



Sustainable
Manufacturing and
Environmental
Pollution
Programme

VISIBLE VALUE CHAINS

Traceability as a tool for sustainable trade and
inclusive industrial transformation

ACTIONABLE INSIGHTS FROM PLASTICS,
LEAD-ACID BATTERIES, TEXTILES & APPAREL, AND LEATHER



June 2026

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This study was produced as part of the Sustainable Manufacturing and Environmental Pollution (SMEP) Programme. The work was coordinated by Dr. Henrique Pacini, Economic Affairs Officer and SMEP Programme Lead under the supervision of Dr. Chantal Line Carpentier, Head of Trade, Environment, Climate Change and Sustainable Development at UN Trade and Development (UNCTAD). The research and drafting team comprised Lorenzo Formenti (UNCTAD) as lead writer, with Elzette Henshilwood (SouthSouthNorth) and Mahesh Sugathan (UNCTAD) as co-writers. The study was informed by an expert working group of practitioners and academics. In particular, the team is grateful to the following experts for their substantive contributions to the sectoral case studies in Chapter 3: Dr. Ebenezer Laryea (Aston University) and Deborah Taylor (Sustainable Leather Foundation) for the leather sector; Atiq Zaman and Benjamin Gazeau (Curtin University) for the plastics sector; Sayed Jobaer Hasan (ARCED Foundation) for the batteries sector; and Jonas Larsson (University of Borås) for the textiles and apparel sector. The research team further acknowledges the valuable inputs provided through key informant interviews and the peer-review process by: Maria Durleva (UNCTAD), Glen Wilson (UNCTAD), Amanda Dinan (SouthSouthNorth), Paulo Mortara Batistic (UNCTAD), Matthias Altmann (UNECE), Mihaela Gaglioti-Verlan (Copenhagen Business School & University of Chinese Academy of Sciences), Adeel Younas (WWF Pakistan), Mizanur Rahman (SERA Bangladesh), Soroush Abolfathi (University of Warwick), Erica Plambeck (Stanford University), Nin Castle (Reverse Resources), Emma Fredman Garrote (Independent Consultant), and Bilal Tufail Bhatti (Outso Wearables AB and PaperTale Technologies). Data and information were also gathered from the diverse ecosystem of startups, manufacturing companies, retailers, technology providers, research institutions, and non-governmental organizations supported as grantees under the SMEP Programme.*

Lia Tostes did desktop layout and graphics. Cover photo: © Elzette Henshilwood.

The SMEP Programme is funded by UK International Development and implemented by the UK Foreign Commonwealth and Development Office (FCDO) in partnership with UN Trade and Development (UNCTAD), who provide Technical Assistance to the programme. Programme management is delivered through a consortium partnership between Pegasys International and SouthSouthNorth.

Disclaimer

Views expressed in this policy brief are those of the authors and do not necessarily reflect those of their institutions or their members. This report has not been formally edited.

* SMEP grantees underwent a rigorous and competitive procurement process, which includes a technical and due diligence assessment before being awarded a grant under the programme.

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Abbreviations

CoC	Chain of custody
DPP	Digital Product Passport
EPR	Extended producer responsibility
ESPR	EU Ecodesign for Sustainable Products Regulation
EU	European Union
EUDR	EU Deforestation Regulation
GHG	Greenhouse gas emissions
HS	Harmonized System
LABs	Lead-acid batteries
MRAs	Mutual recognition agreements
NTMs	Non-tariff measures
PET	Polyethylene terephthalate
RFID	Radio frequency identification
SMEP	Sustainable Manufacturing and Environmental Pollution Programme
MSMEs	Micro, small and medium-sized enterprises
T2T	Textile-to-textile
ULABs	Used lead-acid batteries
UNCTAD	UN Trade and Development
UNTP	UN Transparency Protocol
VSS	Voluntary sustainability standards
ZDHC	Zero Discharge of Hazardous Chemicals

1.

Introduction & conceptual foundations

As regulatory standards increasingly shape global trade, the ability to verify how and where a product was made is becoming a prerequisite for market access. In this context, traceability – the ability to track and verify product-related information across supply chains – has emerged as a critical tool with multiple applications, from ensuring food safety in the agricultural sector to preventing the illicit trade of hazardous chemicals. It is also the primary mechanism for verifying sustainability claims.

