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An Integrated Business Strategy for the Twin Transition: Leveraging Digital Product Passports and Circular Economy Models

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ABSTRACT

Companies face significant challenges in implementing digital transformation, often because of the use of fragmented strategies and limited cross-functional coordination. Furthermore, not all digital innovations align with sustainability objectives. In response to this complexity, recent European Union directives have introduced digital product passports (DPPs) as strategic instruments to bridge the gap between digitalization and sustainability. Although promising, DPP implementation remains in its infancy and requires robust data governance to mitigate the risk of information overload. The present study integrates business perspectives into the design of DPPs, with a particular focus on the textile industry. It explores how DPPs can enhance competitiveness, facilitate sustainability monitoring, and promote circularity. Drawing on insights from textile firms and consulting support, this research employs multicriteria decision-making methodologies—specifically, the analytic hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS). The findings reveal a strong alignment between these methodologies and a shared recognition of the strategic value of DPPs, particularly in facilitating access to information on product reuse, repair, and recycling. Additionally, the analysis highlights consultants' emphasis on the "Made in Italy" designation as a key differentiator. Overall, DPPs are shown to advance the development of circular business models in the textile sector by supporting three strategic priorities: material traceability, repair guidance, and optimized recycling pathways.

1 | Introduction

The global industrial landscape is undergoing a profound transformation known as the twin transition—a dual shift merging the adoption of digital technologies with the pursuit of sustainable practices. This convergence is increasingly recognized as a strategic pathway to enhancing business competitiveness and strengthening the resilience of production systems (Fernández-Miguel et al. 2024a; Hofmann Trevisan et al. 2024). The twin transition requires a coordinated alignment of digitalization and sustainability, emphasizing their mutual reinforcement as drivers of economic and industrial innovation. It underscores the interconnected nature of digital progress and environmental responsibility, representing foundational pillars for the advancement of operational efficiency, resilience, flexibility, and long-term value creation in global supply chains (Tavana et al. 2024; Zaidi et al. 2024).

A critical enabler of this transition is the availability of accurate, comprehensive, and accessible product information across the entire life cycle, from raw material extraction to end-of-life management (Jensen et al. 2023). Data-driven approaches are key in bridging information gaps, monitoring environmental impacts, and supporting decisions aligned with circular economy principles. Within this context, digital product passports (DPPs) have emerged as pivotal tools to operationalize the vision of a digitally empowered, environmentally sustainable business model (Carvalho et al. 2025; Gieß and Möller 2025; Wicaksono et al. 2025).

DPPs are "digital identity cards" intended to systematically collect, manage, and communicate comprehensive, product-specific information across the product life cycle. As a digital twin of the physical product, the DPP serves as an enabler of data-driven circular strategies while supporting compliance with evolving sustainability regulatory frameworks (European Commission 2024a; Gieß and Möller 2025; Plociennik et al. 2022).

DPPs have the potential to enhance transparency, traceability, and accountability by enabling visibility at the product level. This facilitates more responsible product design, sustainable procurement, and collaborative value chain management. The twin transition and DPPs are thus strategically intertwined: While the former articulates a future-oriented vision for a more sustainable and digital economy, the latter provides the practical infrastructure and actionable data needed to realize that vision. In more detail, DPPs complement the twin transition by enabling the efficient management of product-related information throughout the life cycle (Wan and Jiang 2025).

Recognizing this potential, the European Union (EU) has taken significant steps to institutionalize DPPs through initiatives such as the European Green Deal, the Circular Economy Action Plan, and, most recently, the Eco-Design for Sustainable Products Regulation (ESPR) (European Commission 2024b). Since 2024, DPPs have been mandated for select product categories—beginning with industrial batteries (Berger et al. 2023)—and between 2025 and 2026, they will extend to cover all products on the EU market (European Commission 2024b).

The recent literature increasingly highlights the role played by DPPs in promoting sustainable decision-making, reducing dependency on virgin materials, and enabling key circular strategies such as reuse, repair, remanufacturing, and recycling (Koppelaar et al. 2023; Zhang and Seuring 2024). By offering detailed insights into product origins, material composition, durability, and end-of-life pathways, DPPs help close critical information gaps across supply chains (Plociennik et al. 2022). In particular, they improve traceability, support repair operations, and facilitate responsible material recovery. These functions are especially relevant to resource-intensive sectors such as fashion and electronics, with substantial environmental impacts (Chaudhuri et al. 2024).

Despite their potential, most DPP initiatives are still in the conceptual or pilot phase, and significant challenges remain regarding their practical implementation (Plociennik et al. 2022). As DPPs move toward mainstream adoption, research points to the importance of managing dynamic information flows, ensuring real-time data updates, and identifying the most relevant data categories to avoid overload while maximizing utility (Gallina et al. 2023; Voulgaridis et al. 2024). Additionally, the alignment of diverse stakeholders throughout the product life cycle and their contributions to data sharing remain significant challenges (Panza et al. 2023).

The present research adopted a multimethod quantitative–qualitative approach. The first phase employed an analytic hierarchy process (AHP), involving the direct participation of both company managers and consultants to structure and prioritize key criteria. AHPs are widely used to manage complex problems and multidimensional data (D'Adamo et al. 2025; Tavana et al. 2023). In the second phase, the technique for order of preference by similarity to ideal solution (TOPSIS) was applied to test the robustness of the AHP findings. The combined AHP–TOPSIS methodology is gaining traction in sustainability research within the fashion industry (Bathrinath et al. 2021; Phan Ha et al. 2024) and offers a rigorous framework for capturing stakeholder-informed priorities in DPP development.

The textile industry, characterized by its intricate and fragmented supply chains (Saha et al. 2024), presents a strategic and suitable domain for the implementation of DPPs. The sector's complexity—driven by a diverse array of actors operating across various geographical and functional stages—underscores the value of the traceability, transparency, and data standardization offered by DPPs. However, the successful integration of DPPs in the textile sector demands not only technological readiness but also a robust digital infrastructure and a nuanced understanding of the sector's operational and sustainability challenges (Carvalho et al. 2025; Luoma et al. 2022). This aligns closely with the foundational principles of the circular economy, particularly promoting resource efficiency, extending product life cycles, and minimizing waste (Hassan et al. 2024; Kebede et al. 2024).

