's incorporation of Bolt Threads' materials in yoga accessories, this source illustrates the practical application of Bolt Threads' innovations in consumer products.
Bolt Threads' Silk Protein Technology Page	Detailed information on Bolt Threads' Silk Protein technology, providing insights into the company's diverse biomaterial portfolio.

Based on the information provided in Table 1, it is evident that Bolt Threads has embarked on a remarkable journey of innovation and collaboration within the fashion industry. From its founding story to its recent special purpose acquisition company (SPAC0 deal, Bolt Threads has demonstrated a commitment to sustainability, technological advancement and strategic partnerships. Incorporating mushroom-based materials and spider silk into products by renowned brands such as Stella McCartney and Adidas signifies the industry's acceptance and adoption of Bolt Threads' innovations. Furthermore, the practical application of Bolt Threads' materials in retail settings, as seen in Lululemon's yoga accessories, highlights their potential for widespread consumer appeal.

Case study

Bolt Threads, a biomaterials firm, operates at the intersection of biotechnology and fashion (Cumbers, 2019). Bolt Threads focuses on developing materials derived from biological sources, such as proteins or other organic compounds (Elkington, 2019). The company leverages nature as inspiration, employs advanced biotechnology and generates innovative solutions to create sustainable materials (Cumbers, 2019). Traditionally, silk production has been limited to silkworms and spiders. However, at Bolt Threads, the process involves fermentation tanks using yeast, sugar and DNA code derived from spiders (Alsever, 2017). The company addresses resource challenges through products such as spider silk, mushroom leather and silk proteins (Cumbers, 2019). Bolt Threads has developed advanced technology and infrastructure for producing proteins at scale (Elkington, 2019). This innovative approach results in a material spun into fibres akin to traditional methods for silk, rayon and polyester, claimed by the company to surpass steel in strength, exceed spandex in stretchiness and be softer than silk (Alsever, 2017). Overall, Bolt Threads exemplifies the transformative potential of sustainable fashion tech start-ups in reshaping industry practices and promoting environmental responsibility.

Overview of the business model

Bolt Threads, a start-up that specializes in synthetic spider silk products (Robinson, 2017), has a business model that revolves around creating sustainable materials inspired by nature (Cumbers, 2019). The business originated in 2009 when the co-founders Dan, David and Ethan embarked on a venture combining their expertise in microbial silk production and microfluidic devices (Bolt Threads, 2017). Encouraged by their participation in the Idea to IPO class at UCSF, the trio secured research grants, became tenants at the QB3 Garage start-up incubator and later expanded into a larger incubator space in San Francisco (Bolt Threads, 2017). Since 2009, Bolt Threads has been a frontrunner in biotechnological innovation and has embraced the trend of mushroom fashion (Gore, 2021).

As the global fashion industry, valued at around $3 trillion, increasingly gives precedence to sustainability and transparency, the synthetic biology biomaterials sector stands to gain (Cumbers, 2019). Identifying a void in consumer products within the fashion industry, CEO Dan Widmaier prioritized Bolt Threads' mission to introduce new materials inspired by nature to tackle challenges in the consumer marketplace (Gore, 2021). Widmaier acknowledges Mother Nature as a remarkable example of a perfectly circular materials economy, spanning four billion years (Gore, 2021).

Recently, Bolt Threads planned to merge with a special purpose acquisition company (SPAC) called the Golden Arrow Merger Corp (Feldman, 2023). The SPAC is led by investor Timothy Babich, a former professional at Goldman Sachs (Feldman, 2023). After the merger, Bolt Threads will change its name to Bolt Projects Holdings (Feldman, 2023). CEO Dan Widmaier will retain his position in the new company, while co-founder David Breslauer will continue as the Chief Technology Officer (Feldman, 2023). The deal attributes a pro-forma enterprise value of $346 million to Bolt Threads and was expected to be completed in the first quarter of 2024 (Feldman, 2023).

Examination of innovative technologies employed

Bolt Threads is associated with spider silk because it focuses on creating synthetic versions of this material. However, the real breakthrough lies in a different realm: beer and cheese production (Seltenrich, 2015). Rather than directly mimicking the silk production process of spiders, Bolt Threads has engineered a yeast strain (Seltenrich, 2015). When combined with sugar and water and fermented in a similar process to that of beer or cheese, this yeast produces proteins that closely resemble those found in spider silk (Seltenrich, 2015).

These silk-like proteins are then extracted and processed further, resulting in fibres that can be spun into threads suitable for knitting or weaving (Seltenrich, 2015). The company's innovation involves harnessing the natural properties of yeast to create a sustainable and scalable alternative to traditional silk production methods (Seltenrich, 2015).

