

Integrating knowledge management and digital product passports to foster sustainable and collaborative ecosystems

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Abstract

Purpose – The purpose of this study is to explore the potential of the digital product passport (DPP) to support circular and collaborative ecosystems within the fashion and cosmetics industries. By enhancing transparency, traceability and knowledge exchange across complex supply chains, the DPP is examined as an integrative tool embedding sustainability, open innovation (OI) and knowledge management into organizational practice. The research seeks to reconceptualize sustainability as not merely a compliance obligation but also an empowering process for both producers and consumers.

Design/methodology/approach – The study uses a mixed-methods approach, combining two online surveys conducted in the Italian fashion and cosmetics sectors with k-means cluster analysis, principal component analysis and logistic regression. This methodological framework enables consumer segmentation, identification of DPP adoption drivers and an evaluation of the interrelationships among DPP functionalities, sustainability practices and consumer profiles.

Findings – The results demonstrate that the DPP contributes to the circularity of raw materials, enhances supply chain resilience and facilitates the dissemination of shared knowledge. Two distinct consumer segments are identified: aware consumers, who are attuned to sustainability and digital innovation, and unaware consumers, who prioritize immediate, tangible benefits. Successful DPP implementation depends on aligning its technical capabilities with both organizational readiness and consumer engagement.

Originality/value – This research conceptualizes the DPP as a socio-technical and cognitive infrastructure integrating knowledge management, OI and circular economy principles. By emphasizing its dual technical and participatory roles, the research highlights the DPP's strategic value in driving sustainable business transformation. Moreover, it offers actionable insights for promoting responsible consumption and advancing Sustainable Development Goal 12 through digitally enabled, knowledge-intensive collaboration across the value chain.

Keywords Circular economy, Digital product passport, Innovation, Knowledge, Sustainable development

Paper type Research paper

1. Introduction

The green and digital transitions, which are central to the European Green Deal and the EU Digital Strategy, are accelerating the shift from linear to circular economy (CE) models (Muench *et al.*, 2022) and aligning with the sustainable development goals (SDGs). In this context, the Corporate Sustainability Reporting Directive (CSRD), effective as of January 2025, mandates standardized sustainability disclosures to promote transparency, comparability and informed decision-making, thereby fostering trust among stakeholders (Awa *et al.*, 2024). To comply with these regulatory demands, companies must adopt transformative strategies based on digital infrastructures and participatory governance (Fatima and Elbanna, 2023).

Among the emerging digital tools facilitating this transition, the digital product passport (DPP) stands out as a key component of the EU's Ecodesign for Sustainable Products

Regulation, conceived as a digital identity card for products. Designed to deliver structured, verified and interoperable product-specific information across the value chain (Jensen *et al.*, 2024), it aims to enhance transparency, traceability and accountability, while enabling circular strategies such as reuse, repair, remanufacturing and recycling (Zhang and Seuring, 2024). Beyond its technical function, the DPP aligns with knowledge management theory, which emphasizes the transformation of raw data into actionable insights through contextualization and interpretation. As such, the DPP has the potential to operate as a sophisticated knowledge management system, facilitating informed decision-making and fostering continuous organizational learning (Wan and Jiang, 2025).

Innovation research further underscores that innovation is a multidimensional process shaped by the coevolution of actors, institutions and knowledge flows (Zhou *et al.*, 2025). Consequently, the effectiveness of the DPP hinges not only on its technological interoperability but also on the presence of strong organizational capabilities in data governance, lifecycle assessment and multistakeholder collaboration. These elements are critical to the management of complex knowledge related to materials, processes and environmental impacts. Without such alignment, the DPP risks being reduced to a narrow compliance instrument, falling short of its transformative promise (D'Adamo *et al.*, 2025). Moreover, the successful adoption of digital innovations such as the DPP depends on organizations perceiving their strategic and knowledge-based value (Arias-Pérez *et al.*, 2021). Research on digital transformation reinforces that the impact of such tools is contingent on their alignment with a company's internal capabilities, organizational architecture and external operating environment (Mele *et al.*, 2023).

From a consumer perspective, access to verifiable sustainability data significantly increases willingness to pay (WTP) for greener alternatives (Luukkonen *et al.*, 2024). Despite expanding regulatory frameworks and market initiatives, consumer engagement in sustainability remains relatively limited – primarily due to low awareness levels and persistent information asymmetries. By addressing these gaps and mitigating greenwashing practices, the DPP may effectively translate sustainability values into purchasing behaviors (Abdelmeguid *et al.*, 2024). However, genuine consumer empowerment requires that information is not only transparent and accurate but also accessible, emotionally resonant and trust-enhancing (Vătămănescu *et al.*, 2025).

Such outcomes rely on the adoption of open innovation (OI) approaches that actively engage consumers in the codesign and continual adaptation of DPP standards. Previous research has established strong links between OI dynamics and regional knowledge systems (Della Peruta *et al.*, 2018). When grounded in OI principles, participatory frameworks can foster flexible, interoperable and user-relevant infrastructures (Ospital *et al.*, 2023). Importantly, fostering consumer involvement in coproduction processes requires sensitivity to behavioral factors, as willingness to engage in cocreation is influenced by prosocial tendencies and perceptions of reciprocity (Twumasi Ankrach *et al.*, 2024). In this regard, human-centric marketing strategies, integrating technological affordances and absorptive capacity, play a pivotal role in enhancing both eco-innovation and organizational performance (Sharma *et al.*, 2025).

Consumer cocreation of DPP standards enhances usability and legitimacy, facilitating interoperability across diverse production ecosystems and enhancing relevance for end users (Voulgaridis *et al.*, 2024). In this way, the DPP may evolve from a technical repository into a participatory platform integrating stakeholder perspectives, fostering transparency and trust. In fact, its effective deployment may rely on participatory frameworks that engage consumers in shaping sustainability data (Tapia *et al.*, 2025), ensuring that DPPs are technically accurate, legible, meaningful and actionable, thereby empowering consumers and strengthening demand-side acceptance (Colasante *et al.*, 2025).

OI acts as a systemic enabler, connecting stakeholders within collaborative environments promoting transparency and shared learning (Crupi *et al.*, 2020). Although its integration

into digital infrastructures such as the DPP remains underexplored, the DPP presents a strategic opportunity to render business processes more visible and participatory, thereby enhancing citizen engagement and institutional trust (Voulgaridis *et al.*, 2024). However, the DPP's potential to function as a relational and knowledge-based system, linking corporate sustainability strategies with consumer empowerment, remains conceptually and empirically underdeveloped (D'Adamo *et al.*, 2025).

This gap is particularly significant in environmentally and socially visible sectors such as fashion and cosmetics, where traceability, ethical production and transparency directly influence consumer behavior. The textile sector, in particular, is marked by fragmented global value chains and a disproportionate environmental footprint, prompting an urgent call for greater transparency and accountability (Tolentino-Zondervan and DiVito, 2024). Moreover, the cosmetics sector faces distinct challenges related to complex formulations, ingredient traceability, regulatory compliance and the reduction of hazardous substances (Omira *et al.*, 2025). Despite these differences, both sectors offer fertile ground for exploring how DPPs might support sustainable consumption models, encouraging behaviors such as slow fashion consumption (Colasante *et al.*, 2025) and the adoption of products aligned with SDG targets, including cruelty-free and bio-based cosmetics (Kurul *et al.*, 2025). The fashion (Fares *et al.*, 2025) and cosmetics (Cascavilla *et al.*, 2026) sectors are characterized by complex global supply chains, substantial environmental impact and increasing demand for transparency. These factors necessitate a tool such as the DPP to ensure traceability, reliable information and support for more sustainable consumer choices. Addressing the identified gaps, this study examines how the integration of knowledge management and DPP can operationalize DPPs as open innovation tools to foster sustainable and collaborative ecosystems. Using a multimethod research design, including various quantitative analyses within the textile and cosmetics sectors, as well as a cross-sector comparison, the study empirically investigated key patterns relevant to DPP configuration as a relational and participatory knowledge system integrating consumer expectations into corporate sustainability strategies. The findings contribute to our theoretical understanding of the role of the DPP as a mediator between organizational competitiveness and sustainability while supporting the twin transition. In addition, the study generated managerial insights for companies aiming to adopt the DPP as not only a compliance-oriented mechanism but also a strategic enabler of collaborative innovation and sustainable ecosystem development.

2. Literature review

2.1 Theoretical framework

The DPP is emerging as a central tool for enabling circularity and transparency across value chains. It offers a structured approach to consolidating data and supporting decision-making in alignment with the Circular Economy Action Plan. To address the theoretical ambiguity surrounding the DPP, it is essential to distinguish it from traditional traceability systems. While traditional traceability emphasizes the linear flow of information for logistical efficiency (monitoring), the DPP operates as a knowledge infrastructure designed for circular value cocreation (orchestration). Put differently, standard traceability focuses on the chain of custody, tracking location and ownership, while the DPP centers on the chain of knowledge, contextualizing data to support decision-making. This reorients the theoretical lens from information transfer to knowledge activation, positioning consumers not as passive recipients but as active validators of sustainability claims. Table 1 presents a detailed overview of the differences between the DPP and traditional traceability systems.

The DPP constitutes a dynamic architecture capable of managing the complex, nonlinear data flows required by circular strategies such as remanufacturing and recycling (Wan and Jiang, 2025). This paradigm shift from the more static and compliance-oriented traditional traceability systems necessitates organizational readiness and digital maturity, as effective

Table 1 Traditional traceability systems versus digital product passport (DPP)

<i>Dimension</i>	<i>Traditional traceability systems</i>	<i>Digital product passport</i>
Primary function	Monitoring and compliance (logistical focus)	Knowledge orchestration and value cocreation (strategic focus)
Data flow	Linear, one-way (producer to retailer)	Circular, multidirectional (networked ecosystem)
Role of consumer	Passive recipient of information	Active knowledge partner (validator/cocreator)
Theoretical lens	Information systems/supply chain management	Knowledge management/open innovation
Sustainability goal	Eco-efficiency (doing less harm)	Eco-effectiveness (circular practices and supplier monitoring)
Innovation type	Process innovation (internal)	Open innovation

Source(s): Authors' own work

DPP implementation depends on coordination among heterogeneous stakeholders who may not have previously collaborated (Wicaksono *et al.*, 2025). The DPP is recognized as a key enabler of the CE and green logistics (Lopes and Barata, 2024). Nevertheless, its implementation faces significant challenges, particularly related to data governance, ownership, privacy and commercial sensitivity. Firms often hesitate to share proprietary information in the absence of strong guarantees of data sovereignty (King *et al.*, 2023). The DPP facilitates interoperable information flows through blockchain consortia, thereby enhancing transparency and sustainability (Greiner *et al.*, 2024). While interoperability remains vital and may depend on decentralized infrastructures (e.g. blockchain), the absence of standardized communication protocols risks creating fragmented data silos that undermine sustainability goals (Zhang and Seuring, 2024).

To address these risks, the present study conceptualized the DPP as a bidirectional interface able to reduce information asymmetries and enhance relational engagement across the ecosystem. To this end, an OI framework was adopted, drawing on the “Outside-In” perspective (Chesbrough, 2012), with consumers positioned as active contributors to innovation (Bogers *et al.*, 2017; von Hippel, 1986). Designing and adapting DPP standards through an OI lens entails the creation of digital architectures enabling bidirectional data flows, configuring the DPP as a collaborative platform in which consumers act as “prosumers” (Kotler, 2010).

While the literature provides valuable insights into the technological, regulatory and operational foundations of the DPP (Carvalho *et al.*, 2025; De Giovanni, 2025; Kemmer *et al.*, 2025), a conceptual gap remains regarding how the information embedded in DPPs is cognitively processed and transformed into actionable knowledge. The present study addressed this gap by examining users’ capacity to interpret, internalize and apply DPP information. The literature highlights that the value of the DPP goes beyond the data it carries, as further benefits arise from the interaction between quality data and user understanding (Ferrante *et al.*, 2025; Wagner, 2025; Wan and Jiang, 2025). From this perspective, the concept of “absorptive capacity,” traditionally applied to firms’ ability to recognize and exploit external knowledge, becomes relevant at the individual level, helping to explain why DPPs may enable circular practices for some actors while remaining merely informative for others. The differentiation observed across sectors further suggests that varying levels of digital and sustainability knowledge influence how effectively DPPs support circular behaviors (D’Adamo *et al.*, 2025; Petrik *et al.*, 2025). Building on these insights, the present study introduced a user-centered perspective, complementing the dominant technical and regulatory focus.

2.2 Systematic review

To provide a robust theoretical foundation, the study adopted an enhanced systematic review to examine the use of DPPs in driving sustainable transitions in the fashion and cosmetics sectors. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Page *et al.*, 2021), a data set was extracted from the

Scopus database on September 10, 2025, using the search query applied to article/title/keywords/abstract: “INNOVATION” OR “KNOWLEDGE” AND “CIRCULAR ECONOMY” AND “DIGITAL PRODUCT PASSPORT.” The Boolean AND operators were structured to capture the intersection of three domains: digital product passport (DPP), sustainability (circular economy) and cognitive processes (innovation OR knowledge). This initial search retrieved 120 records. Exclusion criteria were applied to: (E1) documents not published in English and (E2) publications other than a journal article or review paper. This resulted in 79 records, which were further screened based on criterion (E3), requiring “DIGITAL PRODUCT PASSPORT” as a keyword in the article title, keywords or abstract. This yielded 22 records, which were then rescreened to exclude those not aligned with the purpose of the present study (E4). A final sample of 16 papers was deemed eligible for full-paper analysis (Figure 1).