As highlighted, DPPs function as both tools for environmental monitoring and strategic drivers of business transformation. By embedding life cycle data into core business processes, DPPs enable companies to align their operations with sustainability, transparency, and circularity—critical dimensions for meeting EU regulatory requirements, fulfilling market expectations, and enhancing supply chain resilience.

The present study aimed to identify and prioritize the types of information that companies perceive as strategically valuable for the effective deployment of DPPs. Specifically, it addressed the following research question: What data do companies and consultants in the textile sector consider essential for inclusion in a DPP? To address this question, this study evaluated the types of information that could enhance competitiveness, facilitate sustainability tracking, and support the development of circular business models through a business-driven approach to DPP design.

The remainder of this paper is organized as follows. Section 2 outlines the theoretical framework that contextualizes the present study. Section 3 describes the research design and methodological approach. The empirical findings are presented in Section 4 and further examined in Section 5. Finally, theoretical contributions and managerial implications are addressed in the concluding section, which outlines the study's limitations and proposes directions for future research.

2 | Literature Review

2.1 | The Twin Transition and the Tool for Data Management

The twin transition integrates digital innovation and the SDGs, offering a strategic framework for enhancing industrial competitiveness, operational resilience, and the environmental stewardship of supply chains (Hofmann Trevisan et al. 2024; Zaidi et al. 2024). The SDGs are relevant to the business sphere (Di Stefano et al. 2024), which encompasses a wide array of stakeholders (D'Adamo et al. 2025). Business decision-making increasingly shows a focus on offshoring strategies (Bettiol et al. 2023), emphasizing the development of supply chains harnessing digitalization to enhance sustainability outcomes (Fernández-Miguel et al. 2024b). Within this context, the human dimension is becoming ever more significant (Tavana et al. 2025), as both internal and external corporate environments seek a balanced integration (Fernández-Miguel et al. 2025). Circular solutions demonstrate strong alignment with the SDGs (Sardianou et al. 2024) and underscore the need for supportive policy frameworks (Arauzo-Carod et al. 2022).

The issue of sustainability is also leading companies to change how they present themselves to the outside world (Jagani and Saboori-Deilami 2025; Saari et al. 2025). A pillar of the twin transition is the growing centrality of data management in industrial sustainability efforts (Muench et al. 2022). Within this context, data are positioned as a critical enabler: Comprehensive, timely, and standardized information allows companies to monitor environmental performance and optimize supply chain processes. Digitalization thus becomes not merely supportive but a fundamental prerequisite for life cycle–based decision-making aimed at maximizing resource utility (Kilinc et al. 2025).

The EU's strategic sustainable frameworks—particularly the ESPR—underscore the importance of digitizing product-specific data to promote transparency, accountability, and stakeholder collaboration across value chains (European Commission 2024b). In this regard, DPPs enable the generation of continuous data flows within and beyond organizational boundaries, integrating technical, managerial, and cultural dimensions (King et al. 2023) while promoting sustainable traceability and transparency at both intra- and inter-organizational levels (Garcia-Torres et al. 2024).

DPPs provide a comprehensive data infrastructure that consolidates product-related information across the entire life cycle (Wan and Jiang 2025). This is especially relevant to sustainable product design, which requires an integrated and iterative approach that combines environmental considerations with product functionality, durability, and modularity. Early-stage design decisions (e.g., material selection, ease of disassembly, and component standardization) are critical in enabling downstream circular strategies, including repair, reuse, and recycling (Mengistu et al. 2024). DPPs directly support this objective by facilitating the tracking of embedded materials and design logic, thereby promoting sustainable product development aligned with circularity principles and compliant with EU regulatory frameworks (Carvalho et al. 2025; Gieß and Möller 2025; Wicaksono et al. 2025).

At an operational level, DPPs act as "digital twins," mirroring physical products through virtual data layers that support traceability and informed decision-making (Jensen et al. 2023; Wan and Jiang 2025; Wicaksono et al. 2025). By consolidating comprehensive information on material inputs, production processes, and end-of-life scenarios (e.g., product composition, material origin, recyclability, and disposal pathways), they represent transformative instruments for data-driven circular practices (Koppelaar et al. 2023; Langley et al. 2023; Zhang and Seuring 2024). Within the evolving ecosystem of data sharing, DPPs facilitate the standardization and accessibility of product data across the entire life cycle (Gieß and Möller 2025; Jensen et al. 2024), thereby supporting companies in enhancing their sustainability performance in alignment with EU regulatory requirements and evolving consumer expectations. Furthermore, DPPs have the potential to drive the strategic transformation of business models toward circularity and broader stakeholder integration. Their strategic importance lies in enabling data-driven decision-making across all business functions, fostering alignment between sustainability objectives, digital competitiveness, and organizational shifts toward a circular economy.

2.2 | Functional Value, Strategic Implications, and Challenges of DPPs in the Textile Sector

At the company level, DPP implementation necessitates a robust digital infrastructure to collect, store, and securely share data. Unique identifiers (e.g., QR codes, RFID, and NFC) enable the linkage of physical products to their corresponding digital profiles (Alves et al. 2024). Blockchain-based storage solutions further enhance this architecture by offering distributed, tamper-resistant data management, improving data integrity, security, and transparency within decentralized networks, and directly supporting DPPs' green technology functionality (Hariyani et al. 2025). Each DPP functionality entails specific trade-offs concerning efficiency, transparency, and real-time data updating. In particular, DPPs can contribute to system-level sustainability by enabling real-time tracking and diagnostics (e.g., predictive maintenance and product aging analysis), thereby addressing critical information gaps (Wan and Jiang 2025).

At the consumer level, DPPs play a pivotal role in influencing sustainable consumption behaviors. By improving transparency around environmental footprints, supply chain ethics, and circularity performance, DPPs empower consumers to make more responsible and informed choices (Carvalho et al. 2025; Gieß and Möller 2025; Wicaksono et al. 2025). Prior research underscores the importance of continuously updated DPP data throughout the product life cycle to facilitate sustainable purchasing, repair, and disposal decisions (Gallina et al. 2023; Voulgaridis et al. 2024).

Thus, DPPs not only serve operational functions but also enhance dynamic capabilities, such as customer knowledge absorption (Trentin et al. 2025). Firms that successfully integrate customer feedback and usage data into product development and innovation processes tend to exhibit stronger alignment with market demands and sustainability expectations. This capability is especially pertinent in data-intensive environments, where real-time consumer insights—enabled through digital interfaces—inform the refinement of product attributes, enhance life cycle management, and support the identification of sustainability-driven innovation opportunities. Effective consumer interfaces and secure access protocols are critical to ensuring data usability and privacy (Wan and Jiang 2025).