Innovative materials

The following section provides an overview of each technology's unique features, such as the use of mycelium in Mylo™ as a sustainable substitute for leathers, the biodegradable and clean beauty aspects of B-Silk protein™ and the eco-friendly nature of Micro silk™ as a vegan silk alternative.

Mylo™ material

Mylo serves as a mycelium-based substitute for both synthetic and natural leather. The production of Mylo™ involves using less harmful chemistry, a design aimed at minimizing lifecycle impacts and implementing rigorous ethical labour and production practices (Bolt Threads, n.d.-a). Mylo™ incorporates environmentally friendly chemistry, is designed to reduce life cycle impacts and adheres to rigorous ethical labour and production standards (Bolt Threads, n.d.-a). Mylo™ supports the United Nations' Sustainable Development Goals on Decent Work and Economic Growth, Industry, Innovation and Infrastructure and Responsible Consumption and Production (Stella McCartney, 2023). Mylo™ is certified as primarily composed of materials derived from renewable sources found in nature (Bolt Threads, n.d.-a).
The certification confirms that the ingredients used in Mylo™ are biobased, meaning that they come from renewable biological sources such as plants or microorganisms (Bolt Threads, n.d.-a).

B-silk protein™

B-silk™ is a biobased and vegan polypeptide, meaning that it is derived from renewable biological sources and contains no animal-derived ingredients (Bolt Threads, n.d.-b). B-silk™ has been clinically proven to deliver positive results in skincare, hair care and colour cosmetics (Bolt Threads, n.d.-b). B-Silk™ performs better than silicone elastomers in beauty and personal care products (Bolt Threads, n.d.-b). B-silk's™ distinctive molecular structure is a lightweight, protective barrier against environmental stressors, such as pollution and blue light, for both skin and hair. Scientific research has proved that B-silk™ can offer protective benefits against these factors when incorporated into skincare, hair care and colour cosmetics products (Bolt Threads, n.d.-b).

Micro silk™ material

Micro silk™ fibre is a vegan alternative to silk, created from environmentally friendly ingredients such as water, sugar, yeast and salt (Bolt Threads, n.d.-b). The technology behind Micro silk™ fibre has moved away from using petroleum-based polymers and unsustainable processes (Bolt Threads, n.d.-b). Instead, it embraces sustainable practices and avoids non-biodegradable fabrics, focusing on renewable inputs and closed-loop production methods.

Case studies of successful projects or collaborations

Bolt Threads has successfully collaborated with major fashion brands to incorporate micro silk into their collections. Bolt Threads has achieved success and collaborations with many renowned brands, including Stella McCartney, Adidas, Patagonia, Vegamour and Lululemon. In July 2019, Stella McCartney and Adidas introduced the Biofabric Tennis Dress (Bolt Threads, n.d.-b). The dress was made using a blend of micro silk and cellulose fibres, specifically designed to be fully biodegradable (Bolt Threads, n.d.-b). As a result, the dress can naturally break down into harmless components in the environment, reducing its environmental impact after use (Bolt Threads, n.d.-b).

Patagonia

Bolt Threads collaborated with the outdoor clothing company Patagonia in 2016 (Kolodny & Dilet, 2016). This collaboration aimed to kickstart the creation and design process of products that integrate Bolt Threads' innovative and visionary threads (Kolodny & Dilet, 2016).

Stella McCartney

Stella McCartney, a luxury brand renowned for its commitment to sustainability and anti-animal product stance, has collaborated with Bolt Threads since 2017 (Webb, 2022). Their inaugural commercially viable product resulting from this partnership was the Frayme Mylo bag (Webb, 2022). The SoHo store celebrated the release of the Frayme Mylo collection in 2022 (Roshitsh, 2022). The event featured prototypes of products like the Falabella bag and trousers, all part of the collection retailing at $3,500 (Roshitsh, 2022). The Frayme Mylo collection uses Bolt Threads' Mylo material derived from mycelium as a sustainable alternative to leather (Roshitsh, 2022).

Adidas

Adidas has partnered with Bolt Threads to develop innovative vegan alternatives for its leather shoes (Williams, 2021). The classic Adidas Stan Smith shoe has been redesigned utilizing the unique properties of Mylo™, a mushroom-based leather made from mycelium found in mushroom roots (Cumbers, 2019).

The latest model of the Stan Smith Mylo footwear, released in 2021, features an environmentally friendly, sustainable, fully mushroom leather body and a natural rubber midsole (Williams, 2021).