At the same time, markets are witnessing a systemic shift from voluntary best practice to mandatory due diligence in sustainability. Emerging sustainability regulations are codifying requirements for geolocation, material origin and recycled content throughout product life cycles, positioning traceability as a cornerstone of compliance. While the “traceability turn” is powered by rapid technological change, limited systems interoperability and regulatory fragmentation remain major adoption challenges.

For producers in developing countries, traceability is becoming a de facto condition for market access. Yet, their capacity to comply remains uneven. Firms often lack access to digital technologies, finance, and specialized skills. Structural issues, including informality, weak digital infrastructure, and unreliable energy supply, further slow adoption. At the same time, multiple buyer requirements and inconsistent standards act as “cost multipliers”. Without targeted support and international cooperation, these barriers risk excluding producers from sustainable trade.

This report, produced under the Sustainable Manufacturing and Environmental Pollution (SMEP) Programme, examines these challenges from a trade and development perspective. Relying on an integrated methodological framework that situates firm-level actions within sustainability megatrends, the study addresses a fundamental question: how can developing country producers navigate increasingly stringent traceability requirements without being marginalized in the sustainability transition?

Combining global data analysis with sector case studies, this study focuses on four sectors central to manufacturing in the Global South and foci of the SMEP Programme:¹ plastics, lead-acid batteries (LABs), textiles and apparel, and leather. These sectors are characterized by significant environmental impacts, complex material flows and growing regulatory pressures, making them illustrative of the role of traceability in industrial transformation, environmental governance, and trade competitiveness.

Chapter 1 outlines the evolution of traceability and introduces key concepts, such as chain of custody (CoC). **Chapter 2** examines the trade-related drivers and challenges shaping traceability adoption, while reviewing policy and market responses. **Chapter 3** applies the framework across the four selected sectors, examining prevailing CoC approaches and sector-specific challenges and opportunities. **Chapter 4** identifies cross-sector insights and convergence pathways while providing evidence-based recommendations for policymakers and industry stakeholders.

¹ The SMEP Programme is funded by UK International Development in partnership with UN Trade and Development (UNCTAD) who provide technical assistance. SMEP is funding research and related interventions aimed at reducing the environmental and socio-economic impacts of the manufacturing sector in focus countries, as well as addressing some of the most pressing challenges associated with plastic pollution.

For more information, see <https://smepprogramme.org/>.



← **Image 1.** Lead-containing waste generated at an informal LAB breaking site. Limited traceability in informal recycling activities affects the monitoring of hazardous materials and the verification of environmentally sound waste management practices.

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| 1.1 Traceability: an evolving concept

Traceability originated as a risk-management and enforcement mechanism, first formalized in European law following food contamination crises in the late twentieth century. European Union (EU) regulation introduced the “one step back and one step forward” principle, requiring supply chain actors to identify their immediate suppliers and customers (European Union, 2002). This enabled products to be tracked through documented transactions across successive stages of production and trade along the whole supply chain, supporting rapid recalls during food-safety and public-health incidents.

From the 2000s onwards, traceability expanded beyond food safety to address illicit trade (e.g., endangered species) and sustainability risks in global supply chains. It became central to initiatives targeting conflict diamonds, fisheries and hazardous substances, with a strong focus on verifying origin to prevent unlawful or unethical sourcing (OECD, 2016; FAO, 2013; Kimberly Process, 2003). The EU biofuels regime further institutionalised traceability by requiring compliance with sustainability criteria, extending traceability obligations beyond EU border and compelling producers and intermediaries to provide supply chain information (European Commission, 2009).

At the same time, the private sector is adopting traceability to fulfil contractual obligations and improve production planning and resource efficiency. However, over time its role has shifted from operational management towards governance and accountability in global value chains (Karlsen et al., 2013). The emphasis increasingly lies on tracing the legality and ethical conditions of production across the supply chain rather than merely product quality or actor identification.