From a strategic standpoint, given their functional value at both company and consumer levels, DPPs can reduce dependence on virgin materials and promote responsible sourcing (Koppelaar et al. 2023; Zhang and Seuring 2024) by facilitating data integration (Jensen et al. 2023), supporting the development of circular ecosystems (Jensen et al. 2024), and enhancing life cycle management (Koppelaar et al. 2023; Zhang and Seuring 2024). However, achieving these objectives requires active engagement across stakeholder networks to drive the dual transition toward digitalization and sustainability (Tabas et al. 2025). Such alignment is foundational to circular business strategies focused on narrowing, slowing, and closing resource loops—an approach that depends on cross-sector collaboration to maximize long-term value creation (Jensen et al. 2024).

Moreover, DPPs can act as tools for competitive differentiation, particularly in industries where transparency and quality are crucial, such as electronics (Chaudhuri et al. 2024) and textiles (Komal and Saad 2024; Saha et al. 2024; Tolentino-Zondervan and DiVito 2024). In this respect, the textile sector offers a compelling context for the deployment of DPPs because it is characterized by fragmented global supply chains, high environmental impact, and increasing consumer demand for sustainability, as evidenced by recent studies (Alves et al. 2024; Carvalho et al. 2025). As a high-impact sector, the textile industry presents a critical context in which digital sustainability tools such as DPPs can function as strategic levers for differentiation, brand positioning, and value chain governance, especially amid increasing regulatory scrutiny and heightened consumer awareness (Civera et al. 2025).

Moreover, advanced functionalities such as the digital life cycle passport expand upon DPP capabilities by collecting end-of-life data, improving design feedback loops, and supporting legal documentation for recycling (Gallina et al. 2023; Koppelaar et al. 2023). By standardizing product information, DPPs help operationalize circular principles such as repair, reuse, and recycling (Voulgaridis et al. 2024; Wicaksono et al. 2025). Moreover, their integration into business models strengthens the three strategic pillars of material traceability, product longevity, and end-of-life optimization (Jensen et al. 2023; Plociennik et al. 2022; Voulgaridis et al. 2024). This enables companies not only to comply with EU regulatory requirements but also to strategically reposition themselves in competitive markets by aligning their business operations with long-term sustainability objectives, thereby strengthening resilience and stakeholder trust.

DPPs also offer the potential to link upstream production decisions with downstream recovery strategies, effectively closing material loops and minimizing waste. Such integration supports practical life cycle assessments and fosters environmentally responsible procurement practices (Gallina et al. 2023; Voulgaridis et al. 2024).

Despite their promising role in advancing the twin transitions of digitalization and sustainability, many DPP initiatives remain in the pilot phase, although the trajectory suggests broader cross-sectoral adoption. However, several implementation barriers persist, including high costs, supply chain complexity, and limited standardization (Koppelaar et al. 2023; Zhang and Seuring 2024). Overcoming these challenges requires the development of interoperable systems and the strengthening of user trust in data integrity (Jensen et al. 2023; Wan and Jiang 2025). Indeed, the application of DPPs in remanufacturing markets—particularly within the textile sector—remains marked by uncertainty and operational complexity (Gallina et al. 2023; Voulgaridis et al. 2024).

Addressing these challenges requires the identification of adequate and relevant data for DPPs, as well as simplified data-sharing processes during the use phase (Wan and Jiang 2025), to enable collaborative data ecosystems to enhance demand forecasting and operational sustainability. Artificial intelligence and other technologies addressing digitalization and the social sustainability of working conditions (Guanglei et al. 2025) could be incorporated into future DPP structures to support broader sustainability goals (Panza et al. 2023).

2.3 | Digital and Sustainable Business Strategies

The integration of digitalization and sustainability has emerged as a foundational driver of organizational innovation, competitiveness, and systemic circularity. Recent studies have underscored the convergence of these domains as mutually reinforcing pillars of a unified business strategy, with digital technologies enhancing operational efficiency while supporting ecological responsibility and circularity.

To navigate this transition, firms must move beyond isolated innovation efforts and embed digital technologies within their value creation, delivery, and capture (Frishammar et al. 2025). The development of business models that effectively harness digital tools (e.g., DPPs) is becoming increasingly essential for addressing the complex demands of circular transformation. Challenges such as information asymmetries and fragmented value delivery systems can be mitigated through the strategic deployment of digital systems that enhance transparency and coordination across value dimensions (Frishammar et al. 2025). The performance of circular supply chains, in turn, hinges on the alignment of technological innovation and eco-efficiency, supported by stakeholder collaboration and data-centric decision-making frameworks (Kurrahman et al. 2025). This alignment is particularly crucial in the textile industry, where the achievement of sustainability targets depends on the availability of interoperable and actionable data infrastructures.

Digital infrastructures such as DPPs support core circular economy strategies (e.g., narrowing, slowing, and closing resource loops) by improving the quality, accessibility, and continuity of life cycle data (Piedra-Muñoz et al. 2025). Transparency, traceability, and stakeholder integration, enabled by digital platforms, are widely recognized as key levers for delivering the "triple bottom line" (Civera et al. 2025; Garcia-Torres et al. 2024). In this vein, DPPs contribute to translating high-level circular principles (e.g., reuse, repair, and recycling) into data-driven operational practices, informing decision-making along increasingly complex value chains (Garcia-Torres et al. 2024; Piedra-Muñoz et al. 2025). More generally, digital technologies enhance environmental innovation by recombining and amplifying sustainability-related information. These capabilities support regulatory compliance and stakeholder engagement by improving transparency and accountability (Sun et al. 2025). However, a disconnect persists between the strategic role played by digital transformation and its representation in corporate sustainability reporting, underscoring the need for a deeper integration of digital sustainability considerations into business models (De Nicola et al. 2024).

At the ecosystem level, the circular economy is increasingly understood as a data-driven, collaborative configuration of actors united by shared objectives and digital interconnectivity (Aryee 2024). This systemic approach is particularly relevant in fashion and textile value chains, where supply chain fragmentation intensifies implementation challenges. Evidence from the circular startup digital adoption (CSDA) framework illustrates that digital technologies can empower emerging enterprises by fostering entrepreneurial orientation, building organizational capabilities, and enhancing responsiveness to stakeholder expectations (Hajoary et al. 2024).