Lulumelon

In July 2021, Lululemon introduced its initial yoga accessory line crafted from Mylo™ (Sergison, 2021). The collection includes an innovative yoga mat constructed from undyed Mylo, intricately woven to create varied patterns that offer hand and foot placement guidance during yoga sessions (Sergison, 2021). The Meditation and Yoga Mat Bag and the Barrel Duffel Bag exhibit Mylo™ in intricately braided handles, zipper pulls and premium embellishments throughout (Sergison, 2021). In October, Lululemon initially committed to using the sustainable Mylo™ material, joining the Mylo™ consortium (Sergison, 2021). This consortium, consisting of members such as Stella McCartney, Adidas and Kering, involves investments and grants exclusive access to the Mylo™ material (Sergison, 2021).

Eighteen B and Vegamour

In recent years, Bolt's primary product moved to B-silk™, a biobased ingredient in skincare and cleansers inspired by spider silk (Feldman, 2023). Initially, Bolt produced its skincare line, Eighteen B, but has since shifted to selling its ingredients to other brands (Feldman, 2023). B-silk™ is now featured in brands such as Vegamour and is available at Sephora stores across the United States. Bolt holds 34 patents for B-silk, with an additional 131 pending (Feldman, 2023). B-silk™ is designed as an environmentally friendly alternative to silicone elastomers, which are non-degradable chemicals and constitute a market estimated at $4 billion, according to Bolt (Feldman, 2023). Vegamour, a vegan beauty brand, collaborated effectively with Bolt Threads to launch the GRO Revitalizing Shampoo and Conditioner in November 2020 (Bolt Threads, n.d.-b). These products utilise B-silk™ protein, enhancing their formulations with its rejuvenating properties (Bolt Threads, n.d.-b). The inclusion of B-silk™ protein creates a nourishing moisture barrier, resulting in increased volume and shine, all without using animal-derived keratin or synthetic polymers (Bolt Threads, n.d.-b).

Potential for industry-wide adoption

The potential for industry-wide adoption lies in the scalability of Bolt Threads' biotechnological processes. Partnerships with influential figures and significant players in the fashion industry play a crucial role in facilitating wider recognition and application of eco-friendly materials such as Micro silk™, Mylo™ and B-silk™. The potential for industry-wide adoption is significant, given Bolt Threads' successful collaborations with major fashion brands. The partnership with Stella McCartney, a prominent luxury brand known for its commitment to sustainability, has resulted in the creation of commercially viable products such as the Frayme Mylo™ bag, signifying that those eco-friendly alternatives to traditional materials are gaining traction in the fashion industry. The collaboration with Adidas to produce the Stan Smith Mylo shoe, a vegan alternative made from mushroom-based "leather", further highlights the industry's openness to adopting sustainable materials.

Furthermore, Bolt Threads' focus on B-silk as a biobased ingredient for skincare and cleansers, incorporated into brands like Vegamour that are available at Sephora, indicates the potential for widespread adoption in the beauty and cosmetics sector. The shift towards eco-friendly alternatives in the skincare industry aligns with increasing consumer preferences for sustainable products. Finally, the impending merger with Golden Arrow Merger Corp. and the formation of Bolt Projects Holdings position the company for further growth and potential collaborations. As Bolt Threads continues to innovate and establish itself as a leader in

biomaterials, industry-wide adoption of its sustainable solution is likely, especially as significant brands seek alternatives to traditional materials focusing on environmental responsibility.

Discussion

This section explores the multifaceted impact of Bolt Threads', highlighting its innovative technologies, collaborations with prominent fashion brands, financial strategies and the company's strategic vision, as discussed in the previous section. This in-depth analysis delves into the core elements that define Bolt Threads' influence on the sustainable fashion landscape, shedding light on its pioneering role in redefining fashion systems, driving design activism, fostering cultural sustainability and embodying social entrepreneurship and social change principles.

Bolt Threads is an exemplary sustainable fashion tech start-up that exemplifies a paradigm shift in the fashion industry's approach to sustainability. The literature review established that sustainability in fashion is multifaceted, encompassing environmental and social considerations together with various concepts such as eco-fashion, slow fashion, green fashion, ethical fashion and sustainable fashion. Moreover, the involvement of entrepreneurs, particularly fashion designers and founders, is highlighted as pivotal for the industry's sustainability (Hofman et al., 2022; Kozlowski et al., 2018).

