



Research article

Bridging digital tools and human skills: A sustainable competence framework for implementing digital product passports in the cosmetics industry

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ABSTRACT

The twin transition – combining digitalisation with sustainability – has emerged as a strategic driver of competitiveness and resilience within industrial systems. Digital product passports (DPPs) constitute a key instrument in this transformation, offering life-cycle data facilitating transparency, traceability and circular strategies. The present study explores the implementation of DPPs in the cosmetics industry – a sector marked by complex formulations and global supply chains, with direct implications for human health and consumer safety. The methodology contributes to the advancement of SDG12 by evaluating both producer and consumer perspectives through multi-criteria decision-making methods (i.e., AHP, TOPSIS, VIKOR) and an online survey. The results reveal that familiarity with digital tools significantly influences consumer behaviour: digitally literate consumers ascribe to the DPP a value that transcends technical information, viewing it as a symbol of transparency, sustainability and social responsibility. This perception enhances brand trust and informs more conscious, value-driven purchasing decisions. In this light, the DPP emerges not merely as an informational resource but as a strategic lever for cosmetics companies, capable of aligning technological innovation with the ethical expectations of digital consumers. The findings indicate that managers should invest not only in digital infrastructure, but also in the human competencies required to interpret, communicate and capitalise on the DPP, thereby transforming it into a strategic asset promoting transparency, consumer trust and competitive advantage.

1. Introduction

The global industrial landscape is undergoing significant transformation driven by the twin transition, which integrates digitalisation and sustainability as a strategic pathway to enhance competitiveness and resilience in production systems (Fernández-Miguel et al., 2024b; Hofmann Trevisan et al., 2024). Central to this transition is the availability of accurate, interoperable and accessible product data across the entire life cycle, from raw material extraction to end-of-life management (Jensen et al., 2023). In this context, digital product passports (DPPs) have emerged as a key digital tool. Conceived as “digital identity cards”, DPPs collect, structure and communicate verified, product-specific information to enable circular strategies and ensure alignment with evolving sustainability frameworks (Carvalho et al., 2025; European

Commission, 2024a; Gieß and Möller, 2025).

The strategic importance of DPPs has been institutionalised through major EU policy initiatives, including the European Green Deal, the Circular Economy Action Plan and the Eco-design for Sustainable Products Regulation (ESPR) (European Commission, 2024b). Beyond their regulatory compliance, however, DPPs are increasingly understood as collaborative digital infrastructures facilitating multi-stakeholder information exchange and offering decision-support capabilities for both the green and the digital transitions. Almost two decades ago, early research highlighted that digital tools, in isolation, are insufficient without the accompanying organisational and human capabilities (Neth et al., 2022; Salter et al., 2009). Recent evidence reinforces this view, emphasising the role of DPPs as hubs for transparency, problem-solving and consumer engagement (Hafferty et al., 2024).

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In addition to these functions, DPPs can serve as operational bridges between life-cycle data and managerial decision-making – a role that is critical for translating complex product information into actionable sustainability strategies (Hammond et al., 2023; Tapia et al., 2025). Nevertheless, successful implementation of DPPs remains a complex undertaking, challenged by dynamic data management, stakeholder alignment and information harmonisation (Gallina et al., 2023; Voulgaridis et al., 2024; Zhang and Seuring, 2024). The definition of priority data categories and interoperability are recognised as prerequisites for effective deployment (D'Adamo et al., 2025). Moreover, the completeness and utility of DPP data depend on ongoing stakeholder engagement and regular updates to support decision-making by both companies and consumers. This complexity underscores the need to move beyond a purely technological outlook towards a knowledge management perspective – one positioning DPPs as not merely compliance tools, but also integrated information systems capable of supporting sustainable business transformation.

From a consumer perspective, DPPs' provision of transparent and reliable information on material composition, provenance and recyclability empowers individuals to counter greenwashing and make informed, sustainable choices (Colasante et al., 2025; Wan and Jiang, 2025). The success of DPPs thus hinges not only on technical integration but also on usability, relevance and communication strategies fostering consumer engagement. In this regard, DPPs are recognised as strategic tools for advancing Sustainable Development Goal (SDG) 12. Specifically, by prioritising information categories pertinent to sustainability monitoring and circular business models, DPPs may directly contribute to SDG 12 targets related to transparency, waste minimisation and resource efficiency. However, their effectiveness is contingent upon their tailored implementation to suit the operational, regulatory and consumer dynamics specific to each industry. A "one-size-fits-all" approach has proven inadequate, as evidenced by developments in the fashion sector, where DPPs function not only as tools of transparency but also as mechanisms influencing consumers' willingness to pay for sustainable products (Colasante et al., 2025; D'Adamo et al., 2025). These findings underscore the need for more industry-specific investigations into DPP design, to overcome persistent barriers to the operationalisation of circular economy (CE) strategies and digital tools (Alnafrah et al., 2025; Trevisan et al., 2023).

The cosmetics industry – characterised by complex formulations, diverse ingredient origins, global supply chains and stringent safety regulations (Alexander-White et al., 2025; Mondello et al., 2024) – represents a strategically significant (D'Adamo et al., 2024) yet under-explored domain for DPP adoption. The sector's intrinsic complexity reinforces its alignment with SDG 12, which advocates for responsible production and consumption, sustainable supply chain practices and the reduction of hazardous substances (Martins and Marto, 2023). DPPs in cosmetics could therefore enhance ingredient traceability, packaging sustainability and consumer trust, while supporting compliance with regulatory requirements (Omira et al., 2025). Nonetheless, the transition within the cosmetics sector demands more than mere technological readiness. It also requires a skilled workforce capable of integrating technical expertise – including data governance, eco-design standards, life-cycle assessment (LCA) and tox-safety literacy (Alexander-White et al., 2025). Without adequate human capital development, there is a risk that DPPs will be reduced to mere compliance instruments, rather than serving as digital infrastructures capable of driving the twin green and digital transitions. This shift will also necessitate the development of new competence frameworks, combining deep disciplinary knowledge with cross-functional literacy – dimensions that remain largely overlooked in current CE education programmes (Trevisan et al., 2025).

To address these gaps, the present study investigated which types of information are considered strategically critical for DPP deployment in the cosmetics sector, drawing on perspectives from both company experts and consumers. The results offer several contributions to theory and practice, by: (i) identifying key data requirements for DPP

implementation in the cosmetics industry and (ii) outlining competence frameworks for the management of information flows and collaborative infrastructures in support of the twin transition.

2. Literature review

To move beyond a purely technological perspective, this study explored the intersection between digital tools and the human skills required for their effective deployment. The literature review focused on the convergence of DPPs, sustainability, digitalisation and human capital, with the aim of identifying key trends and research gaps to inform a skills- and knowledge-based framework for the twin transition. The review followed the PRISMA protocol (Page et al., 2021), ensuring methodological rigour and transparency (Fig. S1).

A Scopus search using the query "digital product passport" AND "green" AND "digital" AND "human" in ALL FIELDS initially retrieved 95 records. During the screening phase, the following exclusion criteria were applied: non-English documents were removed (E1), as well as publications that were not journal articles or review papers (E2). To further refine conceptual relevance, an additional eligibility filter was introduced by including the terms "skill" OR "knowledge" in the title, abstract or keywords (E3). Following this systematic refinement, 16 studies were retained for a comprehensive full-text analysis.