To understand the general themes, the 79 retrieved documents, before the full screening selection, were mapped using an established bibliometric thematic map (Figure 2). The thematic map plotted clusters by density (development) and centrality (relevance), resulting in four thematic quadrants: driving, basic, niche and emerging.

Analysis of the research topics on DPPs showed that the driving themes concerned the CE, sustainable development and economic and social effects. This represented the conceptual and methodological core of the research, where the DPP was positioned as a strategic tool for translating the principles of circularity into data transparency and

Figure 1 PRISMA diagram

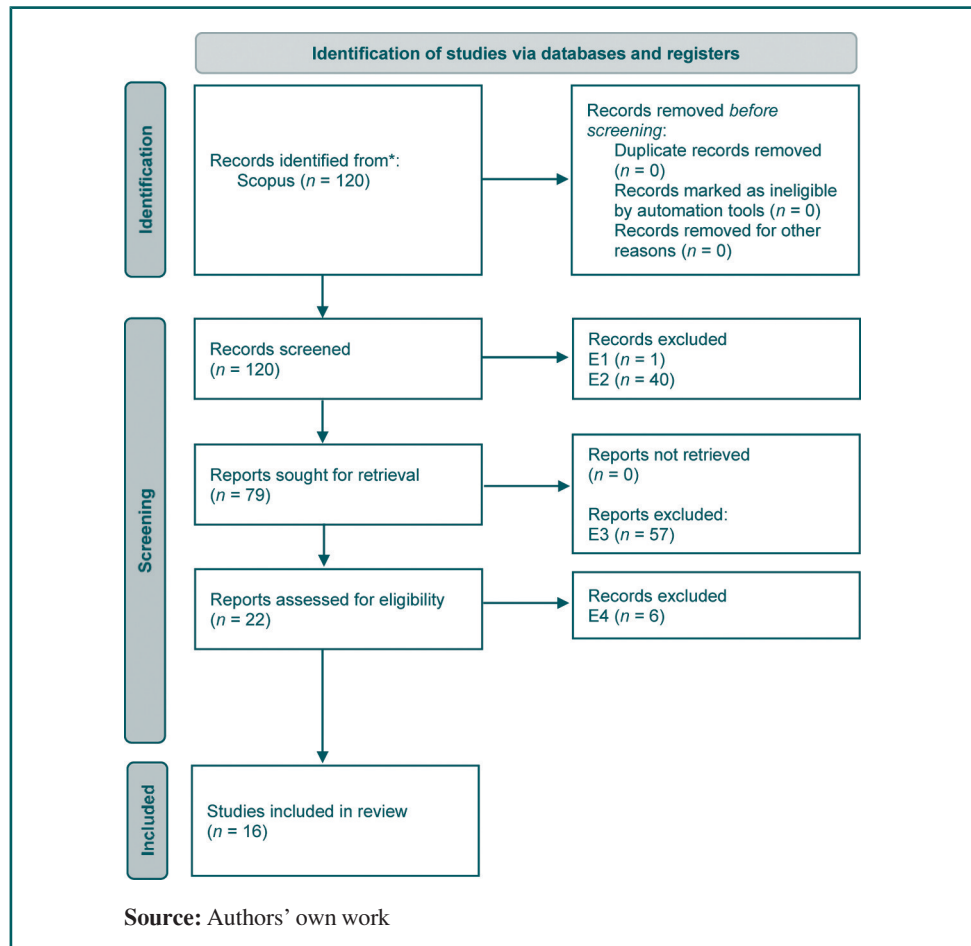
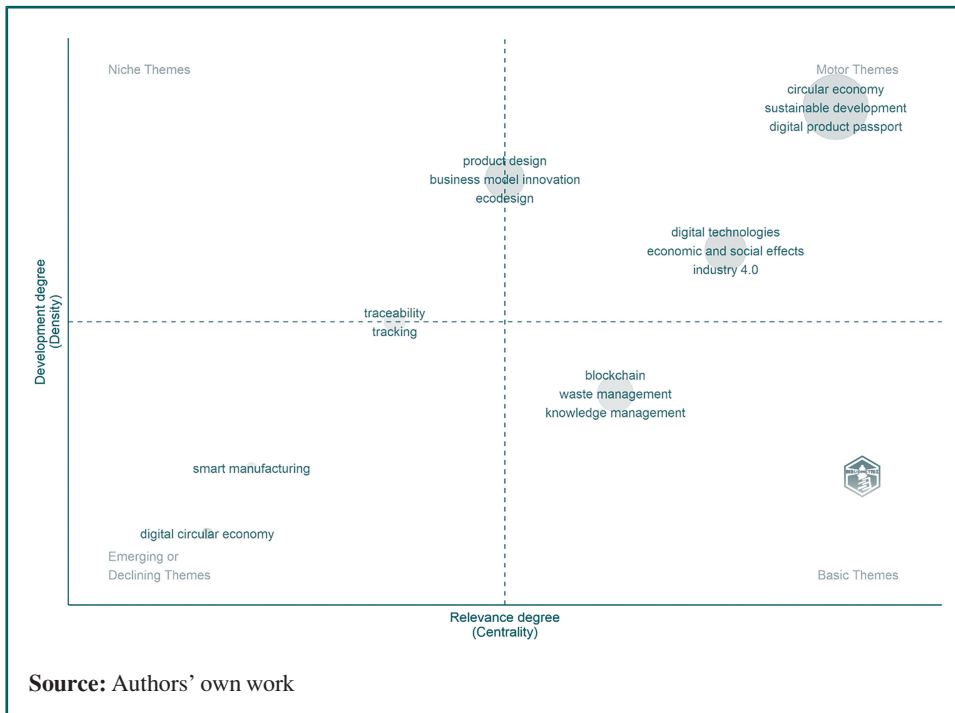


Figure 2 Thematic map



traceability. However, these themes, although central, often remained situated at an abstract or political level, with limited integration of participatory approaches that actively involved consumers and stakeholders. The basic themes included blockchain, waste management and knowledge management. These themes were considered relevant but conceptually fragmented and underdeveloped from an empirical perspective (constituting an important area for future research). Niche topics represented specialist or already mature areas that were not yet central to the main debate. The absence of dominant clusters in this quadrant suggests an opportunity for new interdisciplinary connections and the evolution of emerging research areas. Emerging themes (e.g. the digital CE, smart manufacturing, traceability) were marginal but demonstrated strong growth potential. Although these represent essential technical components of DPPs, they require greater integration into collaborative and user-value-oriented innovation strategies.

The DPP is emerging as a central tool for enabling circularity and transparency across value chains. It provides a structured means to consolidate data and support decision-making in alignment with the Circular Economy Action Plan and the Ecodesign for Sustainable Products Regulation (Carvalho *et al.*, 2025). Research has highlighted the DPP's capacity to enhance material traceability and circular design while also fostering innovation through data-driven collaboration among stakeholders (Marzani *et al.*, 2025). In addition, the DPP has been shown to enable secure information sharing and dynamic lifecycle updates, which may improve maintenance and repair processes (Wan and Jiang, 2025). However, research has also identified several barriers, particularly related to missing or inconsistent data. These include limited information on material composition, dismantling procedures, product condition and certifications (Wagner, 2025). Further challenges arise from fragmented infrastructures, high investment costs and the lack of standardized data protocols (Kemmer *et al.*, 2025; Shehu *et al.*, 2025).

In response, a need has emerged for common indicators and evaluation methods. Standardized key performance indicators, interoperable with DPP frameworks, could

support transparency and comparability across sectors (Ferrante *et al.*, 2025). Moreover, complementary technologies such as blockchain and artificial intelligence also hold promise for enhancing data security, predicting product health and supporting circular decision-making (Langley *et al.*, 2023; Wan and Jiang, 2025).

In specific sectors such as textiles, DPPs have demonstrated the potential to improve competitiveness and sustainability monitoring by ensuring material traceability, providing repair-related information and improving recycling processes, thereby aligning closely with circular business models (D'Adamo *et al.*, 2025). In manufacturing, DPP maturity models may help firms assess their readiness to implement digital traceability systems and enhance sustainability performance (Petrik *et al.*, 2025).

Finally, policy studies have suggested that the effectiveness of DPPs may depend on robust data governance, ethical frameworks and coordinated incentives for stakeholder engagement (De Giovanni, 2025; King *et al.*, 2023). A systemic approach is therefore required to integrate DPPs with digital infrastructures and ensure long-term alignment with CE objectives (Çetin *et al.*, 2023; Zhang and Seuring, 2024).

Overall, the DPP represents a bridge between technology, policy and sustainability. It holds the potential to transform industrial ecosystems by enabling data interoperability, supporting transparency and advancing responsible innovation across global value chains (Fares *et al.*, 2025; Pietroni *et al.*, 2025). By linking these perspectives, this section has framed how the DPP can facilitate circular practices, enhance consumer involvement and drive innovation in line with the SDGs.

3. Methodology

Digital technologies can foster progress toward the SDGs, with emerging priorities, including sustainable supply chains and the integration of CE principles through Industry 4.0 tools such as artificial intelligence, blockchain and the Internet of Things (Tavana *et al.*, 2022). Moreover, there is considerable potential for synergy between OI and CE models (Sondhi *et al.*, 2024).

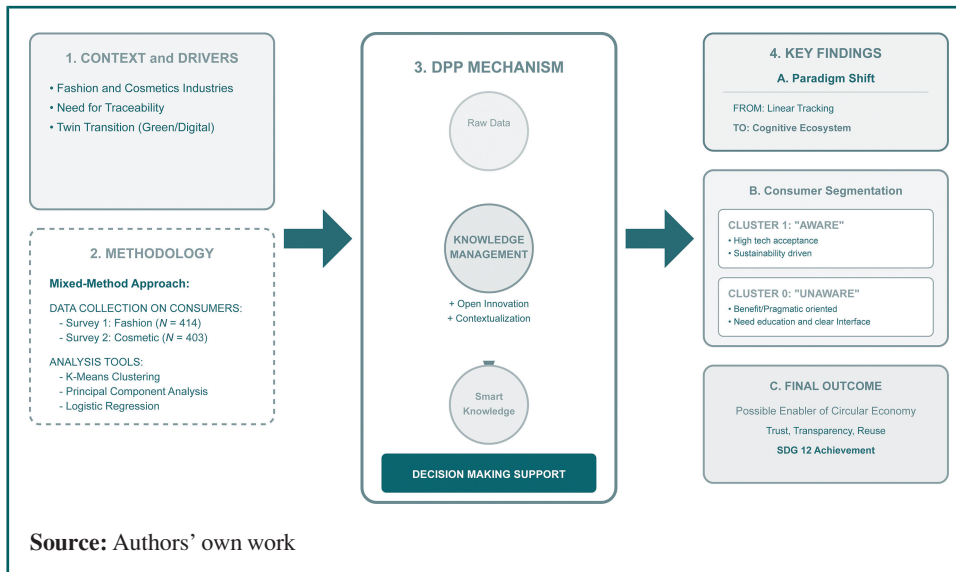
However, the literature lacks sufficient data and largely overlooks the role played by consumers and their perceptions. Given that the OI model relies on stakeholder involvement, the use of an online survey was deemed valuable for gathering quantitative insights. Figure 3 illustrates the research design of the present study on DPPs in the cosmetics and fashion industries.

3.1 Survey

The survey methodology is recognized for its efficiency in large-scale data collection and behavioral pattern analysis, as demonstrated in previous research across various fields involving diverse stakeholder categories (Nguyen and Malik, 2021). Surveys remain among the most reliable and versatile tools in consumer research, enabling participation and effective information management (Kolling *et al.*, 2023; Zhao and Huh, 2025). The approach is particularly well suited to exploring the adoption of emerging digital solutions and sustainability-oriented practices. In addition, surveys are widely used in consumer research, as they facilitate the collection of data from large and heterogeneous samples while offering considerable flexibility in the acquisition and management of information (Cascavilla *et al.*, 2026; Colasante *et al.*, 2025).

The present study was based on a questionnaire proposed in the literature (Colasante *et al.*, 2025) that assessed consumers' awareness and perception of the DPP in the fashion and cosmetics sectors. These sectors were selected because they represent high-velocity consumer markets characterized by pronounced information asymmetries regarding

Figure 3 Research design of the study



chemical composition and supply chain ethics. Moreover, they are priority sectors under the European Commission (2024), making them especially relevant for DPP adoption.