However, the strategic deployment of digital technologies must be weighed against the environmental trade-offs associated with their adoption. Digital strategies, in themselves, do not automatically yield sustainability outcomes. Thus, the environmental impacts of infrastructure, resource extraction, and energy consumption must be critically assessed to ensure that any digital transformation aligns with sustainability objectives (Meinhold et al. 2025). Moreover, research has shown that the economic benefits of digitalization for small- and medium-sized enterprises (SMEs) are dependent on their environmental performance, underscoring the need for strategic coherence between digital investments and sustainability metrics (Miranda et al. 2024).

The ability to achieve a competitive advantage through digital traceability tools such as DPPs is further conditioned by a firm's digital orientation, adaptability, and resource flexibility (Baawain et al. 2025). For SMEs, this transition is frequently hindered by structural barriers, including limited financial resources, skill shortages, and technological complexity (Sonar et al. 2023). In this vein, the successful integration of digital sustainability tools requires not only technological adaptation but also profound structural and cultural reconfiguration within organizations. To fully realize the benefits of these tools (e.g., DPPs), firms must embed them into their core value logic, thereby redefining their business models (Dittmar et al. 2025). Although digital transformation is widely acknowledged as a strategic priority, its potential to shape innovative and sustainable business models remains underutilized (De Nicola et al. 2024). The effective integration of digital and environmental strategies thus necessitates a managerial shift toward enhanced data governance, life cycle thinking, and coordinated stakeholder engagement.

In conclusion, DPPs should be recognized not merely as technical tools but also as strategic enablers of operational resilience, regulatory compliance, and environmental differentiation. Realizing these benefits, however, requires firms to innovate their business models by embedding DPP functionalities. This integration is not optional but essential for organizations navigating the dual imperatives of digitalization and sustainability. Moreover, the literature highlights the urgency of investigating how DPPs may be effectively designed and integrated into core business practices. This need is particularly acute in the textile sector, where data-informed strategies are vital to overcoming adoption barriers, aligning internal capabilities with circular economy principles, and securing competitive advantage in the context of the twin transition.

3 | Methodology

Analytical decision-making is used to frame complex issues to manage a wide range of data. In this respect, multicriteria decision analysis (MCDA) supports companies in making strategic choices. MCDA allows for the evaluation of multidimensional decision-making problems involving conflicting objectives, and the method appears to be used in decision-making processes in the fashion sector (Özdağoğlu et al. 2024; Sellitto et al. 2022). By employing pairwise comparisons, the AHP prevents experts from assigning maximum importance to all criteria. In light of the constant changes inherent to supply chains, the fashion sector has increasingly become a focus of strategic analysis (Bhandari et al. 2022; Komal and Saad 2024).

The initial phase of this empirical study required the managers of each company to conduct an AHP analysis, consisting of an iterative pairwise comparison of the criteria under evaluation. Expert selection plays a fundamental role in AHP conducted in the textile sector (Barletta et al. 2024), given the method's reliance on subjective judgment over objective measures. In the present study, a total of nine criteria were selected to encompass the various dimensions of competitiveness in the textile industry. To validate the selection of criteria, several academics with expertise in business strategy were consulted. The experts assessed the consistency of the criteria, justified their inclusion, and suggested possible revisions, thereby ensuring that respondents were provided with a comprehensive and coherent set of information (Table 1).

Experts were identified through a convenience sampling strategy, with invitations sent via email and LinkedIn outlining the purpose of this study, the data collection method, and the criterion that the first five positive responses would be selected. Two distinct categories of experts were targeted:

TABLE 1 | Strategic purpose of the criteria.

	Criterion	Strategic purpose
C1	Data to improve traceability across the supply chain	Improve operational efficiency, reduce information asymmetries, and enhance communication
C2	Data on company commitment to reducing resource consumption	Optimize logistics and reduce costs and environmental impact
C3	Data to certify safety and harmfulness to human health and the environment	Improve reputation and offer a competitive advantage
C4	Data on social sustainability, including worker job conditions	Improve corporate image
C5	Data useful for creating partnerships with other companies	Create new business synergies
C6	Data useful for promoting "Made in Italy"	Strengthen market positioning and brand recognition
C7	Data provided by consumer feedback	Collect data at no cost and gather new input for strategic improvements
C8	Data on EU certifications	Monitor product quality and combat counterfeiting
C9	Data on the 3R principles: reuse, repair, and recycling practices for products and/or their components	Generate new business opportunities and build customer loyalty through incentives

textile sector professionals managing the digital transition and consultants providing tools and strategies to support this transition within the textile industry. Table A1 describes the 10 selected experts. The convenience sampling approach was deemed appropriate, given the exploratory nature of the research and the need for informed judgments on complex, specialized criteria associated with the design and implementation of DPPs. Convenience sampling is widely employed in studies that prioritize expert insights over generalizable statistical inference (Etikan et al. 2015). Accordingly, the objective was not to achieve population representativeness but to engage highly knowledgeable individuals capable of providing qualified, experience-based evaluations of sustainability criteria pertinent to DPP deployment. Each selected expert possessed domain-specific proficiency in conducting pairwise comparisons using the AHP and in interpreting trade-offs across complex, interrelated factors.

Furthermore, convenience sampling is an established methodological practice in qualitative research, particularly in early-stage or underexplored domains (Doloi 2011; Govindan and Bouzon 2018), such as the implementation of DPPs. While recognizing the inherent limitations of nonprobabilistic sampling (e.g., risk of selection bias), the composition of the present sample, comprising both consultants and industry professionals, facilitated a comparative stakeholder analysis aligned with the study's objective of deriving practically relevant insights on the informational dimensions of DPPs.

Finally, it is worth emphasizing that the AHP method can be effectively applied within organizational settings to foster stakeholder engagement (D'Adamo 2023)—a function deemed strategically important for identifying the most sustainable solutions (Bonifazi et al. 2025).

In the present study, criteria were compared using a 1–9 scale (Table A2), and the consistency ratio (CR) was calculated to evaluate the reliability of the results (Saaty 2008). The CR, representing the ratio between the consistency index and random inconsistency (Table A3), could not exceed 0.10. To streamline the process, the CR was automatically computed within the Excel file completed by the experts.