The refinement process led to the identification of critical skill and knowledge domains for DPP adoption and supported the development of a workforce readiness framework tailored to green-digital transitions. Thematic mapping further highlighted the maturity and relevance of existing research, reinforcing the view of DPPs as not only technological infrastructures but also socio-technical systems requiring targeted human capital development. The thematic map of the 72 studies (including those excluded under E1 and E2) revealed that *circular economy* and *decision-making* represent motor themes, characterised by both high relevance and high development (Fig. S2).

Among the basic themes, *sustainable development* and *life cycle* are foundational within the scientific discourse. In contrast, *smart manufacturing*, *artificial intelligence*, and *life cycle analysis* are niche themes, signalling areas that are still in the process of specialisation but hold significant potential for future development. Focusing specifically on the 16 studies identified using criterion E3, several key insights emerge. The literature underscores that the transition to a CE, enabled by digitalisation, presents considerable opportunities but is also fraught with challenges. One major contribution lies in the identification of barriers hindering this transition: 45 distinct barriers have been catalogued, spanning knowledge management, technological constraints, regulatory complexity and social factors – all of which point to the need for more effective and coordinated public policies (Trevisan et al., 2023). Additional critical issues include the digital divide, high implementation costs and a shortage of relevant skills. These factors necessitate targeted infrastructure investment and the formation of public-private partnerships (Hariyani et al., 2025). In this context, support for small and medium-sized enterprises (SMEs) – through financing mechanisms, digital innovation initiatives and data-sharing protocols – remains crucial to facilitating the uptake of sustainable business models (Akberdina et al., 2023; Awad et al., 2025).

At the same time, digital technologies offer tangible solutions. The Internet of Things (IoT), artificial intelligence (AI) and digital twins contribute to the reduction, reuse and recycling of resources. Augmented reality and human-robot collaboration, moreover, enhance consumer experience by improving decision-making confidence and reuse intention (Jeganathan and Szymkowiak, 2025). These technologies also add value across the circular value chain, generating benefits for individual actors, collaborative partnerships and integrated systems alike (Thakuri et al., 2025). In the construction sector, digitalisation and CE principles also demonstrate potential for enhancing productivity and efficiency, particularly through modular and prefabricated building solutions. Nevertheless, research in this area remains limited (Gutiérrez

et al., 2024; Keena et al., 2025; Nguyen et al., 2025).

A complex picture emerges with respect to consumer behaviour. On the one hand, there is limited familiarity with the DPP concept, yet strong confidence in digital labelling as a tool for transparency. Consumers show a willingness to pay up to 17 % more for certified products, particularly among women, middle-aged adults and high-income individuals (Colasante et al., 2025). On the other hand, emotional ambivalence negatively influences purchase intentions, although clear and verifiable claims can bolster trust even among more sceptical consumers (Tan et al., 2026). Community engagement and a sense of perceived control are also important drivers in encouraging recycling and responsible waste management (Taouahria, 2024).

Finally, regulatory and methodological dimensions are also critical. The adoption of findable, accessible, interoperable and reusable (FAIR) principles, along with the “safe and sustainable by design” paradigm, can enhance interoperability, transparency and trust in data utilisation (Karakoltzidis et al., 2024). Moreover, a hazard-based approach to risk management may enable the integration of circularity with product safety (Börjeson and Ågerstrand, 2025). In summary, the literature shows that a successful twin transition will depend on the systemic integration of technological innovation, supportive policy frameworks and behavioural change.

3. Methodology

The present study adopted a multi-method approach, combining both quantitative and qualitative analytical tools. Within the field of multi-criteria decision analysis (MCDA), several methodological frameworks are available (Ahmed et al., 2024; Soltanifar et al., 2023). Among these, the analytic hierarchy process (AHP) is a hierarchical method used to assign weights to decision criteria (Section 3.1); the technique for order preference by similarity to ideal solution (TOPSIS) is a compensatory method based on proximity to the ideal solution (Section 3.2); and VIKOR (ViseKriterijumska Optimizacija I Kompromisno Resenje) is a compromise ranking method grounded in ideal solution concepts (Section 3.3). The online survey conducted to analyse consumer perspectives is described in Section 3.4.

3.1. The AHP method

An AHP analysis was carried out in two complementary phases, with the objective of developing a decision-making model to identify priority criteria for DPP implementation. In the initial phase, a pairwise comparison was employed, requiring expert respondents to express relative preferences among criteria, thereby avoiding the bias of assuming equal importance across all items. Nine criteria were selected to represent different dimensions of business competitiveness in the context of DPP adoption. These were defined in accordance with the existing literature (D’Adamo et al., 2025) and are presented in Table S1.

- C1 – information on supply chain traceability;
- C2 – descriptive information regarding reductions in consumption and emissions (e.g. water, energy, raw materials, CO₂);
- C3 – information on the treatment of materials with products that are non-harmful to human health and the environment;
- C4 – information concerning social sustainability benefits (e.g., working conditions);
- C5 – information supporting the creation of partnerships for end-of-life (EoL) product management;
- C6 – information promoting the Made in Italy branding;
- C7 – information provided by consumers to improve product sustainability;
- C8 – information on European eco-design certifications and standards; and
- C9 – information on the reuse, repair and recycling of products or their components.

The selection of experts is critically important in the AHP process, as the method relies on subjective judgement rather than purely objective data (Wojnarowska et al., 2021). In the present study, experts were identified through purposive sampling, with invitations sent via email and LinkedIn outlining the study objectives and data collection procedures. In addition, several experts were approached during the Phygital Sustainability Expo® 2025 event, held in Rome on 5–6 June 2025. Two categories of experts were targeted: (i) entrepreneurs and managers with experience in the cosmetics sector and (ii) industry professionals and external consultants specialising in DPP development. Table S2 details the 10 selected experts, who were evenly distributed between the two categories. Convenience sampling was employed, in line with previous research prioritising expert judgement over broad statistical generalisability (Etikan et al., 2015). This approach is also well recognised in qualitative research, particularly in nascent or under-explored fields such as DPP implementation (Govindan and Bouzon, 2018). For inclusion in the study, experts were required to have a minimum of 5 years of professional experience in the relevant sector.

Experts evaluated the selected criteria using a 1–9 scale (Table S3), and the consistency ratio (CR) was calculated to assess the reliability of the pairwise comparisons (Saaty, 2008). The CR, defined as the ratio between the consistency index and the random inconsistency index (Table S4), could not exceed 0.10. This threshold was respected in all individual expert assessments, thereby ensuring the robustness of the analysis. For ease of use, the CR was computed automatically within the Excel worksheets completed by the experts.

3.2. The TOPSIS method

In the second phase of the analysis, the TOPSIS method was applied to verify the robustness of the results obtained via the AHP and to objectively rank the alternatives considered. TOPSIS is an MCDM technique that enables alternatives to be ranked based on their closeness to the positive ideal solution and distance from the negative ideal solution (Tanveer et al., 2023). Unlike the AHP procedure, in which experts conducted pairwise comparisons, the TOPSIS analysis required experts to assign absolute scores on a scale from 1 to 10 for each criterion. These scores were then normalised, with experts clearly informed that the two evaluation methods served distinct analytical purposes.

Normalisation proceeded in accordance with (Hwang and Yoon, 1981), using proportional rescaling – calculated as the ratio of each value to the square root of the sum of the squares in the respective column. This method aims at preserving the original distribution of the data. The alternative receiving the highest score is considered the closest to the ideal solution and, thus, the most preferred. Of note, several studies have successfully employed integrated AHP + TOPSIS approaches (Abdullah et al., 2023; Míguez et al., 2023).