The questionnaires were administered in March 2025 in Italy to two distinct samples – one related to the fashion sector and the other to the cosmetics sector (see Supplementary material). Developed using Google Forms, the questionnaires were disseminated via social media platforms to mitigate common limitations associated with survey-based research (Menegaki *et al.*, 2016). The surveys consisted primarily of closed-ended and multiple-choice questions, supplemented by 10-point rating scales to capture a wide range of responses. The structure comprised four main sections:

1. sociodemographic characteristics of respondents;
2. familiarity with digital tools and cosmetics purchasing behavior;
3. knowledge and perceptions of the DPP; and
4. economic aspects, including the estimation of hypothetical WTP.

Given the anonymity guaranteed by both questionnaires, it was not possible to identify correlations between responses. It should also be noted that one response from the fashion questionnaire and two from the cosmetics questionnaire were discarded from the initial data set.

The survey used a two-stage, nonprobability sampling strategy (Etikan *et al.*, 2015), combining convenience sampling to recruit eligible respondents with snowball sampling to expand recruitment through respondents' social networks, an approach well suited for accessing dispersed populations and emerging practices (Noy, 2008) while also supporting analytical insight and theory building (Baltar and Brunet, 2012).

3.2 Analytical methods

The analysis adopted a combination of two methods frequently used in the literature to explore the intersection of digitalization and sustainability: *k*-means cluster analysis (Joshi *et al.*, 2014) and principal component analysis (PCA) (Chaudhuri *et al.*, 2020; Daraio *et al.*, 2024). The optimal number of clusters was identified using the silhouette coefficient and the elbow method. For each cluster, centroids were calculated and key driver variables

determined. Demographic characteristics were examined using ANOVA for age (reporting η^2 and Cohen's d) and contingency tables for gender and income, with income converted into numerical bands to estimate cluster means.

Subsequently, PCA was conducted to reduce dimensionality and visualize respondents in a two-dimensional space. To further investigate the determinants of consumers' prior knowledge of the DPP, a binary logistic regression model was applied. This technique is the standard approach for statistical analysis when the dependent variable is dichotomous (Hosmer *et al.*, 2013; Menard, 2010) – in the present case, whether respondents reported having previously heard about the DPP (Yes = 1, No = 0). To complement the classical logistic regression and address potential multicollinearity among the explanatory variables, a least absolute shrinkage and selection operator (LASSO) logistic regression was also performed (Friedman *et al.*, 2010; Tibshirani, 1996). This penalized regression framework enables both variable selection and regularization, facilitating the identification of the most relevant predictors influencing consumers' prior awareness of the DPP. The optimal value of the LASSO parameter (λ) was selected through cross-validation (80% of the sample for training, 20% for testing), minimizing model deviance. The final model retained only those covariates with nonzero coefficients, indicating variables that significantly contributed to distinguishing consumers with prior knowledge of the DPP. This two-step analytical approach aligns with established methodological frameworks in consumer and sustainability research (James *et al.*, 2013; Zhao and Huh, 2025).

4. Results

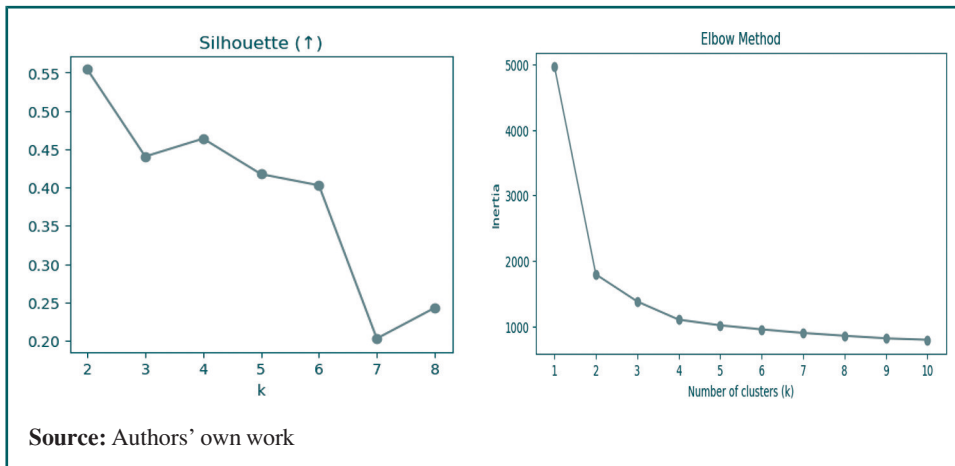
This section presents the results of two parallel analyses conducted for two distinct sectors. Cluster analysis and k -means were applied to the fashion sector (Sections 4.1 and 4.2) to evaluate differences in relation to the DPP. The same approach was then repeated for the cosmetics sector (Sections 4.3 and 4.4). Finally, Section 4.5 presents the regression results concerning DPP knowledge.

4.1 k-Means analysis – fashion sector

Cluster analysis was conducted using the k -means algorithm on the questionnaire data, with the objective of identifying homogeneous respondent segments based on relevance ratings assigned to various consumption aspects (e.g. impact, raw materials, durability, aesthetics, price) and DPP-related dimensions (e.g. raw materials, process, energy, logistics, waste, certifications, social aspects). Following a preliminary data cleaning and standardization phase, the final data set included 414 observations and 12 quantitative variables. The optimal number of clusters, as indicated by the silhouette index (0.554), was found to be 2. This selection was further supported by the elbow method (Figure 4), which revealed a marked drop at $k=2$, beyond which further reductions in inertia were marginal. This inflection point represented an optimal balance between model simplicity and segmentation quality, thereby confirming the validity of the two-cluster solution.

The resulting clusters displayed a relatively balanced distribution (Cluster 0 = 191 respondents; Cluster 1 = 223 respondents) and showed statistically significant differences in both sociodemographic characteristics and questionnaire responses. The average age in Cluster 0 was 40.8 years, higher than in Cluster 1 (34.6 years). The ANOVA results were significant [$F(1, 412) = 15.927$; $p < 0.01$], with an η^2 of 0.037 and a Cohen's d of 0.39, indicating a moderate effect size. Gender and income distributions also differed between clusters. Cluster 0 had a higher proportion of women (59.2%), whereas men predominated in Cluster 1 (53.4%). In terms of economic availability, Cluster 1 was more represented in the lower income brackets (52.9% earning less than €20,000 per year), whereas Cluster 0 exhibited a more balanced distribution, with a comparatively greater share of individuals in the intermediate income range (37.7% earning between €20,000 and €60,000 annually).

Figure 4 Elbow and silhouette method results to identify the number of clusters k



Analysis of the centroids confirmed a clear division into two distinct consumer profiles. Cluster 0 displayed values below the sample average across nearly all dimensions considered, with particularly pronounced negative deviations in DPP-related aspects. Conversely, Cluster 1 showed values above the average for all the analyzed variables, with the most significant differences emerging in dimensions directly linked to the DPP. This group appeared to exhibit a more proactive attitude toward sustainability, demonstrating a stronger propensity to integrate DPP information into their consumption and purchasing decisions. In comparison, Cluster 0 revealed a generally lower sensitivity to environmental concerns and sustainability information, likely favoring more traditional purchasing criteria and showing a reduced inclination to adopt innovative or digital solutions.

Beyond the DPP-specific variables, centroid analysis also highlighted notable differences in more conventional aspects of consumption, including perceived environmental impact, aesthetics, price, durability and raw materials. On average, Cluster 0 assigned lower importance to these characteristics, with negative deviations from the sample mean (e.g. impact -0.63; aesthetics -0.84; price -0.80; durability -0.80). Conversely, Cluster 1 recorded positive deviations across all the same variables (e.g. impact +0.54; aesthetics +0.72; price +0.69; durability +0.69), indicating an attentiveness to both traditional product features and advanced DPP-related dimensions. These findings reinforce the notion that Cluster 1 comprised more demanding and environmentally aware consumers, individuals capable of integrating both classical and innovative criteria into their decision-making processes. Accordingly, the two clusters were designated as follows:

1. Cluster 0 (unaware consumers): traditional consumers with a low orientation toward sustainability and limited attention to the DPP; and
2. Cluster 1 (aware consumers): individuals more attuned to environmental concerns, digitally oriented and more inclined to integrate DPP information into their purchasing choices.

Unaware consumers represent a segment that is generally less receptive to information related to sustainability and the DPP. To engage this group effectively, it may be more appropriate to rely on traditional marketing levers such as price or perceived product durability. Conversely, aware consumers constitute a priority target for communication strategies focused on transparency, digital innovation and product traceability. This more sensitive and proactive group can serve as a strategic ally in promoting sustainable consumption practices, contributing to the enhanced reputation and competitiveness of companies integrating DPP principles into their business models.

Table 2 presents the average values of the variables included in the analysis. Rows correspond to the survey dimensions, while columns report the average values for each cluster.

To further illustrate these differences, Figure 5 provides a heatmap of the standardized centroids for both clusters. The use of standardized values (z-scores) enabled direct comparison across variables by eliminating distortions arising from different measurement scales. A clear color contrast emerged between Cluster 0 (unaware consumers), characterized by negative values across all variables (blue), and Cluster 1 (aware consumers), displaying positive and above-average values (red).

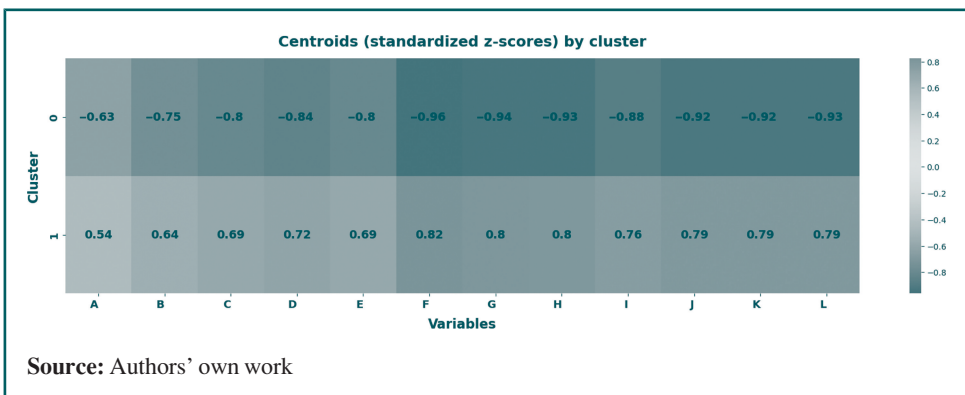
From a managerial perspective, this segmentation provided valuable operational guidance for the development of targeted communication and marketing strategies within the fashion sector. For Cluster 0 (unaware consumers), which demonstrated lower sensitivity to sustainability and DPP-related issues, messages emphasizing tangible and immediately

Table 2 Average values per variable in the two clusters (nonstandardized)

Description	Cluster 0 (n= 191)	Cluster 1 (n= 223)
Relevance impact	2.37	5.27
Relevance raw materials	2.96	6.82
Relevance sustainability	3.08	7.20
Aesthetic relevance	3.78	8.26
Price relevance	3.74	8.0
<i>DPP</i>		
Raw materials	2.94	8.51
Process	2.66	7.79
Energy	2.62	7.94
Logistics	2.29	7.15
Waste	2.72	7.99
Certifications	2.77	7.97
Social	2.74	8.02

Source(s): Authors' own work

Figure 5 Standardized centroids (z-score) of the two clusters. The following acronyms are used: A = importance of environmental impact; B = importance of types of raw materials used; C = importance of product durability and reparability; D = importance of aesthetics; E = importance of price; F = DPP information on raw materials used; G = DPP information on production process; H = DPP information on energy consumption and emissions; I = DPP information on logistics and transport; J = DPP information on waste/waste disposal; K = DPP information on certifications; L = DPP information on social commitment



perceptible attributes (e.g. affordability, durability, other practical product benefits) were more effective. In contrast, for Cluster 1 (aware consumers), strategies highlighting transparency, traceability and the positive environmental and social impacts of the DPP proved more persuasive. These attributes are becoming increasingly salient in the fashion industry, where consumers are expressing heightened interest in the provenance of materials, production conditions and the overall environmental footprint of garments.

The distinction between these two consumer profiles may enable a differentiated calibration of marketing tools and strategic levers into, on the one hand, interventions tailored to pragmatic consumers (focusing on concrete, short-term benefits) and, on the other hand, actions designed to reinforce the trust of more sustainability-aware consumers (through certifications, value-driven communication and loyalty programs aligned with ethical and environmental principles). Within this context, the DPP emerges as a potentially strategic tool for the fashion industry, reducing information asymmetries along the supply chain, providing verifiable assurances of authenticity, quality and sustainability and allowing firms to distinguish themselves in a highly competitive market.

Table 3 summarizes the key differences between the consumer segments, highlighting the polarization revealed through the cluster analysis.

4.2 Principal component analysis – fashion sector

To complete the analysis, PCA was applied to the data used for clustering, with the aim of reducing the dimensionality of the data set and identifying the main latent dimensions explaining the observed variability. The sample adequacy was very high (Kaiser–Meyer–Olkin measure (KMO)=0.94; Bartlett's test significant with $\chi^2 = 7249.29$; $p < 0.001$), confirming the robustness of the procedure.