The TOPSIS was employed to strengthen the methodological framework further and validate the robustness of the proposed model. This method ranks alternatives based on their relative closeness to the ideal positive solution and their distance from the negative ideal solution, according to the established criteria (Stevens et al. 2024). It can be applied using the min–max normalization approach (D'Adamo et al. 2025), and it may also be integrated with AHP (Amiri et al. 2024). Combined AHP–TOPSIS analyses are increasingly utilized within the fashion sector (Bathrinath et al. 2021; Phan Ha et al. 2024).

4 | Results

The starting point for the analysis involved collecting the pairwise comparisons provided by the 10 experts for the nine selected criteria. Each matrix was completed following 36 pairwise comparisons, and the overall judgment was considered consistent when the CR did not exceed 0.10. This condition was met across all matrices (Tables A4–A13), with no correlation observed between the expert number and their evaluations, as noted in Table A1. For example, Expert 1 identified Criterion C6 as the most relevant (0.241), while Criterion C7 was deemed the least relevant (0.032). In contrast, Expert 6 assigned the highest relevance to Criterion C9 (0.222) and the lowest to Criterion C5 (0.043). Table 2 summarizes all responses, with each expert's maximum values highlighted in green and minimum values in pink.

The results revealed significant variation in the evaluations, even within the same criterion. Notably, the highest standard

TABLE 2 | Results of the expert pairwise comparisons.

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
C1	0.036	0.164	0.102	0.154	0.121	0.069	0.054	0.224	0.067	0.146
C2	0.223	0.118	0.075	0.200	0.185	0.080	0.054	0.262	0.129	0.037
C3	0.059	0.071	0.068	0.175	0.175	0.060	0.040	0.082	0.179	0.042
C4	0.120	0.138	0.080	0.191	0.072	0.051	0.059	0.081	0.062	0.071
C5	0.043	0.063	0.075	0.030	0.068	0.043	0.059	0.086	0.045	0.095
C6	0.241	0.044	0.073	0.039	0.071	0.125	0.059	0.073	0.259	0.458
C7	0.032	0.037	0.075	0.036	0.066	0.162	0.229	0.042	0.047	0.027
C8	0.059	0.052	0.099	0.051	0.135	0.188	0.076	0.050	0.018	0.085
C9	0.188	0.313	0.353	0.125	0.107	0.222	0.371	0.100	0.192	0.038

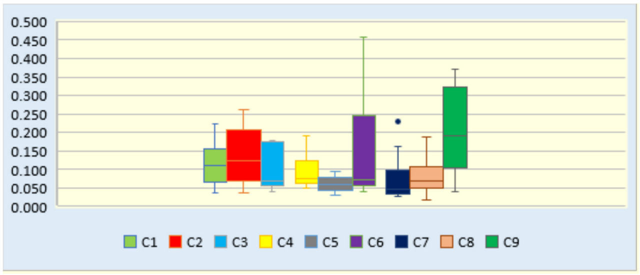

FIGURE 1 | Distribution of ratings assigned to individual criteria.

deviation was associated with Criterion C6 (0.135), which also received the highest individual rating across all cases—0.458 from Expert 10 (Figure 1). This criterion was considered the most relevant by three experts, while others assigned it considerably lower importance. Similarly, Criterion C9 exhibited the second-highest standard deviation (0.114) and was identified as the most relevant by four experts. However, Expert 10 evaluated it as largely irrelevant. Additionally, Criterion C2 was deemed most important by three experts and demonstrated a moderate standard deviation of 0.077, consistent with previous observations. Finally, it is worth noting that Criterion C7 was identified as the least relevant by five experts, although Expert 7 ranked it as the second most important.

The subsequent step involved aggregating the individual judgments, assigning equal weight to each expert. The results were then disaggregated by stakeholder category—companies and consultants—as shown in Table 3. The analysis revealed notable differences between the two resulting rankings. However, a point of convergence emerged on Criterion C9, which held the highest overall weight at 0.201—approximately one-fifth of the total—driven primarily by the consultants' evaluations. In contrast, company representatives ranked Criterion C6 as the most important (0.144), while it was only the sixth most important according to the consultants. Criterion C2 ranked third overall, with a weight of 0.136. Together, Criteria C2, C6, and C9 accounted for approximately half of the total weight. Interestingly, Criterion C2 showed no significant variation in ranking between the stakeholder groups. Criterion C4 consistently ranked fourth across all three perspectives (overall, companies, and consultants), with a weight of 0.114. Nonetheless, the comparative analysis highlighted substantial differences in the rankings of Criteria C4, C6, and C7. In terms of absolute values, the most significant discrepancy was found for Criterion C6, where the score attributed by companies exceeded that of consultants by 0.101. A similar, although smaller, difference was observed for Criterion C7 (0.053).

Conversely, consultants placed greater emphasis on Criterion C4, with a delta of 0.055, and Criterion C2, with a delta of 0.048. Criterion C9 was ranked last overall, with a value of 0.060, and held the second-to-last position in both expert groups. For the consultants, the lowest rank was assigned to Criterion C7, while the companies placed Criterion C4 in the final position.

To assess the robustness of the AHP results, the TOPSIS method was applied by evaluating the Euclidean distance to the ideal and negative solutions (Figure 2). The results supported the earlier findings, with the overall ranking remaining largely consistent. The only variation was the reversal of positions between Criteria C7 and C8, which continued to occupy the lowest ranks. Methodologically, these results confirmed the dominance of Criterion C9, followed by Criterion C6.

Finally, the experts' quantitative assessments were complemented by a qualitative analysis, with interviews providing valuable insights into the characteristics and strategic relevance of DPPs. This integrative approach was enabled through expert collaboration, as participants not only offered analytical evaluations of the factors but also articulated their reasoning and domain-specific knowledge, thereby contributing to the identification of key strengths. Consequently, several benefits emerged, each accompanied by a description and potential expected outcomes: (i) information traceability, (ii) data standardization, (iii) improved operational efficiency, (iv) reduced information asymmetries, (v) enhanced transparency across the supply chain, (vi) more efficient resource management, (vii) increased data security and immutability, and (viii) counterfeiting prevention (Table 4).

Finally, the qualitative data analysis revealed that greenwashing was a concern for both companies and consumers. Although sustainability was often declared as a priority, it was not consistently considered during the purchasing phase. Companies also emphasized the importance of "Made in Italy" labeling,

TABLE 3 | AHP results.