3.3. The VIKOR method

Alongside AHP and TOPSIS, the VIKOR method was also applied (Opricovic and Tzeng, 2004). This technique is well established in the literature as a robust decision-support tool (Mardani et al., 2016). The principal aim of VIKOR is to identify a compromise solution – that is, the option offering the best trade-off between proximity to the ideal solution and attention to the most critical criterion. Similar to the TOPSIS, the VIKOR used the absolute expert ratings from 1 to 10 as input data. Normalisation was carried out using a linear transformation method, facilitating the comparison of criteria expressed in different units of measurement. An aggregation function was then employed to calculate each alternative’s closeness to the ideal solution, factoring in both the assigned criterion weights and a balance between overall satisfaction and individual regret (with the balancing parameter set to 0.5, ensuring equal consideration of these two components). The integration of AHP and VIKOR methodologies is also supported by recent research (Abdul et al., 2022; İc et al., 2022).

3.4. Methodology for the consumer analysis

Surveys represent one of the most established and widely adopted methods in consumer research, due to their capacity to reach large, diverse samples and their flexibility in gathering and managing information (see, e.g. (Colasante et al., 2025; Kolling et al., 2023)). This approach is particularly well suited to examining the adoption of innovative technologies and sustainability-oriented practices. Indeed, prior empirical studies have effectively employed survey-based tools to measure consumers' willingness to pay (WTP) for environmentally friendly solutions, as well as to analyse attitudes towards transparency, the CE and bio-based innovations across various sectors (Fu et al., 2024; Skouloudis et al., 2023), including cosmetics (Kolling et al., 2023; Lee and Chen, 2019). Such methodologies have proven valuable for not only assessing functional product attributes but also capturing intangible dimensions such as perceived corporate ethics and sustainability. In the present study, an online survey was developed to investigate consumers' WTP for cosmetics equipped with a DPP, and to assess the relative importance they attributed to the different types of information embedded within DPPs. The survey instrument was informed by a review of the literature and further refined with input from sector experts. The final version, provided in Appendix B, comprised four main sections: (i) socio-demographic characteristics of respondents; (ii) familiarity with digital tools and cosmetic purchasing habits; (iii) knowledge and perceptions of the DPP; and (iv) economic factors, including the elicitation of a hypothetical WTP.

In line with the literature, the study also sought to examine how socio-demographic factors influence consumer evaluations. Gender, age and income have consistently been identified as key drivers of sustainable consumption, with previous research highlighting systematic differences in environmental awareness, purchasing behaviour and WTP across population segments (Aguilar and Vlosky, 2007; Echavarren, 2023; M. Wiernik et al., 2013).

The survey was administered via Google Forms in March 2025 and disseminated through both digital channels and direct contacts. A total of 405 completed questionnaires were collected from individuals residing in Italy. The survey included a combination of open-ended questions, multiple-choice items and 10-point rating scales, allowing for a nuanced assessment of consumer preferences. Descriptive statistics were first calculated to summarise the distribution of responses. Subsequently, non-parametric statistical tests were employed to assess differences across groups. Specifically, the Mann–Whitney *U* test was used to draw comparisons between two groups; the Kruskal–Wallis test was applied when comparing three or more groups; and the Friedman test was used to analyse repeated measures.

4. Results – producer analysis

The producer analysis outlines the contribution of each expert's assessment to the calculation of the AHP (Section 4.1) and its subsequent aggregation (Section 4.2). Section 4.3 then presents the combined results derived from the application of the AHP, TOPSIS and VIKOR methods.

4.1. AHP analysis results

The first step in the analysis involved collecting the pairwise comparisons made by the 10 experts for the nine selected criteria. Each expert completed an assessment matrix comprising 36 pairwise comparisons, which were necessary to evaluate all possible combinations of the criteria. The reliability of the data was supported by the CR, which remained below 0.10 in all cases (Fig. S3). The data presented below do not necessarily follow the order of experts listed in Table S1. Table S5–S14 display the individual contributions, while Table 1 summarises all responses, highlighting the maximum values in red and the minimum values in green for each expert. For instance, expert E1 assigned the highest importance to C1 (0.22) and the lowest to C7 (0.04), while E2 considered C6 most important (0.29) and C5 least important (0.04).

Fig. 1 presents a box plot illustrating the variability in the experts' assessments of C1–C9, revealing a degree of heterogeneity in both the median values and the dispersion of judgements. Notably, C1 exhibited the highest mean and median values among all criteria, accompanied by a relatively wide dispersion. By contrast, C4 and C7 occupied the lowest

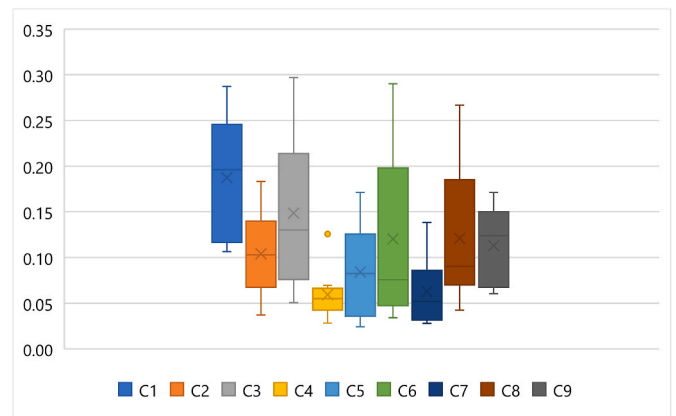


Fig. 1. Distribution of criterion ratings according to experts.

Table 1
Results of the pairwise comparisons made by experts.

| | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 |
|----|------|------|------|------|------|------|------|------|------|------|
| C1 | 0.22 | 0.13 | 0.17 | 0.23 | 0.26 | 0.24 | 0.11 | 0.12 | 0.11 | 0.29 |
| C2 | 0.12 | 0.07 | 0.06 | 0.14 | 0.10 | 0.14 | 0.04 | 0.18 | 0.11 | 0.08 |
| C3 | 0.12 | 0.20 | 0.11 | 0.14 | 0.17 | 0.08 | 0.06 | 0.30 | 0.26 | 0.05 |
| C4 | 0.07 | 0.07 | 0.06 | 0.05 | 0.04 | 0.05 | 0.06 | 0.04 | 0.03 | 0.13 |
| C5 | 0.07 | 0.04 | 0.04 | 0.03 | 0.10 | 0.14 | 0.11 | 0.12 | 0.17 | 0.02 |
| C6 | 0.12 | 0.29 | 0.17 | 0.05 | 0.04 | 0.08 | 0.28 | 0.07 | 0.07 | 0.03 |
| C7 | 0.04 | 0.07 | 0.06 | 0.14 | 0.03 | 0.03 | 0.11 | 0.03 | 0.04 | 0.08 |
| C8 | 0.12 | 0.07 | 0.27 | 0.08 | 0.10 | 0.08 | 0.18 | 0.07 | 0.04 | 0.20 |
| C9 | 0.12 | 0.07 | 0.06 | 0.14 | 0.17 | 0.14 | 0.06 | 0.07 | 0.17 | 0.13 |

positions, with more compact distributions, suggesting a perception of lower relative importance. Of note, C6 and C3 displayed the greatest variability (0.095 and 0.083, respectively). While Tukey's boxplot is often useful for detecting outliers, with small samples ($N < 10$), its indications should be treated cautiously (Dawson, 2011).

4.2. Aggregated AHP results

Once the individual assessments were collected, the experts' judgements were aggregated. At this stage, each expert was assigned equal weighting, with weights distributed uniformly. To explore potential differences in perception among the expert sample, the aggregated data were further disaggregated by stakeholder type. A distinction was therefore made between two groups (Table S15): internal company professionals and external consultants specialising in DPP development.