The first three principal components collectively explained over 93.20% of the total variance, with PC1 alone accounting for 70.1%. This component summarized the overall sensitivity to the DPP in a unified manner: all DPP variables (raw materials=0.934; energy/emissions=0.934; production process=0.932; waste=0.920; social=0.917; certifications=0.915; logistics=0.894) displayed very high loadings (>0.90), along with traditional factors such as durability, aesthetics and product raw materials.

PC2 (9.2%) was characterized by an opposition between age, which had a positive loading (0.658), and traditional variables such as aesthetics (-0.437), price (-0.422) and durability (-0.287), which were negative. This component could be interpreted as a dimension reflecting economic and sociodemographic availability. Finally, PC3 (7.7%) was also influenced by age (0.637), but in combination with environmental impact (0.410) and raw materials (0.444), and

Table 3 Comparison of the average profiles emerging from the two clusters

<i>Dimension</i>	<i>Cluster 0: Unaware consumers</i>	<i>Cluster 1: Aware consumers</i>
Relevance of traditional aspects (impact, raw materials, aesthetics, price, durability)	Below-average values; low attention to classic aspects of consumption	Above-average values; high attention to classic aspects of consumption
DPP orientation	Negative values in all dimensions	Positive values in all dimensions of the DPP
Sensitivity to sustainability	Limited, with little inclination to integrate environmental information into decision-making processes	High, with a strong propensity to consider environmental and social criteria
Expected behavior	Pragmatic, focused on immediate and tangible benefits (e.g. price, perceived durability)	Conscious, oriented toward transparency, traceability and long-term collective benefits
General orientation	Traditional and less receptive to digital innovation	Proactive and value-driven, inclined to adopt innovative solutions related to the DPP

Source(s): Authors' own work

in contrast with some DPP variables. In this sense, it represented a dimension associated with purchasing choices influenced by age and environmental perception.

The scree plot in Figure 6 illustrates the proportion of variance explained by each component, showing that the first two components, alone, explained nearly 80% of the total variability. This confirmed that the original information could be effectively reduced to a few latent dimensions without substantial loss of content.

The scatter plots of the principal components allowed for a visualization of respondents' distributions within the latent space, highlighting the separation between the two clusters (blue=Cluster 0; red=Cluster 1). In the PC1–PC2 projection (Figure 7), the clusters appeared clearly distinct, confirming that the first principal component captured sensitivity to the DPP in a unified manner while PC2 introduced differentiation related to age, price and durability.

In the PC1–PC3 projection (Figure 8), the separation between groups remained evident, further confirming the dominant role of PC1 as an axis summarizing overall sensitivity to the DPP. Although PC3 explained a smaller proportion of the variance, it contributed to identifying additional distinctions, primarily associated with age and environmental factors, thereby complementing the interpretation derived from the PC1–PC2 projection.

The distribution of respondents along the principal components mirrored the segmentation produced by *k*-means clustering. The analysis of individual scores confirmed that respondents in Cluster 1 (aware consumers) tended to score highly on PC1, consistent with a strong focus on DPP and sustainability criteria. In contrast, members of Cluster 0 (unaware consumers) were predominantly located at lower values of PC1, indicating limited sensitivity to sustainability-related information. Components PC2 and PC3 further this distribution, revealing sociodemographic differences primarily linked to age and purchasing behavior.

Thus, PCA not only reduced the dimensionality of the data set but also enhanced the interpretability of the *k*-means clustering, associating each cluster with specific latent

Figure 6 Scree plot of the main components

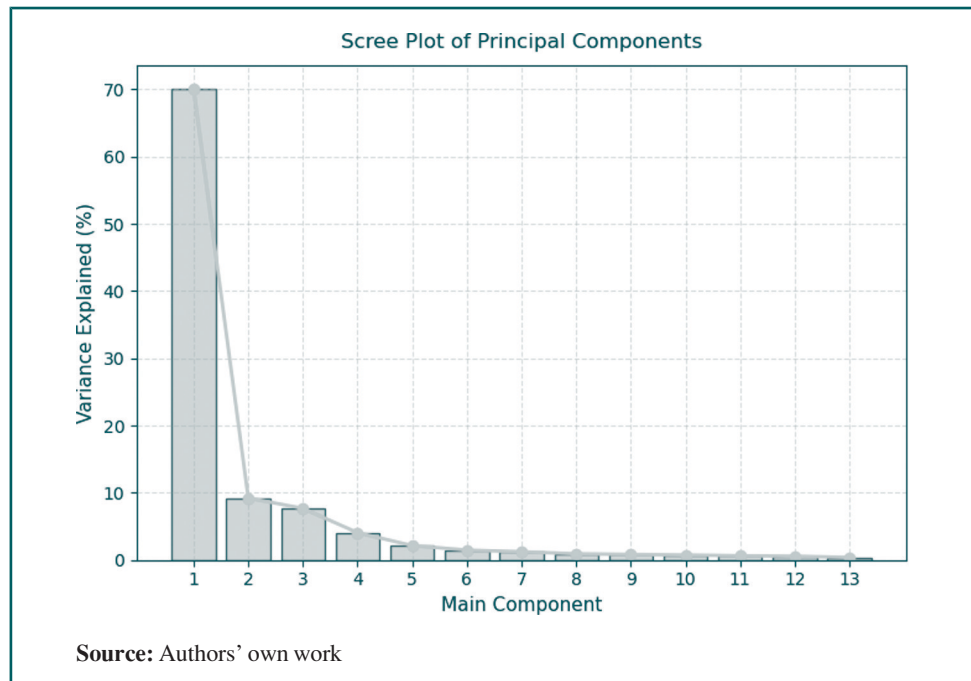


Figure 7 Distribution of the two clusters on the PC1–PC2 components

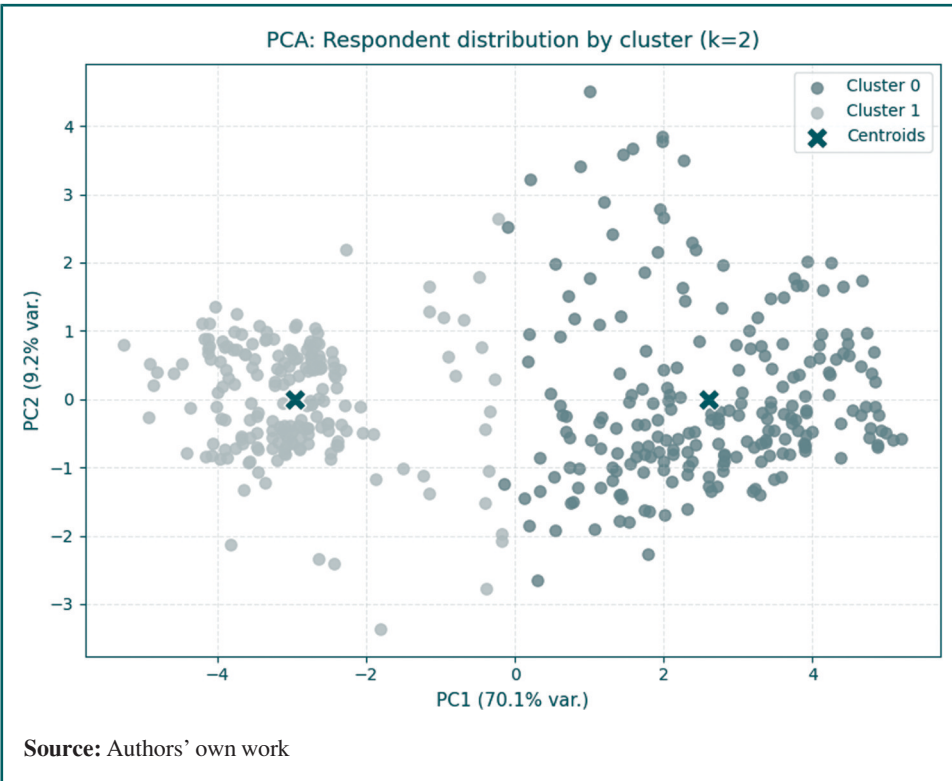
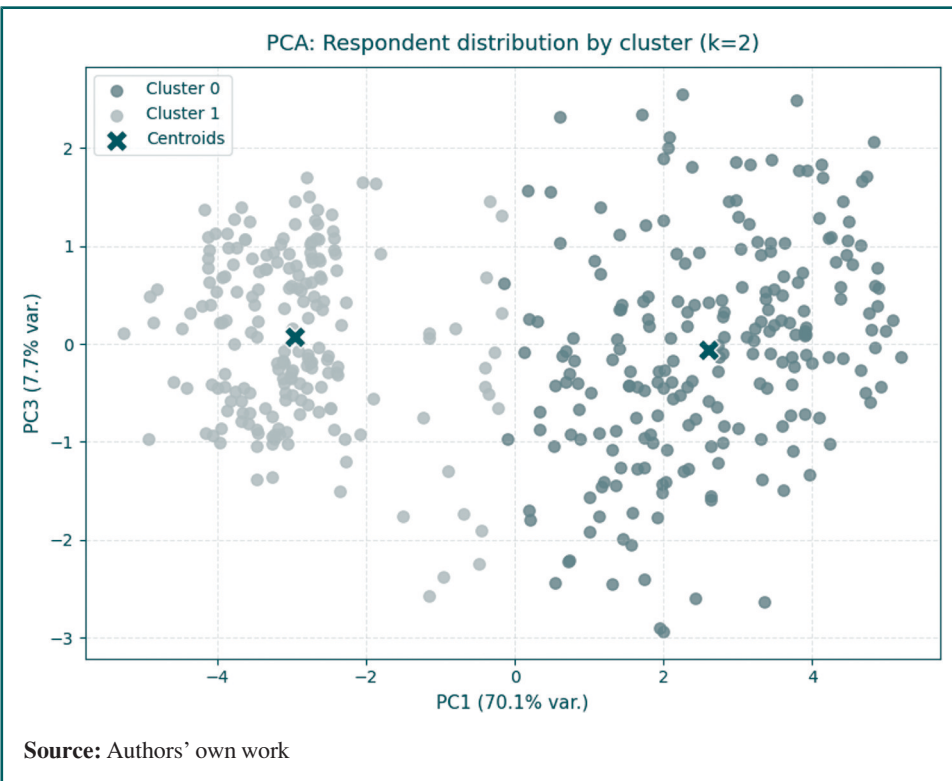


Figure 8 Distribution of the two clusters on the PC1–PC3 components



dimensions. On the one hand, a dimension of sensitivity to sustainability and DPP emerged; while, on the other hand, influences tied to age, economic considerations and aesthetic preferences became apparent.

In the fashion sector, these results highlighted how some consumers were primarily oriented toward practical and immediate benefits (e.g. durability, price, aesthetics) while others demonstrated greater sensitivity to values related to transparency, traceability and social responsibility, associated with the DPP. The validity of the segmentation was thus confirmed, indicating that fashion represents a particularly suitable context for experimenting with differentiated strategies: pragmatic and convenience-oriented approaches for some consumers and value-based, sustainability-driven approaches for others, both essential for fostering the dissemination and adoption of the DPP.

4.3 k-Means analysis – cosmetics sector

Following the same objective as in the fashion sector, the *k*-means analysis was applied to the cosmetics respondents. After a preliminary phase of data cleaning and standardization, the final data set included 403 observations across 12 quantitative variables. The silhouette index indicated a maximum value at $k=2$ (silhouette=0.52), suggesting that this configuration was the most stable (Figure 9). The elbow method showed that inertia decreased significantly when moving from one to two clusters, after which the curve began to stabilize (Figure 9). This trend corroborated the findings of the silhouette index.

The two groups identified had a relatively balanced distribution (Cluster 0=177 respondents; Cluster 1=226 respondents). Cluster 0 was characterized by a slightly higher average age than Cluster 1 (41 vs 36 years), and the ANOVA revealed that this was a statistically significant difference [$F(1, 401)=10.022$; $p < 0.01$], with an η^2 of 0.024 and a Cohen's *d* of 0.32, indicating a moderate effect. Income differences were less pronounced, with both Cluster 0 and Cluster 1 showing higher percentages in the lowest income bracket (51.8% and 46.3%, respectively). Women constituted the majority in both groups (69% and 61%), consistent with their high proportion in the overall sample.

Table 4 presents the average values of the variables analyzed. The variables are listed in rows, while the columns display the averages for each cluster.