Bolt Threads' business model revolves around creating sustainable materials inspired by nature and addressing challenges in the consumer marketplace (Cumbers, 2019). The case studies of successful collaborations with major fashion brands such as Adidas, Stella McCartney, Patagonia and Lululemon underscore the impact of emerging sustainable fashion tech start-ups in reshaping industry practices. The challenges faced by sustainable entrepreneurs, as highlighted in the literature review, are mirrored in the complexities faced by Bolt Threads. Anticipating customer expectations, achieving continuous innovation and integrating social dimensions into business models are recurrent themes. This research paper recognizes that incorporating social aspects into business models is a cultural factor and that short-term economic focus can hinder long-term sustainable practices (Hristov et al., 2022).

- *Innovative technologies and design activism*
  The pioneering use of synthetic spider silk, mycelium-based materials and biodegradable proteins by Bolt Threads showcases design activism in action (Robinson, 2017). Bolt Threads' innovative adoption of synthetic spider silk, mycelium-based materials and biodegradable proteins is a testament to the influential role of design activism in the fashion sector. The company's commitment to leveraging biotechnology for sustainable fashion challenges the traditional norms of material production in the industry (Cumbers, 2019).

- *Cultural sustainability and redefinition of fashion systems*
  Collaborations with renowned brands such as Stella McCartney, Adidas and Lululemon highlight the cultural sustainability of Bolt Threads' innovations (Webb, 2022). By integrating its materials into mainstream fashion, the company contributes to redefining fashion systems, influencing consumer perceptions and fostering a shift toward sustainable alternatives (Sergison, 2021).

- *Design for social change and social entrepreneurship*
  Bolt Threads' approach aligns with design for social change by addressing environmental concerns and promoting cruelty-free alternatives (Cumbers, 2019). The company's commitment to ethical

labour and production practices and collaborations with sustainability-focused brands demonstrates social entrepreneurship at the intersection of technology and fashion (Kolodny & Dilet, 2016).

- *Industry-wide adoption and future outlook*
  The case studies of successful projects and collaborations underscore Bolt Threads' potential for industry-wide adoption (Webb, 2022). The partnerships with major fashion brands signal a broader acceptance of sustainable materials in the industry, indicating a shift towards more environmentally conscious practices (Feldman, 2023). These partnerships indicate a transition towards a more significant consideration of environmental factors and a growing emphasis on sustainability in industry practices.

- *Financial strategies and growth*
  Examining Bolt Threads' fundraising deals with companies like Patagonia and the recent SPAC deal with Golden Arrow Merger Corp provides insights into the financial strategies and growth trajectory (Feldman, 2023). This economic aspect is crucial for understanding how sustainable fashion tech start-ups can navigate the industry and gain widespread acceptance.
- *Diverse biomaterials portfolio*

  Bolt Threads' diverse biomaterials portfolio, including Mylo™, B-Silk protein™ and Micro silk™, showcases the versatility of their technologies (Bolt Threads, 2017). This diversity contributes to the adaptability of their materials across various industries – from fashion to skincare – indicating an integrated approach to sustainability.

- *Consumer reception and practicality*
  The inclusion of sources such as *WWD* on Mushroom Fashion Moment at Stella McCartney Store and *Business Insider* on Adidas' Mushroom Leather Shoe provides insights into real-world examples of the consumer reception and practical application of Bolt Threads' materials in retail settings (Roshitsh, 2022). Understanding how consumers interact with these innovative materials is essential for assessing their long-term viability.

- *Strategic vision and future*
  The information on Bolt Threads' SPAC deal and the formation of Bolt Projects Holdings sheds light on the company's strategic vision and future (Feldman, 2023). This aspect is critical for evaluating the long-term impact and sustainability of the company's business model.

Conclusion

In conclusion, this research paper not only explores the trajectory and influence of Bolt Threads as an emerging sustainable fashion technological start-up but also delves into the broader themes of sustainability, design activism and the role of entrepreneurs in redefining fashion systems. This detailed analysis of Bolt Threads' technologies, collaborations, challenges and industry-wide potential supports critical thinking in the context of sustainable fashion systems and aligns with the outlined research question. Bolt Threads stands out as an exemplar in the fashion industry, leading the redefinition of fashion systems by introducing pioneering and sustainable materials. The company's unwavering commitment to design activism, cultural sustainability and social entrepreneurship actively moulds the fashion industry's

practices, instigating a paradigm shift towards the widespread adoption of sustainable alternatives. Bolt Threads not only underscores the potential of sustainable fashion technology but also establishes an influential precedent for the industry, exemplifying the transformative efficacy of conscientious and environmentally friendly practices.

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