The analysis revealed some notable differences in the partial rankings, alongside elements of convergence between the two groups. The criterion receiving the highest ratings from both consultants and professionals was C1, with values of 0.20 and 0.17, respectively. As a result, C1 also ranked first in the overall ranking, with a value of 0.19. Second place was likewise shared by both groups, who assigned this position to C3, with a value of 0.15.

C8 ranked third in the overall ranking, with a value of 0.12, despite being rated lower by both consultants and professionals, who placed it fourth with values of 0.13 and 0.11, respectively. In fourth place overall was C6 (also with a value of 0.12), although it was perceived differently by the two stakeholder groups: consultants ranked it third (0.13), while professionals placed it seventh (0.11). C9 (0.11) occupied a mid-ranking position overall. This result aligned with the assessments made by company representatives, but not with those of professionals, who placed it third, indicating higher perceived importance.

Regarding the lowest positions in the overall ranking, although there were observable differences between the assessments of the two groups, these were not pronounced. This suggests a generally low level of importance attributed to these criteria. In descending order, the criteria ranked from sixth to ninth place were: C2 (0.10), C5 (0.08), C7 (0.06) and C4 (0.06).

Overall, C1, C3 and C8 emerged as the most significant, accounting for the largest share of the overall weight and reflecting a common understanding between the two stakeholder groups regarding key priorities. C4 and C7 were distinguished by their limited influence, attributable not only to their lower weightings but also the inconsistency in evaluations between the two groups. This disparity underscores a clear divide between the core criteria and those perceived as peripheral within the decision-making process.

4.3. Results of the AHP, TOPSIS and VIKOR

Finally, a combined analysis of the three methods (AHP, TOPSIS and VIKOR) was conducted to compare the rankings and evaluate their overall consistency. The findings indicated a good degree of convergence among the approaches, with only limited discrepancies, primarily reflecting the distinct methodological logics underpinning each technique. As noted in Section 3, the experts were also asked to evaluate the criteria using a 1–10 scale (Table S16). The results of the TOPSIS and VIKOR methods are presented in Fig. 2 (Table S17), where they are also compared with those derived from the AHP.

The criteria rankings were largely consistent – and in some cases identical – across the three methods. In particular, C1, C3 and C5 occupied the same positions in all three rankings, and only minor differences emerged for the remaining criteria. For instance, C2 ranked sixth in both the AHP and VIKOR, while it rose slightly to fifth place in the TOPSIS. A discrepancy was also observed for C4 and C7: in the AHP, they occupied the ninth and eighth positions, respectively, whereas in the other two methods, these positions were reversed (eighth for C4, ninth for C7). A further difference arose with C8 and C9: in the AHP,

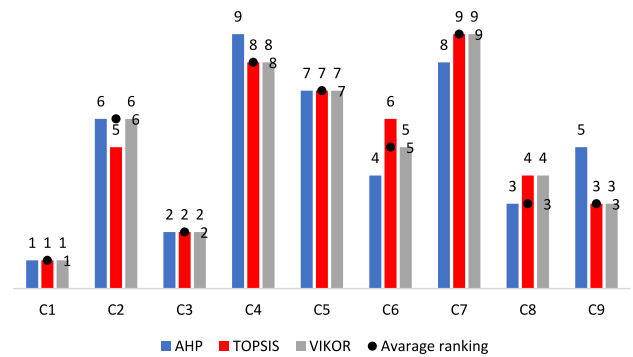


Fig. 2. Ranking of AHP, TOPSIS and VIKOR criteria.

they were ranked third and fifth, respectively, while in both the TOPSIS and VIKOR, C8 ranked fourth and C9 third. The greatest divergence was observed for C6, which ranked fourth in the AHP, sixth in the TOPSIS and fifth in the VIKOR. Nonetheless, the analysis of average ranking values confirmed the overall trend, evidencing a strong degree of consistency among the three methods, with only a few specific deviations. Correlation values between the rankings exceeded 0.9, which is notably high and further supports the robustness of the findings and the effectiveness of the cross-method analysis (Table S18). Appendix A presents a qualitative analysis developed from insights gathered during interviews with the experts.

5. Results of the consumer analysis

The survey collected a total of 405 valid responses from Italian consumers. The first section revealed that the sample was predominantly female (63.95 %), consistent with the literature. Previous research (D'Adamo et al., 2023) has attributed this trend to the greater attention women typically devote to the cosmetics sector. The average age of respondents was 38 years, with the following age distribution: 18–24 (38.3 %), 25–50 (29.4 %) and over 50 (32.3 %). In terms of income, the majority of respondents fell below the 40,000 € threshold: 49.6 % earned less than 20,000 €; 33.3 % earned 20,000–40,000 €; 9.9 % earned 40,000–60,000 €; and 7.2 % earned more than 60,000 €.

5.1. Familiarity with digital tools and cosmetic purchasing habits

The second section showed that familiarity with QR codes and digital devices yielded an average score of 7.62, with a gradual decline observed across age groups: 8.34 for the 18–24 cohort, compared to 6.62 for those over 50 (Kruskal–Wallis test: $\chi^2(2) = 43.34, p < 0.001$). Gender differences were statistically significant (Mann–Whitney $p < 0.001$), with an average score of 7.44 for women and 7.99 for men (Fig. S4).

Interest in cosmetic trends recorded an overall average of 5.31, with younger respondents scoring higher (5.78) than those over 50 (4.69) (Kruskal–Wallis test: $\chi^2(2) = 10.45, p = 0.005$). Women demonstrated significantly higher interest (6.54) than men (3.11), with a Mann–Whitney p value of 0 (Fig. S5).

The frequency of cosmetic product purchases yielded an average score of 4.6 (Fig. S6), with no significant variation across age groups (Kruskal–Wallis test: $\chi^2(2) = 0.57, p = 0.753$). However, gender differences were substantial: women reported a higher purchasing frequency (5.72) than men (2.60), with $p < 0.001$ (Mann–Whitney). Analysis by income bracket revealed no significant differences (Fig. S7; Kruskal–Wallis test: $\chi^2(3) = 0.72, p = 0.869$). The correlation matrix indicated a strong positive relationship (0.78) between interest in cosmetic trends and purchasing frequency (Table S19).

Participants were subsequently asked to identify the factors they considered most relevant when selecting a cosmetic product. The

analysis revealed that the economic factor of price (5.80) played a central role, followed by the types of raw materials used (5.39) and the attributes of durability and availability (5.19) – both of which were deemed more important than the environmental impact (4.67). Aesthetic aspects (4.85) also received comparatively less attention. These findings suggest that, although consumers may not directly prioritise environmental impact in their purchasing decisions, they do attach value to related aspects, such as the raw materials involved. This may be attributed to the difficulty of interpreting environmental impact in concrete, actionable terms – particularly in the absence of clear information provided by companies. Price sensitivity was most pronounced among younger consumers (18–24), who assigned the highest average importance to this factor (6.41) – likely reflecting economic constraints associated with lower or unstable income levels. Among those aged 25–50, price was a key consideration, although attention to raw materials increased (5.92 vs. 5.71). Interestingly, the over-50 group placed greater emphasis on raw materials than the 25–50 group (5.22 vs. 4.95; Fig. 3), suggesting a more informed and mature outlook, possibly shaped by a more established socio-economic status and family-related responsibilities. Likewise, the high importance attributed to price across age groups points to a broader concern with saving and prudent resource management. Statistical analysis using the Friedman test confirmed the presence of significant differences in purchasing priorities across age groups: 18–24 years ($\chi^2(6) = 114.35, p < 0.001$), 25–50 years ($\chi^2(6) = 62.43, p < 0.001$), and over 50 years ($\chi^2(6) = 78.07, p < 0.001$). A significant difference was also observed by gender (both $p < 0.001$; Fig. S8).