Major crises have accelerated this shift. The Rana Plaza textile factory tragedy in Bangladesh in 2013² exposed severe gaps in supply chain visibility, as many brands could not identify all facilities involved in producing their garments (Rich, 2023; Reinecke & Donaghey, 2015; NYU Stern Center for Business & Human Rights, 2014).³ Described as a “transparency shock”, the event prompted regulatory reforms and international governance initiatives, including the Organisation for Economic Co-operation and Development Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector. This guidance positioned traceability as a prerequisite for responsible sourcing, environmental governance, and trust (OECD, 2017; Reinecke & Donaghey, 2015; NYU Stern Center for Business & Human Rights, 2014).

In parallel, the related concept of CoC emerged within forest certification schemes to combat illegal logging in timber trade. These systems track material to prevent mixing of certified and non-certified inputs, thereby safeguarding material integrity throughout processing and trade (Cashore et al., 2004; Forest Stewardship Council, 2004; Gulbrandsen, 2004). CoC thus extended the logic of traceability beyond recording supply chain information of supply to verifying the physical authenticity of materials.

² For more information, see <https://www.theguardian.com/world/2013/apr/24/bangladesh-building-collapse-shops-west>.

³ In other words, the brands were governing invisible supply chain actors, which revealed serious limitations of relying on factory audits alone as the accepted governance system in opaque supply networks.



← **Image 2.** Workers sorting textile production off-cuts. Capturing information on material origin and fibre composition at this stage increases traceability and supports chain-of-custody verification in downstream textile-to-textile recycling.

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(SouthSouthNorth), 2026.

| 1.2 Key definitions & levels of information

Traceability records a product's journey through the supply chain; CoC verifies the continued authenticity and integrity of the material; and transparency determines what information are disclosed externally. Together, these tools and mechanisms form an integrated information and assurance framework that increasingly underpins contemporary sustainability governance and accountability in global supply chains. These concepts are formally defined in **Box 1**.

The conceptual distinction becomes more evident in implementation. While traceability focuses on information flow, CoC assurance relies on four recognized control models, book-and-claim, mass balance, segregation and identity preservation, which governs material handling and the substantiation of sustainability claims (Forest Stewardship Council, 2020). These models are examined in greater detail in **Chapter 3**, where their application across different sectors is discussed (**Box 4**).

Building on this framework, traceability and CoC can also be understood as operating across distinct levels of information granularity. As illustrated in **Figure 1**, using the production lifecycle of a T-shirt as an example, lower levels of traceability focus on mapping supply chain actors and product flows, while higher levels require CoC mechanisms to verify material integrity and substantiate sustainability and safety claims (Doyle, 2022; University of Borås, 2023). These levels provide a structured way of linking information capture to verification and underpin the application of CoC control models discussed in **Chapter 3**.

↓ Source: García-Torres et al. (2024); Forest Stewardship Council (2020); Olsen and Borit (2013); ISO (2020 and 2007).