	Description	Consultants		Companies		Total	
		Value	Ranking	Value	Ranking	Value	Ranking
C1	Data to improve traceability across the supply chain	0.115	4	0.112	4	0.114	4
C2	Data on company commitment to reducing resource consumption	0.160	2	0.112	3	0.136	3
C3	Data to certify safety and harmfulness to human health and the environment	0.110	5	0.081	7	0.095	5
C4	Data on social sustainability, including worker job conditions	0.120	3	0.065	9	0.093	6
C5	Data useful for creating partnerships with other companies	0.056	8	0.065	8	0.060	9
C6	Data useful for promoting "Made in Italy"	0.094	6	0.195	1	0.144	2
C7	Data provided by consumer feedback	0.049	9	0.102	5	0.075	8
C8	Data on EU certifications	0.079	7	0.083	6	0.081	7
C9	Data on the 3R principles: reuse, repair, and recycling practices for products and/or their components	0.217	1	0.185	2	0.201	1

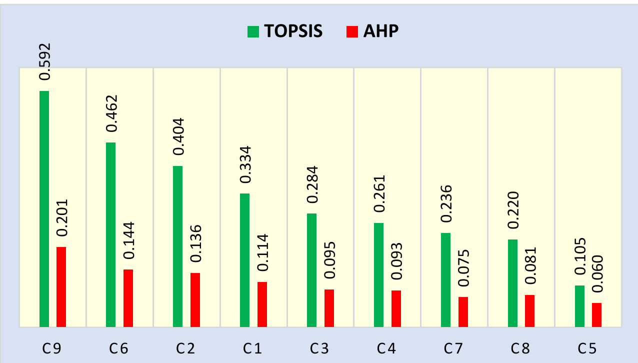

FIGURE 2 | Results of TOPSIS versus AHP.

noting that DPPs could support sales by providing consumers with verifiable information about the actual origin of products. Additionally, information related to reuse, repair, and recycling emerged as a practical feature capable of addressing consumer inquiries.

Integration of the quantitative findings derived from the AHP and TOPSIS with the qualitative insights gained from the expert interviews underscored the multidimensional value of DPPs in supporting the twin transition. Notably, the consistent prioritization of Criterion C9 (information on reuse, repair, and recycling) across all expert groups closely aligned with the qualitative benefits associated with efficient resource management, as reflected in the empirical findings (Table 4). Indeed, by enabling firms to track product components throughout their life cycle, C9 may facilitate data-driven decision-making, optimized regeneration cycles, reduced material waste, and streamlined inventory processes—key pillars of both operational and environmental efficiency.

Similarly, companies' strong emphasis on Criterion C6 (information on "Made in Italy") was directly linked to DPPs' potential to mitigate risks associated with counterfeiting. In sectors such as fashion and textiles—where brand heritage and product origin are critical differentiators—DPPs may serve as verifiable authentication mechanisms, reinforcing consumer trust, enhancing brand equity, and supporting compliance with origin claims. This illustrates how certain criteria—although not directly tied to environmental metrics—may nonetheless contribute to sustainability by safeguarding product integrity and strengthening local value chains.

While C9 emerged as a shared top priority, divergences in the rankings of other criteria revealed significant interpretive insights. For example, C6 was ranked highest by companies but placed sixth by consultants, whereas C2 (reduction of emissions and resource consumption) received a higher ranking from consultants than from firms. These discrepancies may reflect differing strategic orientations. Companies—particularly SMEs in consumer-facing industries—may prioritize C6 for its immediate marketing utility, its potential for competitive differentiation, and its alignment with consumer expectations of authenticity. From this perspective, DPPs may be viewed as branding tools that reinforce national identity and enhance market visibility.

Conversely, consultants may adopt a broader, more systemic perspective, interpreting DPPs primarily through the lens of governance and compliance. In the present analysis, consultants' emphasis on C2 and C4 (social sustainability) aligned closely with regulatory frameworks and environmental, social, and governance (ESG) performance metrics, as well as with long-term ecological and social responsibility objectives. This interpretive divergence underscores that DPPs should not be understood solely as technological or operational instruments but also as strategic tools shaped by institutions, organizational culture, and intended use.

These contrasting priorities suggest that a singular, fixed DPP architecture may be insufficient to meet the heterogeneous

TABLE 4 | Benefits linked to the DPP implementation.

Benefits	Description of benefits	Expected results
Information traceability	A digital archive that collects data on the product life cycle, accessible in real-time	Enhanced product monitoring and management accelerated decision-making
Data standardization	Creation of a common language for communication across the supply chain, reducing data incompatibility	Fewer interpretation errors and improved communication and information flow
Improved operational efficiency	Optimization of supply chain management through the reduction of waiting times and enhanced coordination	Reduced downtime, better operational coordination, and quicker response to market demands
Reduced information asymmetries	Access to detailed information for all supply chain actors, preventing unequal access	Elimination of problems stemming from a lack of transparency, improved operations, and resource management
Enhanced transparency along the supply chain	Details on product origin, materials, and processes, supporting sustainability compliance	Increased trust among stakeholders, lower regulatory risks, and improved corporate reputation
More efficient resource management	Precise tracking of regeneration or replacement timelines, improving inventory and cost control.	Lower operating costs, enhanced sustainability, and optimized resource allocation
Increased data security and immutability	Use of blockchain to ensure secure, unalterable, and verifiable records of transactions and product changes	Stronger protection against fraud and tampering, enhanced transparency, and brand credibility
Counterfeiting prevention	Prevention of counterfeit products through guarantees of authenticity and transparency	Protection of brand value, sustained consumer trust, and reduced economic and employment-related risks

needs of all stakeholders. Instead, the findings highlight the necessity of a modular and customizable DPP framework capable of addressing both compliance-driven requirements and market-facing applications. The AHP/TOPSIS results reinforce this need, revealing that while certain data categories (e.g., C9) garner broad consensus, the value and function of others (e.g., C6 and C2) may be context dependent.