Based on these results, interpretative labels were assigned to the two clusters, in line with the previous analysis:

1. Cluster 0 was defined as representing “unaware consumers,” showing limited sensitivity to the evaluated criteria; and

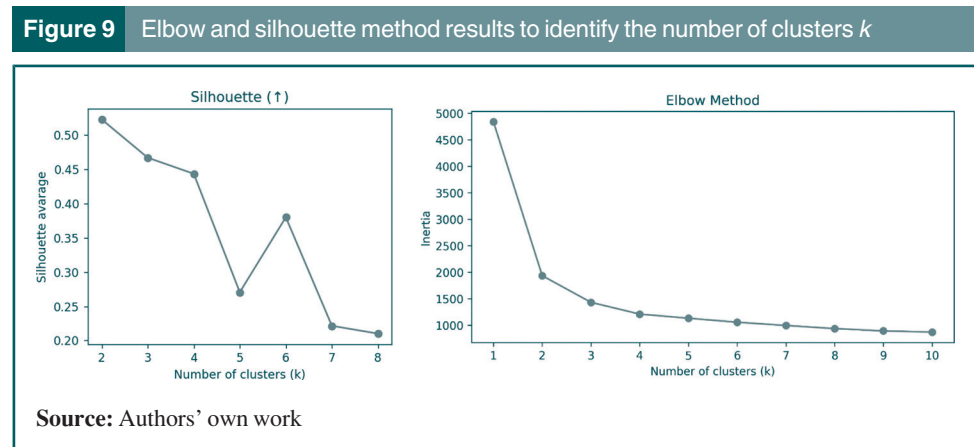


Table 4 Average values per variable in the two clusters (nonstandardized)

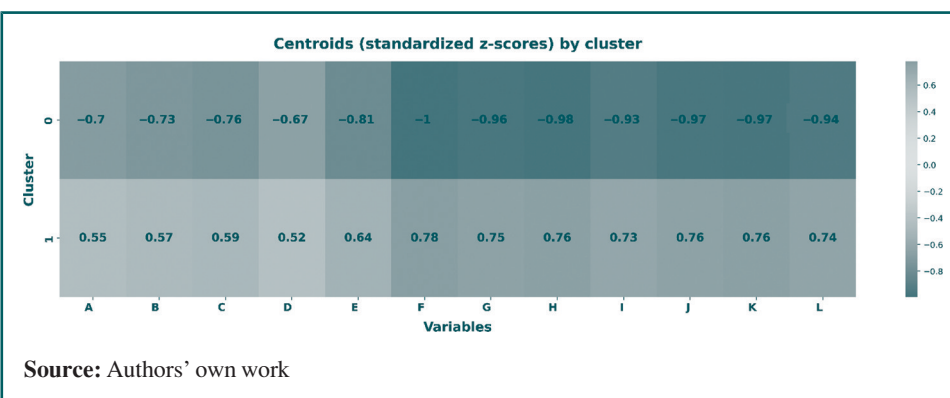
Description	Cluster 0 (n = 177)	Cluster 1 (n = 226)
Relevance impact	2.71	6.20
Relevance raw materials	3.17	7.12
Relevance sustainability	3.02	6.88
Aesthetic relevance	2.95	6.32
Price relevance	3.48	7.61
<i>DPP</i>		
Raw materials	3.61	8.87
Process	3.17	8.04
Energy	3.03	8.18
Logistics	2.55	7.32
Waste	3.11	8.21
Certifications	3.58	8.59
Social	3.13	8.07

Source(s): Authors' own work

- Cluster 1 represented “aware consumers,” recognizing the relevance of environmental, social, and product related aspects.

Subsequent analysis of the centroids (Figure 10) highlighted a clear distinction between two consumer profiles. The variables were reported in normalized form (using z-score standardization) to facilitate comparison between groups and to identify the most relevant dimensions for each cluster. Cluster 0, shown in blue, was characterized by values below the sample average across all dimensions considered, with particularly pronounced deviations in the variables related to the DPP (from F to L). Conversely, Cluster 1, in red, exhibited systematically above-average values, with the DPP dimensions emerging as especially salient. This group demonstrated a proactive attitude toward sustainability, incorporating DPP information into both decision-making and purchasing processes, whereas Cluster 0 showed a generally lower sensitivity to environmental and sustainability-related issues, likely favoring more traditional criteria and exhibiting a reduced inclination toward innovative or digital solutions.

Figure 10 Standardized centroids (z-score) of the two clusters. The following acronyms are used: A = importance of environmental impact; B = importance of types of raw materials used; C = importance of product durability and reparability; D = importance of aesthetics; E = importance of price; F = DPP information on raw materials used; G = DPP information on production process; H = DPP information on energy consumption and emissions; I = DPP information on logistics and transport; J = DPP information on waste/waste disposal; K = DPP information on certifications; L = DPP information on social commitment



In addition to DPP-related aspects, the centroids revealed significant differences across more traditional consumption dimensions, including perceived environmental impact, aesthetics, price, durability and raw materials. Cluster 0 attributed a low average level of relevance to these elements (environmental impact = -0.70; raw materials = -0.73; durability = -0.76; aesthetics = -0.67; price = -0.81). In contrast, Cluster 1 recorded positive, above-average values for the same variables (respectively, +0.55; +0.57; +0.59; +0.52; +0.64), indicating a stronger overall focus on both conventional product attributes and the advanced dimensions represented by the DPP. These results suggest that Cluster 1 consisted of more aware and demanding consumers, demonstrating a greater concern for product features as well as sustainability and social responsibility. This group appeared capable of integrating both traditional and innovative criteria into their purchasing decisions.

These distinctions also influenced how respondents engaged with the DPP (Table 5). Cluster 0 (unaware consumers) considered DPP information of limited relevance, using it primarily when it was presented in a simple format and linked to immediate, tangible benefits (e.g. financial incentives). In contrast, Cluster 1 (conscious consumers) regarded the DPP as a valuable tool for making more informed and responsible choices, enhancing both their understanding of the supply chain and their trust in brands. This duality indicated that the DPP has the potential to not only raise consumer awareness but also reinforce informed purchasing behaviors.

4.4 Principal component analysis – cosmetics sector

To further explore and contextualize these results, the PCA method was applied. The sample demonstrated high adequacy for the analysis (KMO = 0.936 > 0.6), and Bartlett's test was significant ($\chi^2 = 6300.494$; $p < 0.001$), confirming the robustness of the procedure. The cumulative variance explained by the two-dimensional PCA was 0.724. As shown in the scree plot (Figure 11), the first principal component accounted for over 70% of the variance, while the subsequent components contributed only marginally. Together, the first two components explained 84% of the total variance, a notably high proportion supporting the adoption of a two-dimensional representation.

PCA identified two principal dimensions. PC1 (x-axis in Figure 12) aggregated the variables most relevant to evaluating and purchasing based on the DPP. All observed variables showed positive values and high factor loadings (e.g. F = 0.31; A = 0.24), indicating that a high PC1 score corresponded to consumers strongly oriented toward sustainability, transparency and overall product quality. PC2 (y-axis in Figure 12) captured a distinction between interest in product features (variables A–E, positive values; e.g. aesthetics = 0.40) and attention to sustainable processes (variables F–L, negative values; e.g. energy information = -0.24). Consumers with high PC2 scores showed greater interest in product

Table 5 Comparison of average profiles emerging from the two clusters

Dimension	Cluster 0: Unaware	Cluster 1: Aware
Relevance of traditional aspects	Below-average values; little interest in traditional aspects of consumption	Above-average values; high interest in traditional aspects of consumption
DPP orientation	Limited, poor integration into choices	High, integrates DPP information into purchasing processes
Sensitivity to sustainability	Low, minimal attention to environmental and social aspects	High, marked attention to environmental and social impacts
Expected behavior	Less inclined toward digital innovation; use of DPP only if simple and immediately useful	Proactive, use of DPP for informed and responsible decisions; trust in brands
General orientation	Traditional, conservative, with low awareness of sustainable criteria	Proactive, aware, integrates classic and innovative criteria into purchasing decisions

Source(s): Authors' own work

Figure 11 Scree plot of the main components

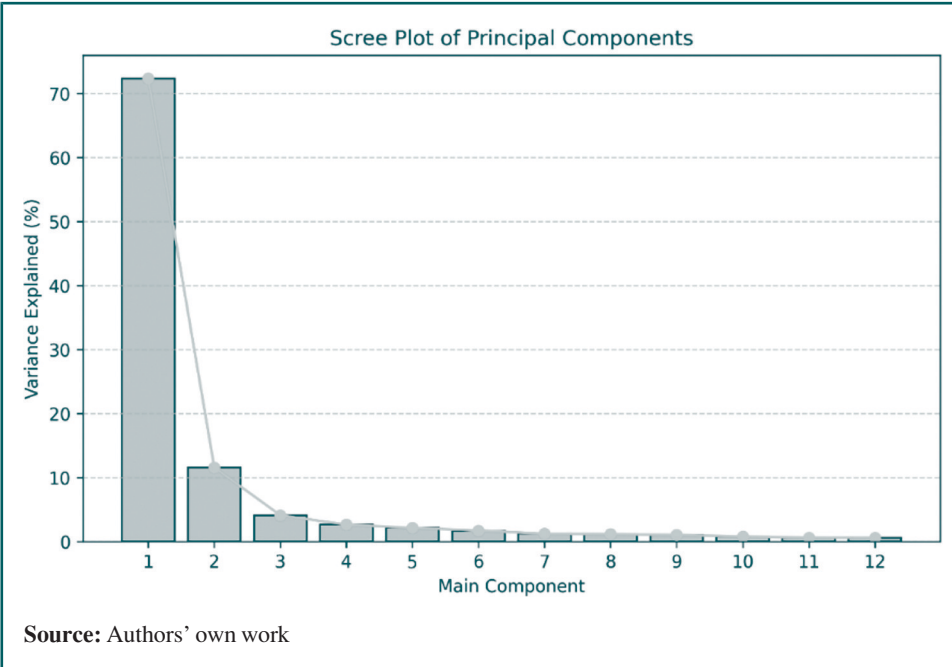
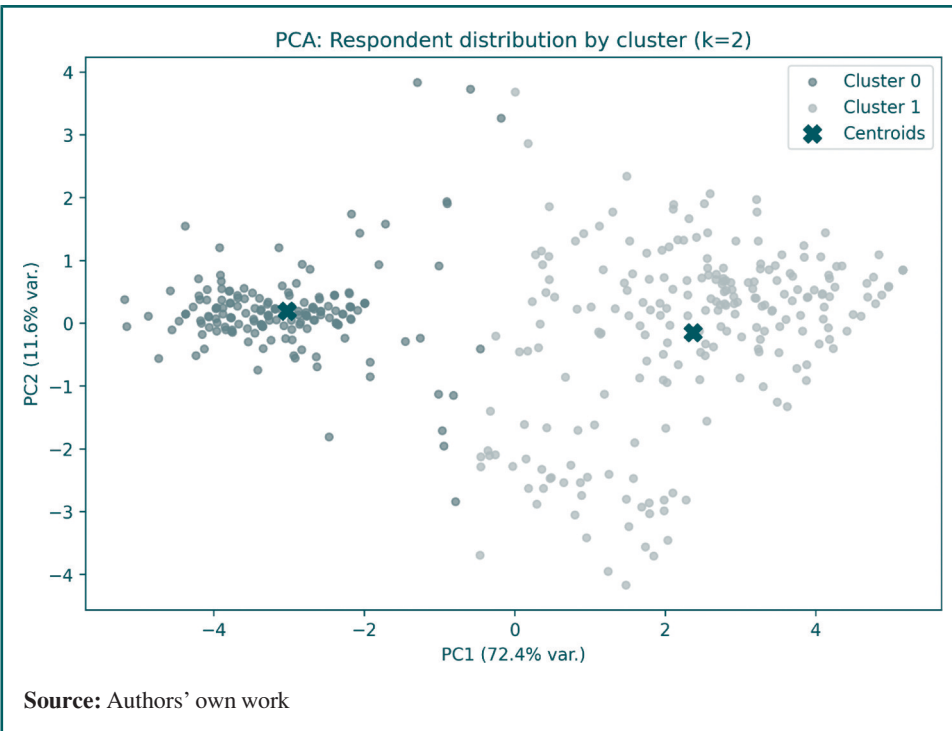


Figure 12 Distribution of the two clusters on the PC1–PC2 components



characteristics and tended to be more active buyers, whereas those with lower scores showed greater attention to sustainability processes, independent of product appeal. When the cluster analysis was projected onto the PCA dimensions (Figure 12), two clearly distinct groups emerged:

1. Cluster 0 (blue): Characterized by low PC1 values, this group included consumers with an older average age and lower interest in sustainability and overall product quality.
2. Cluster 1 (orange): Associated with higher PC1 values, this cluster grouped consumers who were, on average, younger, more attentive to sustainability and transparency and exhibiting a stronger propensity to purchase particularly products with a DPP. However, this cluster also displayed considerable dispersion, suggesting heterogeneity in behavior.

Centroid analysis indicated that both clusters exhibited similar values along PC2 (close to 0), implying comparable behaviors with respect to that component. Nevertheless, the clusters were clearly separated along PC1, confirming significant differences between the groups and validating the segmentation. These distances justified the development of differentiated marketing strategies. For the “unaware” cluster (likely Cluster 0), simple and direct communication strategies were recommended, emphasizing convenience, practicality and reliability potentially supported by promotions and loyalty programs. For the “aware” cluster (likely Cluster 1), marketing approaches focused on sustainability, transparency and social responsibility were more appropriate. Within this latter group, further message differentiation based on consumers’ sensitivity to innovation and quality versus prioritization of ethical and environmental concerns was also feasible, along with the adoption of a premium pricing strategy.