The questionnaire evaluated the perceived relevance of digital labels in the cosmetics sector, yielding an average score of 7.11. This suggests a considerable level of interest in tools facilitating more informed consumer choices (Fig. S9). By age group, respondents aged 25–50 assigned the highest score (7.25), followed by those aged 18–24 (7.19) and individuals aged 50 and above (6.88). However, no statistically significant differences emerged (Kruskal–Wallis test: $\chi^2(2) = 1.57, p = 0.456$). In terms of gender, women expressed stronger support (mean score: 7.29) than men (6.80) – a difference confirmed by the Mann–Whitney test ($p = 0.042$).

Nonetheless, the high level of importance attributed to digital labels did not necessarily reflect a corresponding depth of knowledge. Indeed, considerable heterogeneity emerged in awareness of the DPP, both across age groups and between genders. As shown in Fig. 4, awareness was highest among younger respondents (18–24: 25.81%), decreased slightly among those aged 25–50 (22.69%) and was lowest among respondents aged 50 and above (18.32%). This trend mirrors the age gradient observed in digital familiarity. From a gender perspective, men

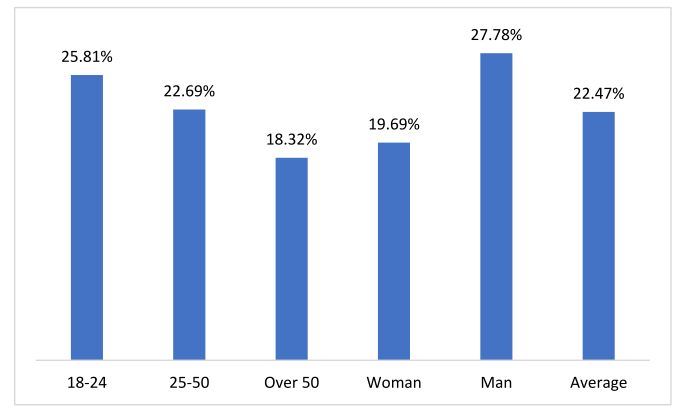


Fig. 4. Respondents who had heard of the DPP, by gender and age.

demonstrated substantially greater awareness (27.78%) compared to women (19.69%). These findings indicate that, although overall awareness of the DPP remains limited, it is more prevalent among groups with higher exposure to digital tools and information channels. This pattern aligns with earlier results from the dataset – namely, higher QR code familiarity among younger respondents and relatively modest gender differences in digital use – and suggests that outreach initiatives concerning DPPs should be tailored to specific demographic groups. Specifically, older consumers may require more targeted engagement, and communication strategies should extend beyond QR-based formats to address informational gaps more inclusively. The discrepancy between high interest and limited knowledge may be explained by an intuitive appreciation of the potential benefits. Even without direct familiarity, consumers appear to recognise the value of such tools, demonstrating a readiness to embrace innovative solutions that support more informed and responsible consumption. An additional analysis explored the correlation between age, familiarity with QR codes and digital devices, as well as the increased confidence associated with the use of digital labels. This analysis revealed no statistically significant relationships (Table S20).

5.2. Knowledge and perceptions of the DPP

The third section of the questionnaire, following a brief definition of the DPP, explored consumers’ willingness to purchase cosmetic products from companies adopting this tool. Fig. S10 illustrates the increase in purchase intention in the presence of a DPP, with the average score reaching 7.78 out of 10 – a strong indicator of the perceived value of transparency in cosmetic products. Notable differences emerged across age groups: respondents aged 25–50 reported the highest average score (7.97), followed by those over 50 (7.73), while the youngest cohort (18–24) assigned a slightly lower score (7.69). A similar pattern was observed by gender, with women demonstrating a marginally greater willingness to increase their purchases (7.86) compared to men (7.69). However, in neither case was the difference statistically significant (Kruskal–Wallis test: $\chi^2(2) = 0.74, p = 0.689$; Mann–Whitney $p = 0.6522$). Consumers appeared to view the DPP as not merely a technical instrument, but also a vehicle for ethical and relational value – enhancing brand trust and supporting more responsible purchasing behaviours.

A second key finding, presented in Fig. 5, concerns the varying importance attributed to different types of information provided within the DPP across age groups. Overall, the most highly valued information related to raw materials (6.56) and certifications (6.39). These results indicate a growing consumer interest in the composition and provenance of cosmetic ingredients, viewed as central markers of product quality and sustainability, alongside a broader awareness of ethical business practices. Conversely, information on logistics and transport

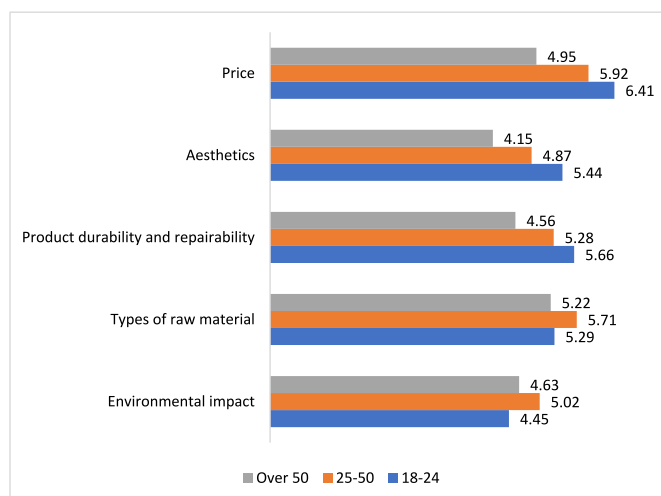


Fig. 3. Factors considered at the time of purchase, based on age.

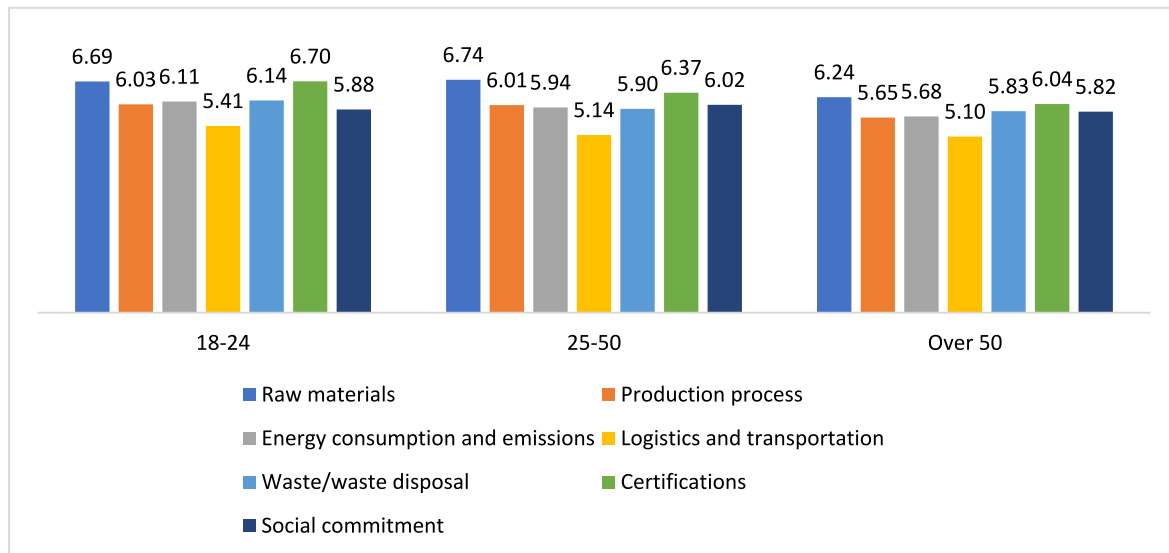


Fig. 5. Importance of information on DPP, by age.

received the lowest score (5.23). Other dimensions – including waste management (5.97), energy consumption and emissions (5.92), and the production process and social commitment (5.90) – occupied intermediate positions.