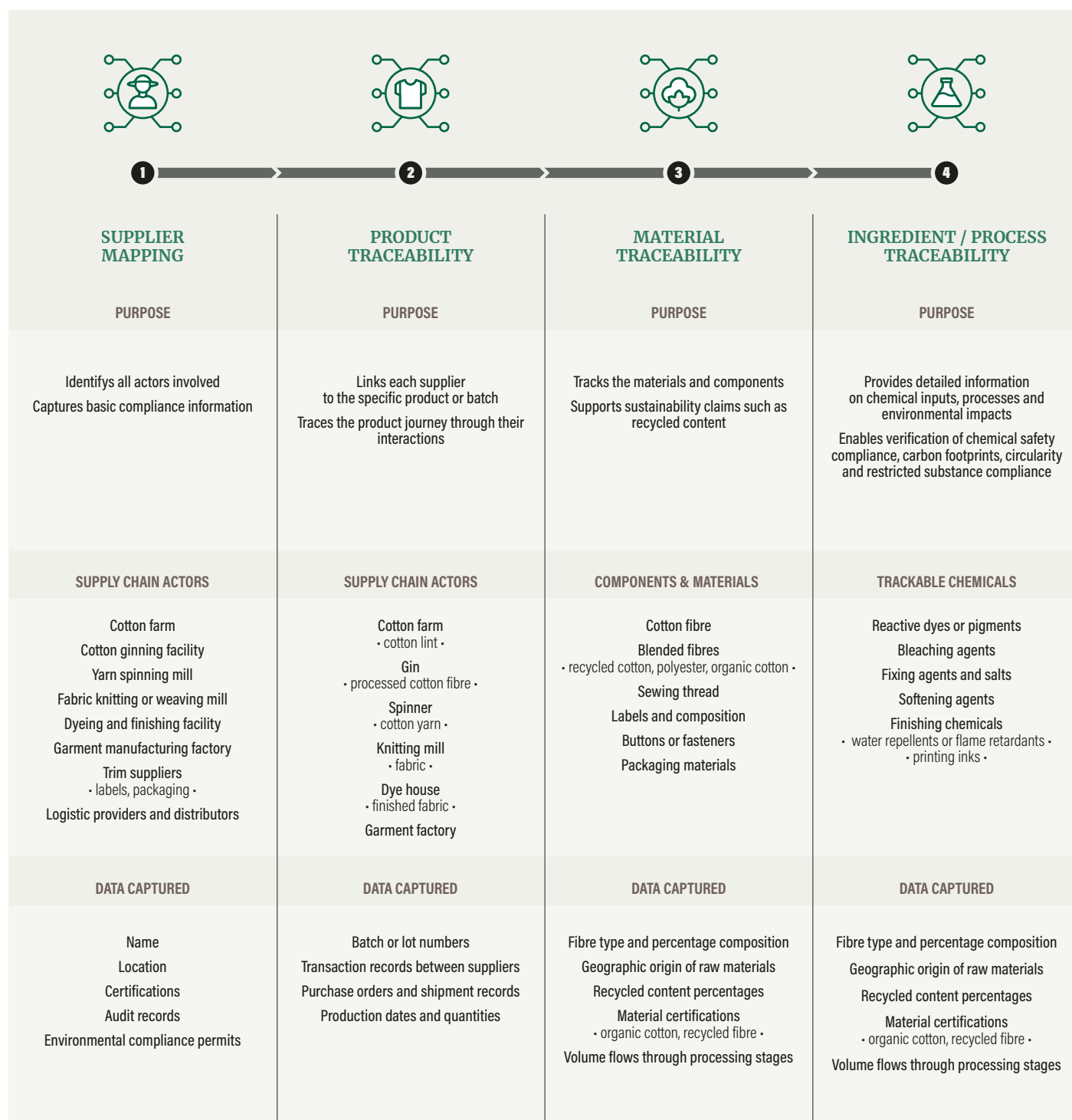
Box 1. Key definitions: traceability, transparency and chain of custody



Supply chain **traceability** is now commonly regarded as the “ability to trace the history, application or location of an object” (ISO, 2015) through successive stages of production, processing and distribution (Olsen and Borit, 2013; ISO, 2007).

Supply chain **transparency** refers to the “extent of quality information disclosed to internal or external stakeholders” (García-Torres et al., 2024).

Chain of custody (CoC) concerns material integrity and refers to the documented tracking of materials through successive stages of processing and distribution to ensure that product claims remain valid (ISO, 2020; Forest Stewardship Council, 2014).



↑ **Figure 1. Traceability and chain-of-custody information levels: the cotton T-shirt product lifecycle**

Source: Prepared by the authors based on Figure 2 in *Traceability Tools for Textile Supply Chains* (University of Borås, 2023).

Note: The original figure was adapted from definitions developed by Meghan Doyle in the *Traceability Playbook* (TruTrace, 2021).