4.5 Logistic and least absolute shrinkage and selection operator regression

To identify the consumer characteristics most strongly associated with prior awareness of the DPP across both sectors, two complementary models were estimated: a standard binary logistic regression and a penalized LASSO logistic regression. Both analyses were conducted on the merged data set comprising respondents from the fashion and cosmetics sectors, with the question “Have you ever heard of the DPP?” serving as the dependent variable (Yes=1; No=0). Predictors included the variables previously used in the

Table 6 Logistic regression results. Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
Variable	Estimate	SE	z value	Pr(> z)	Significance
(Intercept)	-1.8651	0.2479	-7.5220	0.0000	***
Relevance impact	0.0961	0.0582	1.6530	0.0984	.
Relevance raw materials	0.1564	0.0690	2.2680	0.0233	*
Relevance sustainability	0.0297	0.0666	0.4460	0.6554	
Aesthetic relevance	-0.0780	0.0567	-1.3750	0.1690	
Price relevance	-0.0611	0.0652	-0.9380	0.3484	
<i>DPP</i>					
Raw materials	-0.0665	0.0860	-0.7730	0.4393	
Process	0.0623	0.0855	0.7290	0.4661	
Energy	-0.0406	0.0960	-0.4230	0.6725	
Logistics	-0.0345	0.0763	-0.4530	0.6508	
Waste	0.0242	0.0900	0.2690	0.7882	
Certifications	-0.0246	0.0754	-0.3260	0.7446	
Social	0.0593	0.0772	0.7680	0.4425	
<i>Sector</i>					
Fashion	0.1858	0.1954	0.9510	0.3417	
Source(s): Authors’ own work					

clustering analysis, along with one categorical variable representing the questionnaire sector. Table 6 presents the results of the classical logistic regression.

The model demonstrated an acceptable goodness of fit (residual deviance = 833.34; AIC = 861.34), with stable coefficient estimates and no indication of overdispersion. Among the predictors, relevance of raw materials emerged as the only statistically significant variable at the 5% level, while relevance of environmental impact was marginally significant. The positive coefficients for both variables indicated that respondents who attached greater importance to raw materials and environmental impact were more likely to have already heard of the DPP. In contrast, the coefficients associated with other variables, including those directly related to DPP dimensions (i.e. process, energy, logistics, waste, certifications, social), were not statistically significant. This suggests that prior knowledge of the DPP was not driven by familiarity with DPP-specific information, but by attitudes toward sustainability. Sectoral affiliation (fashion vs cosmetics) did not significantly influence awareness levels, confirming that the determinants of DPP knowledge were consistent across sectors. To validate and refine these findings, a LASSO logistic regression was conducted using the optimal penalty parameter $\lambda = 0.0093$. The LASSO procedure retained only variables with nonzero coefficients, effectively filtering out less influential predictors and addressing potential multicollinearity among the sustainability dimensions. As shown in Table 7, the LASSO results confirmed the centrality of general sustainability sensitivity, particularly the perceived importance of raw materials and environmental impact as the most distinctive characteristics of consumers already familiar with the DPP. The slightly negative coefficient for price relevance suggests that respondents primarily motivated by price had been less exposed to, or engaged less with, sustainability-oriented innovations such as the DPP.

5. Discussion

The literature emphasizes the growing centrality of knowledge management in sustainability and digital transformation processes, particularly its role in fostering organizational innovation and addressing major social and technological challenges (Ardito *et al.*, 2024; Del Giudice *et al.*, 2023; Shrivastav *et al.*, 2025). At the same time, significant critical issues have emerged, including inequalities in access to knowledge, information overload, skills obsolescence and “technostress” all of which can undermine workers’ well-being and the

Table 7 LASSO regression results

<i>Variable</i>	<i>LASSO coefficient</i>
(Intercept)	-1.8459
Relevance impact	0.0723
Relevance raw materials	0.0989
Relevance sustainability	.
Aesthetic relevance	.
Price relevance	-0.0063
<i>DPP</i>	
Raw materials	-0.0363
Process	.
Energy	.
Logistics	.
Waste	.
Certifications	.
Social	.
<i>Sector</i>	
Cosmetic	.
Fashion	.
Source(s): Authors' own work	

effectiveness of knowledge management practices (Martínez-Navalón *et al.*, 2023; Shrivastav *et al.*, 2025). In this context, skills development and a human-centered approach are widely recognized as key to enhancing digital knowledge in a sustainable way and strengthening the role of organizations and communities (D'Adamo, 2025; Del Giudice *et al.*, 2023).

The present analyses revealed that the effectiveness of the DPP did not depend on the complexity or completeness of the information provided, but rather on consumers' preexisting ability to contextualize and interpret that information within a sustainability framework. These findings challenge the dominant paradigm underpinning digital transparency initiatives, which often assume a linear relationship between information disclosure and consumer engagement, leading to more informed and responsible behavior (King *et al.*, 2023; Popowicz *et al.*, 2025). Instead, the DPP should be conceived as a learning infrastructure that fosters awareness by integrating information with consumers' interpretive systems. However, the results indicate that the DPP currently operates within what can be described as a capability-dependent knowledge system, where consumers' absorptive capacity (i.e. the ability to recognize, assimilate, apply new information) (Mata *et al.*, 2024) is a necessary precondition for effective information use and responsible purchasing decisions (Gieß and Möller, 2025; Saenz *et al.*, 2024). This structural limitation underscores the absence, in the current design of the DPP, of mechanisms for activating knowledge (Oludapo *et al.*, 2024).

A cluster analysis across both sectors confirmed this division, identifying two distinct groups of aware and unaware consumers, respectively. Aware consumers exhibited lead-user characteristics (von Hippel, 1986), demonstrating both motivation and cognitive readiness to engage with detailed traceability information. They functioned not merely as recipients of information but also as knowledge partners, capable of cocreating and validating sustainability data (Vătămănescu *et al.*, 2025). Conversely, unaware consumers perceived the DPP as overly complex or peripheral to their decision-making processes. Regression analyses, both logistic and LASSO, showed that prior awareness of the DPP, across the combined sample, was significantly correlated with general sustainability orientations (e.g. the perceived importance of raw materials and environmental impact), but presented little or no association with the specific information dimensions of the DPP.

This lack of significance suggests that, for the mass market, the DPP may function as a black box. In the sample, consumer awareness appeared to be driven by a general sensitivity to raw materials as a tangible proxy for quality rather than engagement with the detailed data provided by the DPP. This points to a capability gap, as the tool offers complex knowledge that the average (unaware) may not be interested in or may lack the specific absorptive capacity to process. This technical barrier cannot be addressed by simply enhancing data presentation. Importantly, engagement strategies must prioritize capacity building and the development of sustainability literacy, rather than focusing solely on interface improvements. In contrast, for aware consumers, engagement should center on cocreation and validation. Involving them in the iterative development of DPP standards, communication formats and usability testing may transform the DPP into a participatory knowledge platform a dynamic interface through which producers and consumers may collaboratively construct a shared understanding of sustainability (Chaurasia *et al.*, 2020).

At the industry level, cross-sectoral findings from the fashion and cosmetics sectors suggest that sustainability-oriented consumers tend to apply consistent evaluative criteria across different product categories. This behavioral coherence implies that best practices in sustainable design and communication may be transferable across industries, supporting corporate alignment with the sustainability reporting requirements outlined in the CSRD (Di Leo *et al.*, 2023). For unaware consumers, interventions emphasizing material origin, quality and authenticity may serve as effective entry points, linking traditional product attributes with sustainability transparency.

The results confirmed that the DPP constitutes a viable OI tool capable of engaging consumers as active knowledge partners. By enabling two-way information flows between producers and users, the DPP represents a dynamic knowledge management ecosystem in which transparency and participation coevolve. These technical and participatory dimensions position it as a strategic enabler of the circular transition (Jensen *et al.*, 2023).

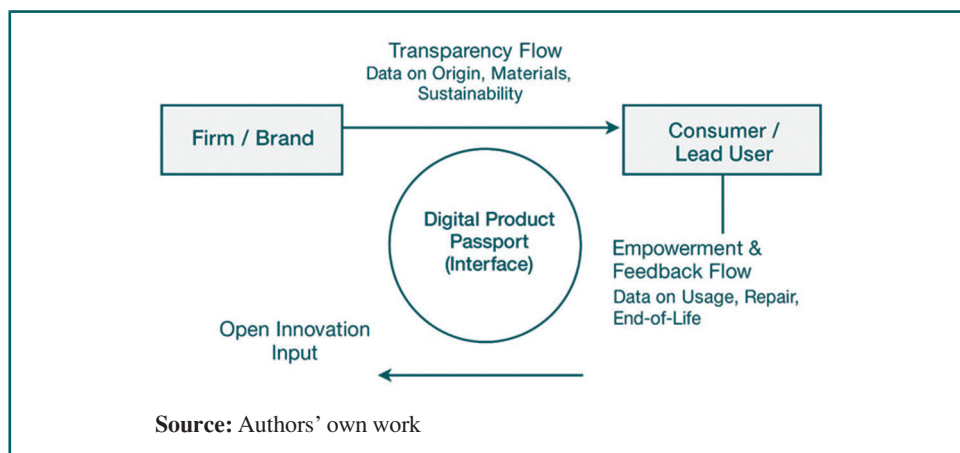
Existing information systems for circularity typically operate as static repositories of technical attributes, primarily intended to optimize recycling (Kristoffersen *et al.*, 2020). However, data availability alone is insufficient to support circularity. To address this limitation, the present study conceptualized the DPP as a boundary tool designed to facilitate bidirectional data flows, transforming the consumer from a passive recipient into an active knowledge contributor within the information loop (Belk, 2014). Framing DPP standardization through an OI lens may empower consumers to act as “prosumers” (Kotler, 2010), thereby activating the “coupled process” through which companies and partners collaboratively cocreate value (Enkel *et al.*, 2009). Specifically, the DPP may redefine conventional boundaries by operationalizing OI with the end-consumer as a value cocreator. By monitoring usage patterns (e.g. product repair, intensive use), firms can systematically identify “lead users” (von Hippel, 1986), converting raw consumer feedback into actionable insights for circular strategies. However, the success of this operationalization hinges on consumer maturity. For unaware consumers, the DPP may function primarily as a cognitive scaffold for sustainability education (“Inside-Out” flow). For aware consumers, however, it may evolve into a platform for active collaboration (“Outside-In” flow), as illustrated in Figure 13. In practical terms, the user interface would serve as the essential bridge enabling this transition. Accessed via QR codes or near-field communication, the DPP landing page would act as an interactive exchange environment. The embedding of asynchronous feedback mechanisms such as structured evaluation tools (e.g. circular performance ratings) and qualitative comment features could further allow the DPP to overcome the limitations of static ledgers.

Figure 13 illustrates the bidirectional flow in which corporate transparency (outbound) fosters consumer trust, thereby enabling the collection of usage and end-of-life data (inbound).

6. Conclusions

The present work investigated the potential of the DPP to promote innovation and circularity in the fashion and cosmetics sectors. The DPP was framed as a socio-technical

Figure 13 The DPP as an open innovation tool



infrastructure aligning technological transparency with cognitive and participatory functions, thereby addressing a gap in the literature (which is predominantly focused on regulatory aspects). The results of this study fill this gap also by showing that awareness of the DPP is predicted not by familiarity with its technical components, but by sustainability orientations.

Empirically, the study yielded two main outcomes. First, the identification of “unaware” and “aware” clusters substantiated the notion of a capability-dependent knowledge system: individuals with higher sustainability literacy were able to interpret and activate DPP information, while others remained excluded from its potential benefits. This dual segmentation reflects what the literature describes as capability-dependent knowledge structures. Second, the perceived relevance of raw materials emerged as the primary predictor of DPP awareness, surpassing technical familiarity.

From a managerial perspective, the observed “aware/unaware” dichotomy suggests a dual strategic approach. For the unaware cluster, the DPP should be simplified within value propositions (e.g. “Scan to verify authenticity” or “Scan for detailed instructions”). For aware customers, the DPP should be positioned as a verification tool for ethical values, encouraging them to act as brand ambassadors. This reframes the DPP from a regulatory obligation into a customer relationship management channel.

From a socio-political perspective, DPP implementation raises concerns about the digital divide. If the DPP becomes the standard for sustainability verification, small- and medium-sized enterprises that lack the resources to manage complex data governance systems may face exclusion from the market. Moreover, if access to DPP knowledge is limited to digitally literate consumers.

Despite the aforementioned contributions, this study is not without limitations. First, the sample’s geographical context may affect the generalizability of the results, as the analysis of questionnaire responses is inherently dependent on the participants interviewed. In addition, the absence of a detailed economic cost analysis warrants further investigation to assess the feasibility of DPP implementation for enterprises. However, by integrating OI principles, the DPP offers a cognitive infrastructure connecting data, knowledge and innovation. In particular, its capacity to document raw material provenance positions it as a vital tool for advancing resilient supply chains and supporting the achievement of SDG 12.