Younger consumers (18–24) assigned systematically higher values across nearly all categories, particularly for raw materials (6.69) and certifications (6.70), reflecting greater exposure to environmental issues and digital information channels. The 25–50 age group placed similar emphasis on raw materials (6.74), while also showing heightened appreciation for social commitment (6.02), likely influenced by family and professional responsibilities reinforcing ethical awareness. In contrast, respondents aged over 50 consistently reported lower scores, suggesting less interest in transparency-related aspects of the DPP – possibly due to lower digital engagement and a more traditional, product-oriented perspective on consumption. Finally, with regard to gender (Fig. S11), both men and women identified raw materials as the most relevant information to be included in the DPP. Interestingly, men attributed a higher average level of importance to this criterion than women (6.79 versus 6.43). To assess the significance of these differences, a Friedman test was conducted across both gender and age groups, revealing statistically significant differences in all cases ($p < 0.001$; Table S21).

Another aspect explored was consumers' willingness to provide feedback on purchased products – through evaluation questionnaires, online reviews or dedicated platforms – to help improve the information contained in DPPs. The overall average score was 6.22, indicating a moderate level of interest in participating in such processes. In generational terms (Fig. S12), younger respondents reported a higher willingness (6.40) compared to older individuals (6.02), likely attributable to the younger cohort's greater familiarity with digital feedback platforms. However, the Kruskal–Wallis test revealed no statistically significant differences ($\chi^2(2) = 1, p = 0.605$). By gender, women expressed a significantly higher willingness to provide feedback (mean score: 6.63) than men (5.50), and this result was confirmed by the Mann–Whitney test ($p < 0.001$). Analysis by income level (Fig. S13) indicated that individuals with lower incomes were more inclined to provide feedback, possibly perceiving this as an accessible and non-monetary means of promoting transparency and contributing to business improvement (Kruskal–Wallis test: $\chi^2(3) = 10.16, p = 0.017$).

Finally, QR codes emerged as the preferred method for accessing information contained in DPPs, selected by 65.2 % of respondents – likely due to their convenience and immediacy (Fig. S14). However, use of QR codes declined with age: 71 % of those aged 18–24 and 68.9 % of

those aged 25–50 reported using this tool, compared to just 55 % among the over-50 group, who displayed a stronger preference for traditional paper labels. With regard to gender (Fig. S15), both men and women showed a clear preference for QR codes, although the rate was higher among men (71.5 %) than women (62.2 %), suggesting a potential gender gap in digital literacy.

5.3. Economic aspects and WTP

The fourth section of the questionnaire demonstrated that the introduction of a DPP is likely to elicit a clear premium effect in consumers' WTP across all socio-demographic groups. On average, respondents were willing to pay 24.58 € for the baseline product without a DPP and 30.63 € for the same product with a DPP – representing an approximate increase of +24.6 % (Fig. 6). This finding reinforces the perception of the DPP as not merely a technical feature, but also a value-added attribute associated with transparency, trustworthiness and corporate responsibility. Notable differences emerged across demographic groups. First, women displayed a greater WTP premium than men (+27.8 % vs +18.7 %), consistent with prior evidence indicating heightened female sensitivity to environmental and ethical considerations. Second, older consumers (50+) reported the highest absolute WTP (35.98 € with DPP), although their relative premium was more modest (+17.8 %). In contrast, younger consumers (18–24) exhibited the largest proportional increase (+32.8 %), reflecting both a heightened responsiveness to sustainability claims and a lower baseline valuation. Income also played a role. While WTP increased with income, the strongest relative premiums were observed at both extremes of the income distribution: among those earning $\leq 20,000$ € (+30.2 %) and those earning $\geq 60,000$ € (+30.1 %). For lower-income consumers, a DPP may enhance the perceived value of the product beyond its monetary cost, whereas higher-income individuals may interpret the DPP as a credible certification worth a premium. Taken together, these findings suggest that DPPs may allow firms to command measurable sustainability premiums. For cosmetics manufacturers, this implies that investment in transparency tools such as DPPs may yield tangible benefits in terms of consumer valuation, albeit with differentiated impacts across gender, age and income segments. Statistical differences across all groups were confirmed (Table S22).

To complement the analysis of consumer preferences, Fig. 7 and S16 compare consumer choices across three purchasing scenarios: a standard product (P1), the same product with a DPP (P2), and the DPP product combined with a charitable donation (P3). Across all age and income

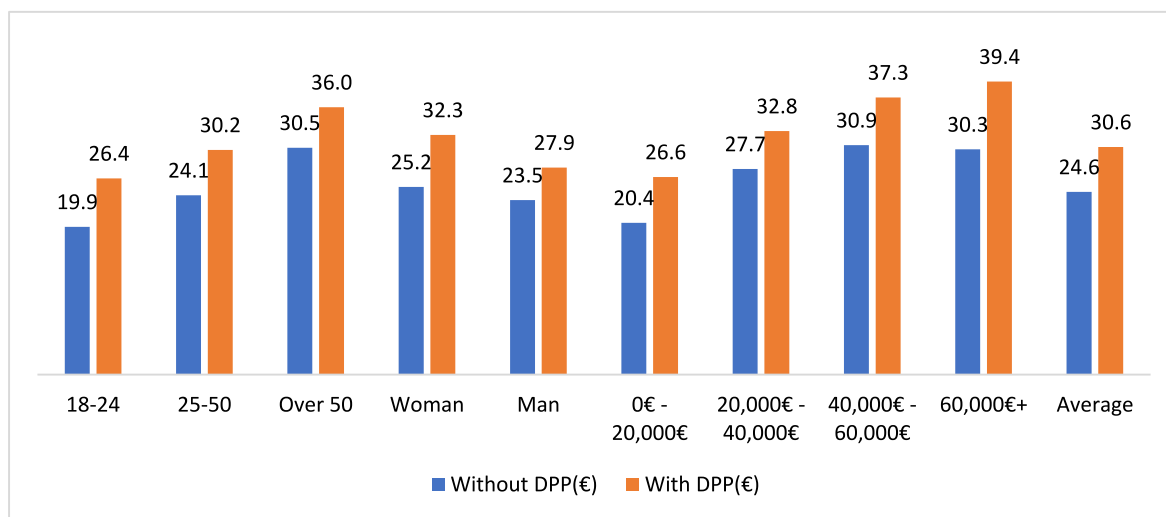


Fig. 6. WTP for a product with or without DPP, by gender, age and income.