5 | Discussion

The main findings of this study show that DPPs have the potential to completely transform the fashion industry by providing insightful information about how to recycle, repair, and reuse fashion items while also emphasizing sustainability and the authenticity of premium "Made in Italy" products. They facilitate the shift to a more circular economy, increase transparency, and empower customers to make more responsible and knowledgeable purchases. The adoption of sustainable materials and effective communication of their advantages could contribute to a production system that places equal emphasis on social and environmental well-being and profitability. Additionally, some analyses have shown that "Made in Italy" in the fashion sector can generate a competitive advantage and a precise market positioning to defend business ecosystems (D'Adamo et al. 2024).

While competitiveness increasingly hinges on the achievement of sustainability objectives, the current landscape is shaped by a dual transition—green and digital (Kurniawan et al. 2023; Sassanelli et al. 2023). DPPs offer substantial benefits from both circular economy and sustainability perspectives (Kebede et al. 2024; Langley et al. 2023; Lopes and Barata 2024). The traditional notion of value is being replaced by the concept of shared value, aligning with the principles of corporate social responsibility and supporting progress toward SDG 12. As a result, all actors along the value chain can leverage the benefits of DPPs, enhancing visibility, accountability, and traceability (Jansen et al. 2023). DPPs also facilitate the monitoring of key indicators such as greenhouse gas emissions (Jensen et al. 2023), promote more efficient resource management and energy savings (Hedberg and Šipka 2021), and provide critical data for the valorization of materials, thereby optimizing supply and production processes (Adisorn et al. 2021). Moreover, the granularity of information accessible through DPPs empowers more environmentally conscious consumption. Specifically, DPPs offer trustworthy data regarding recycled content, raw material sources, and end-of-life options such as recycling, repair, and reuse (Götz et al. 2022).

The available evidence underscores the strong connection between resource circularity and DPPs (Barwasser et al. 2024). However, to effectively inform consumers, comprehensive data covering the entire product life cycle must be accessible (Jensen et al. 2024). Therefore, pragmatic sustainability assessments are essential to enrich the data conveyed through DPPs. Life cycle analysis (LCA) may play a central role in this process, offering detailed insights into the economic, environmental, and social dimensions of sustainability, moving beyond purely ideological interpretations. Although digitalization presents significant opportunities, it must not be uncritically embraced as an inherent good. Instead, resources should be allocated toward achieving true effectiveness and efficiency.

The textile sector illustrates this complexity well, as contradictions between innovative sustainability initiatives and persistent economic interests often mark it. Moreover, fast fashion models continue to dominate, bringing with them the risk of greenwashing. Within this landscape, DPPs may enable cultural and operational shifts, fostering a more informed and environmentally responsible industry (Carvalho et al. 2025). Key supporting mechanisms include increased transparency—potentially enforceable as a legal requirement (Tolentino-Zondervan and DiVito 2024)—and the integration of blockchain technologies to enhance traceability across the value chain (Alves et al. 2024).

DPPs represent powerful instruments for advancing circularity in the fashion industry, fostering transparency and consumer awareness, and optimizing business operations. In more detail, the present findings emphasize that DPPs may contribute to three strategic pillars. First, material traceability: DPPs offer comprehensive records of material composition, enabling stakeholders (i.e., consumers, manufacturers, and recyclers) to identify components suitable for reuse, repair, or recycling at the end of a product's life. Second, repair facilitation: DPPs may include repair manuals, guides, or tutorials for both consumers and technicians, thus encouraging maintenance and extending product lifespans. Third, optimized recycling pathways: DPPs can indicate the most efficient methods for recycling each material, ensuring appropriate end-of-life treatment, and minimizing landfill waste. Ultimately, the present study contributes to the strategic management literature by positioning DPPs as integrative tools aligning digital innovation with sustainability compliance and competitive advantage—particularly in sectors navigating both environmental and digital transformations, such as textiles.

While this study employed two well-established decision-making methodologies (AHP and TOPSIS), more advanced approaches may be applied to validate or challenge the results. Nevertheless, it is crucial to establish a starting point grounded in methods that, as demonstrated in Sections 1 and 3, have proven effective in supporting decision-making processes.

From a qualitative perspective, the divergence in prioritization rankings offers a key empirical insight that enriches the theoretical understanding of how different stakeholder groups engage with digital sustainability tools. The contrasting perspectives of companies and consultants illuminate the influence of strategic, cultural, and functional logic on data prioritization. These insights highlight the need for further investigation into how such divergences might be reconciled through participatory design processes, ensuring that DPP implementation aligns with both industry pragmatism and policy imperatives.

Furthermore, the convergence between the high-priority quantitative criteria and the reported qualitative benefits underscores the potential of DPPs as tools for strategic integration. Their emphasis on traceability, transparency, and data standardization (linked to Criteria C1 and C9) translates into tangible benefits, such as enhanced operational efficiency, risk mitigation, and improved supply chain collaboration. These synergies reveal that DPPs are not merely repositories of product information, but dynamic instruments that, when thoughtfully designed, foster organizational learning, adaptive decision-making, and sustainable innovation.

In conclusion, the integration of quantitative prioritization with qualitative benefit mapping offers a holistic perspective on the strategic relevance of DPPs. DPPs' dual role—serving as both compliance-oriented tools for environmental performance and market-driven mechanisms for competitive differentiation—highlights their transformative potential within increasingly digitalized and sustainability-focused sectors (e.g., textiles). To fully realize their potential, DPPs must be adaptable, stakeholder informed, and aligned with both normative expectations and operational realities.

The present study has illustrated how DPPs might catalyze transformation in the fashion industry by promoting sustainability, material traceability, and circular economy practices. DPPs deliver critical information on repair, recycling, and reuse while strengthening the credibility of the "Made in Italy" label. They support responsible production, enhance resource efficiency, and contribute to achieving the SDGs. Ultimately, they represent strategic tools capable of bridging the digital and environmental transitions, combating greenwashing, and bolstering competitiveness within the textile sector.

6 | Conclusions

The EU has undertaken concrete measures to institutionalize DPPs through major policy frameworks, including the European Green Deal, the Circular Economy Action Plan, and the ESPR. Since 2024, DPPs have been mandated for select product categories, and a progressive rollout is planned across all goods placed on the EU market. This evolving regulatory roadmap highlights the strategic role of DPPs in advancing transparency, traceability, and resource efficiency, particularly within high-impact sectors (e.g., textiles) that are central to the twin transition. The textile industry, identified as a priority category because of its crucial impact on sustainability, is increasingly the focus of policy efforts to promote waste reduction, reuse, and recycling. Within this framework, DPPs represent essential tools for catalyzing the twin convergence of technological innovation and sustainable production.