References

- Abdelmeguid, A., Afy-Shararah, M. and Salonitis, K. (2024), “Towards circular fashion: management strategies promoting circular behaviour along the value chain”, *Sustainable Production and Consumption*, Vol. 48, pp. 143-156, doi: [10.1016/j.spc.2024.05.010](https://doi.org/10.1016/j.spc.2024.05.010).
- Ardito, L., Natalicchio, A., Messeni Petruzzelli, A. and Del Giudice, M. (2024), “Converting inventions into innovations to address cancer grand challenges: the role of scientific and digital search intensity”, *Journal of Product Innovation Management*, Vol. 41 No. 2, pp. 267-292, doi: [10.1111/jpim.12701](https://doi.org/10.1111/jpim.12701).
- Arias-Pérez, J., Velez-Ocampo, J. and Cepeda-Cardona, J. (2021), “Strategic orientation toward digitalization to improve innovation capability: why knowledge acquisition and exploitation through external embeddedness matter”, *Journal of Knowledge Management*, Vol. 25 No. 5, pp. 1319-1335, doi: [10.1108/JKM-03-2020-0231](https://doi.org/10.1108/JKM-03-2020-0231).
- Awa, H.O., Etim, W. and Ogbonda, E. (2024), “Stakeholders, stakeholder theory and corporate social responsibility (CSR)”, *International Journal of Corporate Social Responsibility*, Vol. 9 No. 1, p. 11, doi: [10.1186/s40991-024-00094-y](https://doi.org/10.1186/s40991-024-00094-y).
- Baltar, F. and Brunet, I. (2012), “Social research 2.0: virtual snowball sampling method using Facebook”, *Internet Research*, Vol. 22 No. 1, pp. 57-74, doi: [10.1108/10662241211199960](https://doi.org/10.1108/10662241211199960).
- Belk, R. (2014), “You are what you can access: sharing and collaborative consumption online”, *Journal of Business Research*, Vol. 67 No. 8, pp. 1595-1600, doi: [10.1016/j.jbusres.2013.10.001](https://doi.org/10.1016/j.jbusres.2013.10.001).
- Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L. and Frederiksen, L. (2017), “The open innovation research landscape: established perspectives and emerging themes

- across different levels of analysis", *Industry and Innovation, Routledge*, Vol. 24 No. 1, pp. 8-40, doi: [10.1080/13662716.2016.1240068](https://doi.org/10.1080/13662716.2016.1240068).
- Carvalho, C., Silva, C.J. and Abreu, M.J. (2025), "Circular economy: literature review on the implementation of the digital product passport (DPP) in the textile industry", *Sustainability*, Vol. 17 No. 5, p. 1802, doi: [10.3390/su17051802](https://doi.org/10.3390/su17051802).
- Cascavilla, A., D'Adamo, I., Grosso, C. and Trusiani, C. (2026), "Bridging digital tools and human skills: a sustainable competence framework for implementing digital product passports in the cosmetics industry", *Journal of Environmental Management*, Vol. 397, p. 128281, doi: [10.1016/j.jenvman.2025.128281](https://doi.org/10.1016/j.jenvman.2025.128281).
- Çetin, S., Raghu, D., Honic, M., Straub, A. and Gruis, V. (2023), "Data requirements and availabilities for material passports: a digitally enabled framework for improving the circularity of existing buildings", *Sustainable Production and Consumption*, Vol. 40, pp. 422-437, doi: [10.1016/j.spc.2023.07.011](https://doi.org/10.1016/j.spc.2023.07.011).
- Chaudhuri, R., Chavan, G., Vadalkar, S., Vrontis, D. and Pereira, V. (2020), "Two-decade bibliometric overview of publications in the Journal of Knowledge Management", *Journal of Knowledge Management*, Vol. 25 No. 6, pp. 1550-1574, doi: [10.1108/JKM-07-2020-0571](https://doi.org/10.1108/JKM-07-2020-0571).
- Chaurasia, S.S., Kaul, N., Yadav, B. and Shukla, D. (2020), "Open innovation for sustainability through creating shared value-role of knowledge management system, openness and organizational structure", *Journal of Knowledge Management*, Vol. 24 No. 10, pp. 2491-2511, doi: [10.1108/JKM-04-2020-0319](https://doi.org/10.1108/JKM-04-2020-0319).
- Chesbrough, H. (2012), "Open innovation: where we've been and where we're going", *Research-Technology Management, Routledge*, Vol. 55 No. 4, pp. 20-27, doi: [10.5437/08956308X5504085](https://doi.org/10.5437/08956308X5504085).
- Colasante, A., D'Adamo, I., Desideri, S., Iannilli, M. and Mangani, V. (2025), "Environmental concerns in the fashion industry: a twin transition with the digital product passport", *Business Strategy and the Environment*, Vol. 34 No. 7, pp. 9242-9256, doi: [10.1002/bse.70078](https://doi.org/10.1002/bse.70078).
- Crupi, A., Del Sarto, N., Di Minin, A., Phaal, R. and Piccaluga, A. (2020), "Open innovation environments as knowledge sharing enablers: the case of strategic technology and innovative management consortium", *Journal of Knowledge Management*, Vol. 25 No. 5, pp. 1263-1286, doi: [10.1108/JKM-06-2020-0419](https://doi.org/10.1108/JKM-06-2020-0419).
- D'Adamo, I. (2025), "Sustainable communities: we are the world", *Scientific Reports*, Vol. 15 No. 1, p. 8068, doi: [10.1038/s41598-025-91952-7](https://doi.org/10.1038/s41598-025-91952-7).
- D'Adamo, I., Fratocchi, L., Grosso, C. and Tavana, M. (2025), "An integrated business strategy for the twin transition: leveraging digital product passports and circular economy models", *Business Strategy and the Environment*, Vol. 34, pp. 9008-9022, doi: [10.1002/bse.70065](https://doi.org/10.1002/bse.70065).
- Daraio, C., Di Leo, S. and Simar, L. (2024), "Viable eco-efficiency targets for waste collection communities", *Scientific Reports*, Vol. 14 No. 1, p. 15038, doi: [10.1038/s41598-024-66077-y](https://doi.org/10.1038/s41598-024-66077-y).
- De Giovanni, P. (2025), "A dynamic game of circular economy with environmental producer responsibility and digital product passport", *International Game Theory Review*, Vol. 28 No. 1, p. 2540003, doi: [10.1142/S0219198925400031](https://doi.org/10.1142/S0219198925400031).
- Del Giudice, M., Scuotto, V., Orlando, B. and Mustilli, M. (2023), "Toward the human-centered approach. A revised model of individual acceptance of AI", *Human Resource Management Review*, Vol. 33 No. 1, p. 100856, doi: [10.1016/j.hrmr.2021.100856](https://doi.org/10.1016/j.hrmr.2021.100856).
- Della Peruta, M.R., Del Giudice, M., Lombardi, R. and Soto-Acosta, P. (2018), "Open innovation, product development, and inter-company relationships within regional knowledge clusters", *Journal of the Knowledge Economy*, Vol. 9 No. 2, pp. 680-693, doi: [10.1007/s13132-016-0356-x](https://doi.org/10.1007/s13132-016-0356-x).
- Di Leo, A., Sfofera, F., Cucari, N., Mattia, G. and Dezi, L. (2023), "Sustainability reporting practices: an explorative analysis of luxury fashion brands", *Management Decision*, Vol. 61 No. 5, pp. 1274-1297, doi: [10.1108/MD-02-2022-0142](https://doi.org/10.1108/MD-02-2022-0142).
- Enkel, E., Gassmann, O. and Chesbrough, H. (2009), "Open R&D and open innovation: exploring the phenomenon", *R&D Management*, Vol. 39 No. 4, pp. 311-316, doi: [10.1111/j.1467-9310.2009.00570.x](https://doi.org/10.1111/j.1467-9310.2009.00570.x).
- Etikan, I., Musa, S.A. and Alkassim, R.S. (2015), "Comparison of convenience sampling and purposive sampling", *American Journal of Theoretical and Applied Statistics*, Vol. 5 No. 1, pp. 1-4, doi: [10.11648/j.ajtas.20160501.11](https://doi.org/10.11648/j.ajtas.20160501.11).
- Fares, N., Islam, M.S., Jauhar, S.K. and Kucukaltan, B. (2025), "Towards an international digital product passport: the new paradigm of a worldwide circular economy", *Circular Economy and Sustainability*, Vol. 5 No. 6, doi: [10.1007/s43615-025-00690-5](https://doi.org/10.1007/s43615-025-00690-5).

- Fatima, T. and Elbanna, S. (2023), "Corporate social responsibility (CSR) implementation: a review and a research agenda towards an integrative framework", *Journal of Business Ethics*, Vol. 183 No. 1, pp. 105-121, doi: [10.1007/s10551-022-05047-8](https://doi.org/10.1007/s10551-022-05047-8).
- Ferrante, M., Vitti, M. and Sassanelli, C. (2025), "The evolution of circular economy performance assessment: a systematic literature review", *Renewable and Sustainable Energy Reviews*, Vol. 217, p. 115757, doi: [10.1016/j.rser.2025.115757](https://doi.org/10.1016/j.rser.2025.115757).
- Friedman, J.H., Hastie, T. and Tibshirani, R. (2010), "Regularization paths for generalized linear models via coordinate descent", *Journal of Statistical Software*, Vol. 33 No. 1, pp. 1-22, doi: [10.18637/jss.v033.i01](https://doi.org/10.18637/jss.v033.i01).
- Gieß, A. and Möller, F. (2025), "Exploring the value ecosystem of digital product passports", *Journal of Industrial Ecology*, Vol. 29 No. 2, doi: [10.1111/jiec.13621](https://doi.org/10.1111/jiec.13621).
- Greiner, M., Seidenfad, K., Langewisch, C., Hofmann, A. and Lechner, U. (2024), "The digital product passport: enabling interoperable information flows through blockchain consortia for sustainability", in Phillipson, F., Eichler, G., Erfurth, C. and Fahrnberger, G. (Eds), *Innovations for Community Services*, Springer Nature, Cham, pp. 377-396, doi: [10.1007/978-3-031-60433-1_21](https://doi.org/10.1007/978-3-031-60433-1_21).
- Hosmer, D.W., Jr., Lemeshow, S. and Sturdivant, R.X. (2013), *Applied Logistic Regression*, John Wiley & Sons, New Jersey.
- James, G., Witten, D., Hastie, T. and Tibshirani, R. (2013), "An introduction to statistical learning", *With Applications in R*, Vol. 103.
- Jensen, S.F., Kristensen, J.H., Adamsen, S., Christensen, A. and Waehrens, B.V. (2023), "Digital product passports for a circular economy: data needs for product life cycle decision-making", *Sustainable Production and Consumption*, Vol. 37, pp. 242-255, doi: [10.1016/j.spc.2023.02.021](https://doi.org/10.1016/j.spc.2023.02.021).
- Jensen, S.F., Kristensen, J.H., Christensen, A. and Waehrens, B.V. (2024), "An ecosystem orchestration framework for the design of digital product passports in a circular economy", *Business Strategy and the Environment*, Vol. 33 No. 7, pp. 7100-7117, doi: [10.1002/bse.3868](https://doi.org/10.1002/bse.3868).
- Joshi, H., Chawla, D. and Farooque, J. (2014), "Segmenting knowledge management (KM) practitioners and its relationship to performance variation – some empirical evidence", *Journal of Knowledge Management*, Vol. 18 No. 3, pp. 469-493, doi: [10.1108/JKM-10-2013-0380](https://doi.org/10.1108/JKM-10-2013-0380).
- Kemmner, F.-A., Legenvre, H. and Hameri, A.-P. (2025), "Sharing data to implement the circular economy: the case of digital product passports", *Industrial Management & Data Systems*, pp. 1-20, doi: [10.1108/IMDS-04-2024-0403](https://doi.org/10.1108/IMDS-04-2024-0403).
- King, M.R.N., Timms, P.D. and Mountney, S. (2023), "A proposed universal definition of a digital product passport ecosystem (DPPE): worldviews, discrete capabilities, stakeholder requirements and concerns", *Journal of Cleaner Production*, Vol. 384, p. 135538, doi: [10.1016/j.jclepro.2022.135538](https://doi.org/10.1016/j.jclepro.2022.135538).
- Kolling, C., Ribeiro, J.L.D., Morea, D. and Iazzolino, G. (2023), "Corporate social responsibility and circular economy from the perspective of consumers: a cross-cultural analysis in the cosmetic industry", *Corporate Social Responsibility and Environmental Management*, Vol. 30 No. 3, pp. 1226-1243, doi: [10.1002/csr.2415](https://doi.org/10.1002/csr.2415).
- Kotler, P. (2010), "The prosumer movement", in Blätzel-Mink, B. and Hellmann, K.-U. (Eds), *Prosumer Revisited: Zur Aktualität Einer Debatte*, VS Verlag für Sozialwissenschaften, Wiesbaden, pp. 51-60, doi: [10.1007/978-3-531-91998-0_2](https://doi.org/10.1007/978-3-531-91998-0_2).
- Kristoffersen, E., Blomsma, F., Mikalef, P. and Li, J. (2020), "The smart circular economy: a digital-enabled circular strategies framework for manufacturing companies", *Journal of Business Research*, Vol. 120, pp. 241-261, doi: [10.1016/j.jbusres.2020.07.044](https://doi.org/10.1016/j.jbusres.2020.07.044).
- Kurul, F., Doruk, B. and Topkaya, S.N. (2025), "Principles of green chemistry: building a sustainable future", *Discover Chemistry*, Vol. 2 No. 1, p. 68, doi: [10.1007/s44371-025-00152-9](https://doi.org/10.1007/s44371-025-00152-9).
- Langley, D.J., Rosca, E., Angelopoulos, M., Kamminga, O. and Hooijer, C. (2023), "Orchestrating a smart circular economy: guiding principles for digital product passports", *Journal of Business Research*, Vol. 169, p. 114259, doi: [10.1016/j.jbusres.2023.114259](https://doi.org/10.1016/j.jbusres.2023.114259).
- Lopes, C. and Barata, J. (2024), "Digital product passport: a review and research agenda", *Procedia Computer Science*, Vol. 246, pp. 981-990, doi: [10.1016/j.procs.2024.09.517](https://doi.org/10.1016/j.procs.2024.09.517).
- Luukkonen, R., Närvänen, E. and Becker, L. (2024), "Consumer collectives in the circular economy: a systematic review and research agenda", *Sustainable Production and Consumption*, Vol. 45, pp. 281-293, doi: [10.1016/j.spc.2024.01.006](https://doi.org/10.1016/j.spc.2024.01.006).