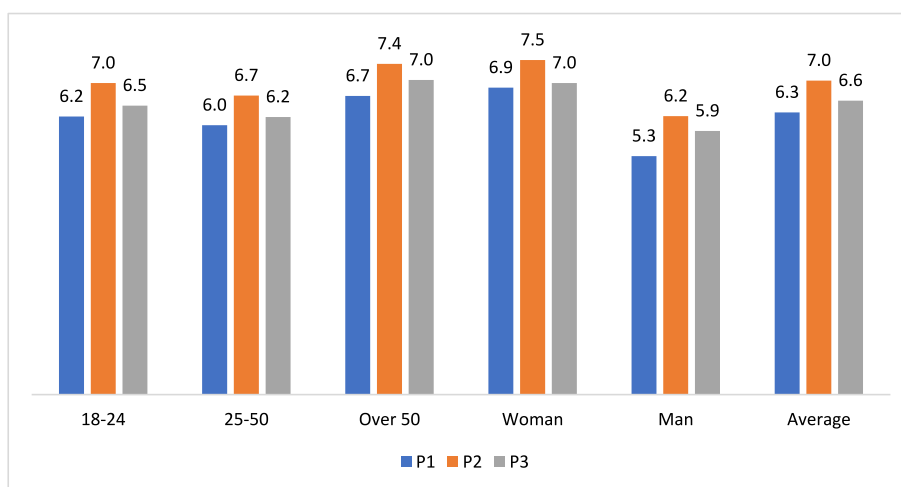


Fig. 7. Choice of product without DPP, with DPP, and with DPP plus donation, by age and gender.

groups, P2 consistently emerged as the most preferred option, confirming that the transparency and traceability afforded by the DPP are the primary drivers of consumer value. Older consumers (50+) showed a slightly greater inclination towards P3, suggesting that social responsibility initiatives may resonate more strongly with this group. Finally, income effects were relatively modest: lower- and middle-income consumers expressed a clear preference for P2, whereas higher-income respondents demonstrated a more balanced interest in both P2 and P3. Statistical tests confirmed significant differences in most cases (Table S23).

To enhance the robustness of the consumer analysis and assess the statistical persistence of a “DPP premium” across different consumer groups, two separate multivariate OLS regression models were estimated. In the first specification, the dependent variable was purchase intention for the baseline cosmetic product (without DPP), while the main explanatory variable was purchase intention for the same product with DPP. This enabled us to test whether the higher propensity to purchase that was observed in the descriptive analysis remained statistically significant after controlling for individual characteristics. The set of control variables included consumer habits – specifically, the frequency of cosmetic purchases and the importance of trend-following behaviour – as well as socio-demographic factors such as income level, age and gender. The second model focused on economic valuation, using

WTP for the baseline product without DPP as the dependent variable and WTP for the same product with DPP as the main regressor. The same control variables used in the previous model were retained. This specification allowed us to determine whether the presence of the DPP continued to exert a positive and statistically significant influence on consumers’ valuation, even when accounting for individual differences in income, gender and purchasing behaviour. The OLS regression estimates are presented in Table 2.

According to the regression estimates presented in column (1) of Table 2, purchase intention for the product with a DPP was significantly higher than for the baseline cosmetic product, *ceteris paribus*, confirming that the introduction of the DPP positively influenced consumers’ purchasing propensity. Furthermore, column (2) shows a consistent – and even stronger – result in relation to WTP: the presence of a DPP was associated with a significantly higher WTP, with statistical significance at the 1 % level. The effect of the control variables was consistent across both specifications. The variable *trend-following behaviour*, capturing interest in fashion and trends, exhibited a positive and statistically significant association with both purchase intention (at the 10 % level) and WTP. This suggests that consumers who are more attentive to market trends may be more likely to value the DPP attribute. Among socio-demographic factors, age and gender emerged as the primary predictors of variation in WTP. Older consumers and men displayed a

Table 2
Regression (OLS) results for purchase intention and WTP as dependent variables in columns 1 and 2, respectively.

| | (1) | (2) |
|-------------------------------|-----------------------------------|----------------------|
| | Purchase Intention Without DPP | WTP Without DPP |
| Purchase intention with DPP | 0.774*** (0.039) | |
| WTP with DPP | | 0.799*** (0.038) |
| Trend-following behaviour | 0.118** (0.060) | 0.500* (0.261) |
| Cosmetic purchasing frequency | -0.081 (0.063) | -0.364 (0.325) |
| Gender (Male) | 0.351* (0.196) | 2.849*** (1.057) |
| Age | 0.007 (0.005) | 0.099*** (0.034) |
| Income (20,000–40,000€) | -0.034 (0.189) | 0.888 (1.010) |
| Income (40,000–60,000€) | -0.162 (0.272) | 0.071 (1.441) |
| Income (>60,000€) | -0.563* (0.302) | -1.464 (2.251) |
| Constant | 0.528 (0.355) | -5.887*** (2.144) |
| Observations | 405 | 405 |
| R-squared | 0.644 | 0.799 |

Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

higher valuation for the cosmetic product without DPP, whereas income did not show statistically significant effects in either model.

6. Discussion

Technologies such as ICT (Balsalobre-Lorente et al., 2025), green technologies (Ikram et al., 2021; Ikram and Sadki, 2024), additive manufacturing (Fernández-Miguel et al., 2024a) and assessment tools including carbon accounting (Di Vaio et al., 2024) and LCA (Settembre Blundo et al., 2014), alongside knowledge management systems (Sassanelli et al., 2021), are fundamental levers for advancing sustainability. However, their effectiveness is contingent upon the capacity of organisations and workers to deploy them strategically. Recent studies on Industry 5.0 (Carminati et al., 2025) and the circular economy (Wu, 2025) have highlighted the importance of human capital – particularly digital, ecological and collaborative competencies – as the critical enabler allowing businesses and economic systems to enhance resilience, transparency and competitiveness. Accordingly, the sustainable transition is not merely a technological endeavour but, above all, skills-based, grounded in integrated knowledge and the capacity for continuous learning.

The results of this study offer valuable insights into the application of the DPP within the cosmetics sector, revealing both alignments with and departures from the existing literature. Previous research has stressed that the digital and sustainable transition necessitates not only technological instruments but also organisational and human capabilities (Hofmann Trevisan et al., 2024; Salter et al., 2009). The present findings also confirm the potential of DPPs to foster transparency, support circular practices and ensure regulatory compliance (Carvalho et al., 2025; Wicaksono et al., 2025). Moreover, the evidence extends these claims to a sector distinguished by complex product formulations, rigorous regulatory frameworks and globalised supply chains (D'Adamo et al., 2024; Mondello et al., 2024).

Relative to previous analyses (D'Adamo et al., 2025), in which greater emphasis was placed on reuse, repair, recycling and the “Made in Italy” branding, cosmetics sector experts in the present study attributed

greater importance to supply chain traceability and the management of potentially harmful materials. These findings reinforce the role of the DPP as a strategic lever within the CE, supporting supply chain transparency, mitigating the risks of overproduction and enhancing operational efficiency (Zhang and Seuring, 2024). The integration of AHP, TOPSIS and VIKOR methodologies revealed a high level of convergence among experts, with only slight variations between professionals and consultants. Additionally, the qualitative analysis underscored the central role of transparency as a core value of the DPP (Awad et al., 2025), positioning it as both a competitive advantage for companies and a mechanism for fostering customer loyalty. Nonetheless, widespread implementation is currently constrained by regulatory and organisational barriers. Overcoming these challenges requires the development of clear guidelines, standardised frameworks and alignment between corporate practices and public claims, along with the integration of automated processes to avoid cost increases deemed unacceptable to consumers.

This final point underscores that sustainability is exerting an increasing influence on purchasing decisions, although price remains the primary consideration (Wan and Jiang, 2025). Compared to previous research, the present study revealed a notable shift in consumer attention towards environmental concerns over secondary attributes such as aesthetics (Colasante et al., 2025), reflecting a rising awareness shaped by the broader diffusion of information. However, the challenge of translating such values into concrete consumer behaviour persists. Importantly, limited awareness of the DPP did not appear to diminish consumer interest; rather, it was perceived as a valuable tool for promoting transparency and informed decision-making – a perception that also corresponded with increased WTP.