The present study examined the innovative potential of DPPs as strategic enablers of the twin transition, with a particular focus on the Italian textile industry. By integrating insights from both consultancy professionals and industry experts, this research offered an empirically grounded analysis of the strategic role played by DPPs in advancing digital and sustainable transformation. Through a multistakeholder lens, this study identified and prioritized critical data categories that should be embedded within DPPs to enhance their functionality and long-term value. Three key strategic areas emerged as levers of the twin transition. First, material traceability was identified as fundamental for ensuring transparency across supply chains and promoting accountability in sourcing and production. Second, the inclusion of repair-related information (e.g., manuals, tutorials, and technical guidelines) was seen as crucial for empowering both consumers and repair professionals, thereby extending product life cycles through reuse and repair. Third, DPPs were envisioned as enablers of recycling pathways by guiding appropriate end-of-life treatment for various materials. This function was seen to directly support the reduction of landfill waste and the advancement of circular fashion practices.

The study findings indicate that DPPs have significant potential to future-orient supply chains in the textile sector by delivering actionable insights into recycling, repair, and reuse while simultaneously emphasizing sustainability and the authenticity of premium “Made in Italy” products. Crucially, when designed to incorporate high-priority data on reuse, repair, recycling, traceability, and environmental performance, DPPs may act as vital enablers of digitally integrated, circular supply chains. The consistently high prioritization of reuse, repair, and recycling information underscores the growing importance of sustainability and circularity as primary drivers of innovation within digitalized value chains.

The results offer multiple contributions at theoretical, managerial, and governance levels, thereby enriching the emerging literature by providing a macrolevel understanding of the informational dimension of digitalized value chains. Methodologically, this study confirms the value of multicriteria decision-making tools—specifically the AHP and TOPSIS—in capturing nuanced expert evaluations.

From a business strategy perspective, DPPs represent not only tools for regulatory compliance but also strategic assets for value creation. The divergence in prioritization between companies and consultants observed in the present study (e.g., in terms of the emphasis placed on “Made in Italy” branding vs. emissions reduction information) underscores the need for flexible DPP architectures capable of accommodating sector-specific and stakeholder-specific priorities. This strategic divergence highlights the dual role played by DPPs, bridging internal capabilities and external expectations and reconciling short-term competitive objectives with long-term sustainability transitions.

In addition to contributing to the theoretical discourse, the present findings offer practical guidance on DPPs as digital enablers of business model innovation, supporting the broader proposition that effective digital sustainability requires both flexibility and intentionality, particularly in complex and dynamic sectors such as textiles.

This study also provides guidelines on the types of data considered strategically important by both managers and consultants. It empirically validates the strategic relevance of key informational categories within DPPs and reveals the diversity of stakeholder priorities, offering valuable insights into differing information needs. Moreover, the findings demonstrate how DPP implementation could enhance competitive advantage by reducing informational asymmetries, improving operational efficiency, and enabling differentiated value propositions (e.g., product authenticity and environmental responsibility). These benefits may be particularly relevant to sectors such as textiles, which are characterized by complex and fragmented supply chains.

Companies could leverage the present findings to reconfigure their data management strategies in ways that foster greater collaboration across the supply chain. In particular, the results corroborate the need for a customized DPP design as a critical enabler for strategic integration within business models. This implies a modular DPP architecture capable of addressing both regulatory requirements and market imperatives. Furthermore, the results enhance our understanding of the way in which data prioritization shapes strategic value creation. Companies emphasizing traceability, brand positioning, and consumer feedback appear to adopt a more externally responsive business model, leveraging digital tools to enhance engagement, visibility, and differentiation. In contrast, consultants' focus on emissions and social criteria suggests a longer term orientation rooted in institutional alignment and policy compliance.

At the governance level, the study findings align with ongoing European initiatives to institutionalize product-level environmental data, such as the ESPR. The analysis highlights the urgent need for coordinated frameworks and robust stakeholder engagement to ensure DPP standardization and broad adoption. Specifically, this study identifies several key implications. First, the divergence in stakeholder priorities reinforces the need for flexible policy frameworks that can guide the standardization of DPP content while accommodating sector-specific adaptability. Second, targeted incentives for SMEs (e.g., digitalization support, training programs, and financial subsidies) may be critical to promote widespread adoption and prevent a growing digital divide. Third, DPPs possess the potential to function as policy instruments for enforcing transparency, circularity, and consumer protection, particularly when embedded within legal frameworks governing eco-design, labeling, and extended producer responsibility. Additionally, DPPs may serve as public–private interfaces, with structured, interoperable, and verifiable data informing not only firm-level decisions but also governmental monitoring systems and sustainability reporting. In this regard, DPPs represent foundational components of a future-oriented governance infrastructure, supporting both supply chain accountability and data-driven policymaking.

Despite some limitations—namely, the focus on a single industrial sector and reliance on a limited sample—the present study offers actionable insights for managers, policymakers, and digital product system designers aiming to operationalize sustainability within complex industrial ecosystems. Furthermore, this study takes an initial step in supporting companies in the achievement of a responsible consumption and production business model, contributing to SDG 12. The results identify the information criteria through which DPPs may foster more sustainable consumption patterns and production systems by facilitating informed decision-making. Additionally, the prioritization of information related to transparency, traceability, and data standardization underscores the critical role that DPP may play in operationalizing SDG 12. This contribution aligns the present study with the growing academic and industry interest in the intersection of digitalization and sustainability, which is central to the twin transition.

Future research should consider expanding the sample size and adopting a cross-sectoral approach to better assess the role of enabling technologies in enhancing data management and supporting dynamic updates. Additionally, further investigation is needed into consumer behavior, particularly the influence of access to DPP data on purchasing decisions and product engagement. The present study emphasized that DPPs should be conceptualized not merely as tools for compliance but also as strategic instruments within digital platforms, bridging environmental objectives with digital innovation to foster a more competitive and circular industrial ecosystem. Given that research on DPPs remains in its infancy, continued exploration is important to assess their operational feasibility. In particular, research should aim to identify both enabling and inhibiting factors affecting DPP implementation and examine the potential of an open innovation approach—incorporating bottom-up project design—to ensure that DPPs remain effective and adaptable across diverse industrial sectors.

Author Contributions

All authors equally participated in the definition and writing of this paper.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.