- Martínez-Navalón, J.G., Gelashvili, V., DeMatos, N. and Herrera-Enríquez, G. (2023), "Exploring the impact of digital knowledge management on technostress and sustainability", *Journal of Knowledge Management*, Vol. 27 No. 8, pp. 2194-2216, doi: [10.1108/JKM-07-2022-0544](https://doi.org/10.1108/JKM-07-2022-0544).
- Marzani, G., Tondelli, S., Kuma, Y., Cruz Rios, F., Hu, R., Bock, T. and Linner, T. (2025), "Embedding circular economy in the construction sector policy framework: experiences from EU, U.S., and Japan for better future cities", *Smart Cities*, Vol. 8 No. 2, p. 48, doi: [10.3390/smartcities8020048](https://doi.org/10.3390/smartcities8020048).
- Mata, M.N., Moleiro Martins, J. and Inácio, P.L. (2024), "Collaborative innovation, strategic agility, absorptive capacity adoption in SMEs: the moderating effects of customer knowledge management capability", *Journal of Knowledge Management*, Vol. 28 No. 4, pp. 1116-1140, doi: [10.1108/JKM-10-2022-0803](https://doi.org/10.1108/JKM-10-2022-0803).
- Mele, G., Capaldo, G., Secundo, G. and Corvello, V. (2023), "Revisiting the idea of knowledge-based dynamic capabilities for digital transformation", *Journal of Knowledge Management*, Vol. 28 No. 2, pp. 532-563, doi: [10.1108/JKM-02-2023-0121](https://doi.org/10.1108/JKM-02-2023-0121).
- Menard, S. (2010), *Logistic Regression: From Introductory to Advanced Concepts and Applications*, SAGE Publications, Thousand Oaks, CA, doi: [10.4135/9781483348964](https://doi.org/10.4135/9781483348964).
- Menegaki, A.N., Olsen, S.B. and Tsagarakis, K.P. (2016), "Towards a common standard – a reporting checklist for web-based stated preference valuation surveys and a critique for mode surveys", *Journal of Choice Modelling*, Vol. 18, pp. 18-50, doi: [10.1016/j.jocm.2016.04.005](https://doi.org/10.1016/j.jocm.2016.04.005).
- Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salivi, M. and Scapolo, F. (2022), *Towards a Green & Digital Future*, Publications Office of the European Union, Luxembourg, doi: [10.2760/977331](https://doi.org/10.2760/977331).
- Nguyen, T.-M. and Malik, A. (2021), "Employee acceptance of online platforms for knowledge sharing: exploring differences in usage behaviour", *Journal of Knowledge Management*, Vol. 26 No. 8, pp. 1985-2006, doi: [10.1108/JKM-06-2021-0420](https://doi.org/10.1108/JKM-06-2021-0420).
- Noy, C. (2008), "Sampling knowledge: the hermeneutics of snowball sampling in qualitative research", *International Journal of Social Research Methodology*, Routledge, Vol. 11 No. 4, pp. 327-344, doi: [10.1080/13645570701401305](https://doi.org/10.1080/13645570701401305).
- Oludapo, S., Carroll, N. and Helfert, M. (2024), "Why do so many digital transformations fail? A bibliometric analysis and future research agenda", *Journal of Business Research*, Vol. 174, p. 114528, doi: [10.1016/j.jbusres.2024.114528](https://doi.org/10.1016/j.jbusres.2024.114528).
- Omira, A., Grira, S., Mourad, A.-H.I. and Alkhedher, M. (2025), "The new generation of cosmetics packaging: a paradigm shift", *Global Transitions*, Vol. 7, pp. 223-246, doi: [10.1016/j.glt.2025.04.004](https://doi.org/10.1016/j.glt.2025.04.004).
- Ospital, P., Masson, D., Béler, C. and Legardeur, J. (2023), "Toward product transparency: communicating traceability information to consumers", *International Journal of Fashion Design, Technology and Education*, Vol. 16 No. 2, pp. 186-197, doi: [10.1080/17543266.2022.2142677](https://doi.org/10.1080/17543266.2022.2142677).
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D. and Shamseer, L. (2021), "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews", *BMJ*, p. 372, doi: [10.1136/bmj.n71](https://doi.org/10.1136/bmj.n71).
- Petrik, D., Dzierzawa, F. and Warthmann, K. (2025), "A maturity model for digital product passports: a design science study", *IEEE Access*, Vol. 13, pp. 114575-114594, doi: [10.1109/ACCESS.2025.3584842](https://doi.org/10.1109/ACCESS.2025.3584842).
- Pietroni, G., Marconi, M., Favi, C., Tamborrini, P.M., Marino, C. and Fiore, E. (2025), "Circular economy for electrical and electronic equipment: a life cycle design and management platform", *International Journal on Interactive Design and Manufacturing (IJIDeM)*, doi: [10.1007/s12008-025-02406-3](https://doi.org/10.1007/s12008-025-02406-3).
- Popowicz, M., Pohlmann, A., Schögl, J.-P. and Baumgartner, R.J. (2025), "Digital product passports as information providers for consumers—the case of digital battery passports", *Business Strategy and the Environment*, Vol. 34 No. 6, pp. 7700-7722, doi: [10.1002/bse.4346](https://doi.org/10.1002/bse.4346).
- Saenz, J., Felsch, T., Walter, C., König, T., Poenicke, O., Bayrhammer, E. and Vorbröcker, M. (2024), "Automated disassembly of e-waste—requirements on modeling of processes and product states", *Frontiers in Robotics and AI*, Vol. 11, doi: [10.3389/frobt.2024.1303279](https://doi.org/10.3389/frobt.2024.1303279).
- Sharma, M., Singh, P., Bolatan, G. and Daim, T. (2025), "Embracing human centric marketing for enhanced firm performance: the role of innovation strategy in India", *Journal of Knowledge Management*, Vol. 29 No. 6, pp. 1880-1913, doi: [10.1108/JKM-03-2024-0321](https://doi.org/10.1108/JKM-03-2024-0321).
- Shehu, M.O., Almeida, R. and Mahapatra, K. (2025), "Opportunities for digital tracking technologies in the precast concrete sector in Sweden", *Frontiers in Built Environment*, Vol. 11, doi: [10.3389/fbuil.2025.1566784](https://doi.org/10.3389/fbuil.2025.1566784).

- Shrivastav, S.K., Bag, S. and Bhattacharya, R. (2025), "Sustainable knowledge management in the digital era: leveraging natural language processing to identify trends, challenges and future directions", *Journal of Knowledge Management*, Vol. 29 No. 9, pp. 2843-2872, doi: [10.1108/JKM-10-2024-1251](https://doi.org/10.1108/JKM-10-2024-1251).
- Sondhi, S.S., Salwan, P., Niranjana, S., Hawkins, T., Behl, A., Pereira, V. and Del Giudice, M. (2024), "Exploring open innovation dynamics: service and delivery interplay in circular economy", *IEEE Transactions on Engineering Management*, Vol. 71, pp. 15511-15524, doi: [10.1109/TEM.2024.3483750](https://doi.org/10.1109/TEM.2024.3483750).
- Tapia, F., Ochoa-Peralta, D. and Reith, A. (2025), "From design to action: service design tools for enhancing collaboration in nature-based solutions implementation", *Journal of Environmental Management*, Vol. 379, p. 124739, doi: [10.1016/j.jenvman.2025.124739](https://doi.org/10.1016/j.jenvman.2025.124739).
- Tavana, M., Shaabani, A., Raeesi Vanani, I. and Kumar Gangadhari, R. (2022), "A review of digital transformation on supply chain process management using text mining", *Processes*, Vol. 10 No. 5, p. 842, doi: [10.3390/pr10050842](https://doi.org/10.3390/pr10050842).
- Tibshirani, R. (1996), "Regression shrinkage and selection via the Lasso", *Journal of the Royal Statistical Society: Series B (Methodological)*, Vol. 58 No. 1, pp. 267-288, doi: [10.1111/j.2517-6161.1996.tb02080.x](https://doi.org/10.1111/j.2517-6161.1996.tb02080.x).
- Tolentino-Zondervan, F. and DiVito, L. (2024), "Sustainability performance of Dutch firms and the role of digitalization: the case of textile and apparel industry", *Journal of Cleaner Production*, Vol. 459, p. 142573, doi: [10.1016/j.jclepro.2024.142573](https://doi.org/10.1016/j.jclepro.2024.142573).
- Twumasi Ankrah, S., He, Z., Arku, J.K. and Asare-Kyire, L. (2024), "Enhancing customer perception of co-production knowledge sharing: navigating scepticism and leveraging prosociality to unlock active feedback behaviour in co-creation", *Journal of Knowledge Management*, Vol. 29 No. 2, pp. 442-479, doi: [10.1108/JKM-01-2024-0076](https://doi.org/10.1108/JKM-01-2024-0076).
- Vătămănescu, E., Dinu, E., Gazzola, P. and Dabija, D. (2025), "Framing consumer empowerment in the digital economy: from networks and engagement toward sustainable purchase", *Business Ethics, the Environment & Responsibility*, Vol. 34 No. 4, pp. 1011-1032, doi: [10.1111/beer.12691](https://doi.org/10.1111/beer.12691).
- Von Hippel, E. (1986), "Lead users: a source of novel product concepts", *Management Science*, Vol. 32 No. 7, pp. 791-805, doi: [10.1287/mnsc.32.7.791](https://doi.org/10.1287/mnsc.32.7.791).
- Voulgaridis, K., Lagkas, T., Angelopoulos, C.M., Boulogeorgos, A.-A.A., Argyriou, V. and Sarigiannidis, P. (2024), "Digital product passports as enablers of digital circular economy: a framework based on technological perspective", *Telecommunication Systems*, Vol. 85 No. 4, pp. 699-715, doi: [10.1007/s11235-024-01104-x](https://doi.org/10.1007/s11235-024-01104-x).
- Wagner, E. (2025), "Information barriers to circularity for electronic products and the potential of digital product passports", *Sustainability*, Vol. 17 No. 12, p. 5554, doi: [10.3390/su17125554](https://doi.org/10.3390/su17125554).
- Wan, P.K.F. and Jiang, S. (2025), "Enabling a dynamic information flow in digital product passports during product use phase: a literature review and proposed framework", *Sustainable Production and Consumption*, Vol. 54, pp. 362-374, doi: [10.1016/j.spc.2025.01.014](https://doi.org/10.1016/j.spc.2025.01.014).
- Wicaksono, H., Mengistu, A., Bashyal, A. and Fekete, T. (2025), "Digital product passport (DPP) technological advancement and adoption framework: a systematic literature review", *Procedia Computer Science*, Vol. 253, pp. 2980-2989, doi: [10.1016/j.procs.2025.02.022](https://doi.org/10.1016/j.procs.2025.02.022).
- Zhang, A. and Seuring, S. (2024), "Digital product passport for sustainable and circular supply chain management: a structured review of use cases", *International Journal of Logistics Research and Applications*, Vol. 27 No. 12, pp. 2513-2540, doi: [10.1080/13675567.2024.2374256](https://doi.org/10.1080/13675567.2024.2374256).
- Zhao, J. and Huh, S.-Y. (2025), "Do consumers value carbon neutral clothing? A contingent valuation study in South Korea", *Journal of Cleaner Production*, Vol. 525, p. 146596, doi: [10.1016/j.jclepro.2025.146596](https://doi.org/10.1016/j.jclepro.2025.146596).
- Zhou, Q., Wang, S., Wang, L. and Xu, W. (2025), "Knowledge governance and innovation ambidexterity in the platform context: exploring the role of knowledge transformation", *Journal of Knowledge Management*, Vol. 29 No. 4, pp. 1301-1329, doi: [10.1108/JKM-03-2024-0256](https://doi.org/10.1108/JKM-03-2024-0256).

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Supplementary material

The supplementary material for this article can be found online.

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