Despite the robustness of the empirical findings – supported by the multivariate regression analysis of purchase intentions and WTP – the study relied on hypothetical WTP measures that may be subject to hypothetical bias, as respondents often overstate their WTP in non-incentivised settings (for a methodological discussion, see (Cascavilla et al., 2025a)). Furthermore, the analysis may have been influenced by the well-documented intention-behaviour gap, whereby stated purchase intentions do not necessarily translate into actual market behaviour. Various analyses point to the presence of a circular premium for sustainable products. Subsidies help activate this premium by boosting consumer preference for circular options, whereas carbon taxes show only a limited effect (Cascavilla et al., 2025b).

The results showed that familiarity with digital tools declined with age and varied by gender, shaping consumers' awareness of the DPP. Nevertheless, interest in transparency was strong across all groups, particularly regarding raw materials and certifications. The DPP significantly enhanced purchase intentions across demographic segments, functioning as both a technical and ethical driver of trust. Women and lower-income consumers showed greater willingness to purchase and to provide feedback, offering strategic insights for targeted marketing interventions. Interestingly, the data did not confirm a direct correlation between sustainability preferences and altruistic values (Colasante et al., 2025). In the choice experiment, the DPP emerged as the decisive factor over the donation option, which was less preferred across all groups analysed.

From a managerial perspective, the positive relationship observed between digital literacy and WTP suggests that the “DPP premium effect” may be mediated by consumers' proficiency in using digital tools. Accordingly, managerial strategies should focus on not only promoting DPP adoption but also fostering a broader culture of digital competence and sustainability awareness among consumers. Companies might integrate DPP-related training into marketing campaigns, loyalty programmes or personalised mobile applications – establishing a participatory model in which consumers actively contribute to value creation through feedback and data sharing.

Based on the study findings, cosmetics companies should implement DPPs not only as tools for regulatory compliance, but also as strategic

resources for brand differentiation and customer engagement. The results reveal a structural asymmetry between consumers' high interest in transparency and their limited awareness of DPPs – a gap with significant implications for both sustainability outcomes and market competitiveness. This divergence suggests that, although DPPs are acknowledged as valuable instruments for promoting responsible consumption, their strategic potential will remain largely underexploited unless companies proactively invest in closing the information gap between technical data and consumer understanding. Thus, the effectiveness of DPPs in the cosmetics sector appears to rely on the integration of digital technologies with domain-specific expertise, such as data governance, eco-design and toxicological safety (Alexander-White et al., 2025; Trevisan et al., 2025).

To address the information and engagement gap, cosmetics companies should adopt multi-level communication strategies. A first strategy could be to integrate digital traceability tools with accessible, consumer-friendly interfaces that translate complex lifecycle data (e.g., emissions, sourcing, recyclability) into simplified narratives and visual cues aligned with consumer values. Second, hybrid labelling systems – combining physical and digital touchpoints – could be employed to improve inclusivity for consumers with lower digital literacy, and particularly older demographics who may be less familiar with QR codes and digital labels. Furthermore, companies should consider educational initiatives framing DPPs as part of a broader sustainability discourse with end users. Collaborations with certification bodies, NGOs or eco-label consortia may further enhance credibility and help companies align DPP communications with established sustainability standards.

In the present study, benefits related to social sustainability were assigned relatively low importance, reflecting its limited perceived relevance at this early stage of DPP implementation. This finding may be interpreted in light of the current regulatory and technological orientation of DPP initiatives, which prioritise traceability, compliance and the integration of environmental data to address urgent transparency and circularity demands. As DPPs are still primarily designed to operationalise material flows and product information within supply chains, social indicators (e.g., labour conditions, ethical sourcing, community impacts) remain insufficiently standardised and challenging to encode into interoperable digital formats. As a result, experts may view these social dimensions as long-term objectives to be incorporated once the digital and environmental foundations of DPPs are more firmly established.

From a managerial perspective, the findings suggest a strategic opportunity for companies to gradually expand the functional scope of DPPs to include social impact indicators alongside environmental and economic data. Organisations should begin developing integrated sustainability dashboards within DPP systems, enabling stakeholders to visualise not only environmental footprints but also metrics such as fair labour practices, supplier diversity and contributions to local communities. Embedding these functionalities within DPP traceability platforms would allow companies to better respond to rising consumer demand for products demonstrating credible and comprehensive sustainability value.

7. Conclusions

The present study has provided original empirical evidence on the application of DPPs in the cosmetics industry, advancing both theoretical understanding and managerial practice within the broader discourse on the twin green and digital transitions. Integrating MCDA techniques such as AHP, TOPSIS and VIKOR, the research has introduced a methodological framework for prioritising sustainability information and aligning it with sector-specific operational and consumer dynamics. The findings indicate that DPPs can function as critical enablers of transparency, traceability and circular value creation – key dimensions of SDG 12 – when complemented by appropriate organisational and human capabilities. From a managerial perspective, the results highlight

the urgency of addressing persistent information and digital literacy gaps constraining the full potential of DPP implementation. Although both manufacturers and consumers value transparency and traceability, varying levels of familiarity with and readiness to use digital devices necessitate targeted strategies tailored to consumer-specific segments. Companies are encouraged to adopt DPPs as hybrid technological and relational infrastructures translating complex sustainability data into accessible and engaging communication formats, thereby fostering consumer trust and securing competitive advantage. Inclusive communication strategies and participatory feedback systems may help bridge digital divides – particularly across different generations – and expand the sustainability premium effect among diverse demographic groups.

The cosmetics industry occupies a strategic position at the intersection of health, beauty and ethical consumption, where brand credibility and consumer trust are decisive purchasing drivers. Firms in this sector can transform DPPs from compliance tools into trust-building mechanisms, enhancing perceived product value and increasing consumers' WTP when transparency is communicated clearly and verifiably. This is particularly relevant in the cosmetics sector, where consumer perceptions are intertwined with ethical, aesthetic and safety concerns. In this context, DPPs represent a strategic tool capable of reshaping circular value creation across the entire product life cycle while accelerating the transition towards digitally empowered, responsible production and consumption systems.

The study is not without limitations, as the findings may vary depending on the consumer sample, geographical scope and expert panel consulted. Future research should therefore aim to broaden the scope of analysis by involving a wider panel of experts to refine the identified priorities across multiple industrial sectors. Additional studies could also validate these findings through field experiments and longitudinal analyses aimed at quantifying the extent of the “DPP premium effect” across consumer segments. On the consumer side, qualitative investigations involving participants from different generations and with varying levels of digital literacy are needed to co-design assisted access workflows that enhance usability and inclusiveness. Complementary behavioural experiments could also examine the effects of information framing, trust cues and participatory feedback mechanisms (e.g., consumer reviews contributing to DPP data completeness) on perceived credibility and purchase intention. Finally, from a corporate perspective, future research should conduct firm-level cost–benefit and life-cycle analyses to evaluate the economic feasibility and environmental returns of DPP implementation across different business models.

The effective exploitation of DPPs requires the development of organisational and digital capabilities throughout the supply chain, bridging literacy gaps and fostering new human competencies essential for supporting the twin green and digital transitions.

CRedit authorship contribution statement

Alessandro Cascavilla: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Idiano D'Adamo:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Chiara Grosso:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Cecilia Trusiani:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2025.128281>.

Data availability

Data will be made available on request.

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