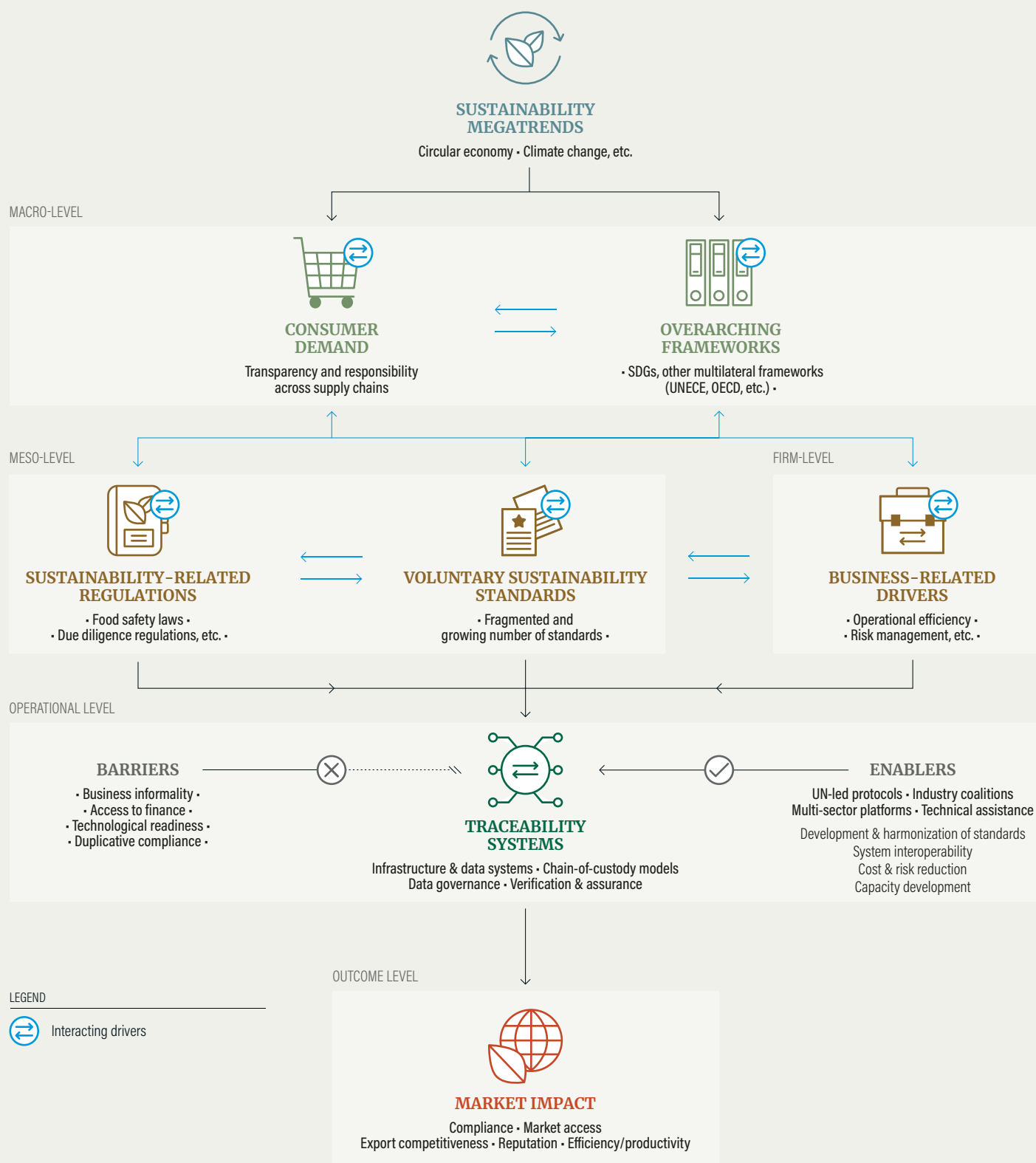
1.3 Methodological framework & scope

To examine how traceability systems develop and shape markets, this study employs a multi-level methodological framework that situates traceability within broader sustainability transitions (Figure 2). Traceability systems are shaped by regulatory requirements in both domestic and export markets, as well as by macro-level sustainability trends such as climate change, shifting consumption patterns and the circular economy. These dynamics drive demand for transparency, and influence policy frameworks guiding corporate actions, including the Sustainable Development Goals. At the meso-level, they translate into concrete drivers of traceability uptake, namely sustainability-related regulations and voluntary sustainability standards (VSS). At the firm-level, business-related drivers such as risk-management and operational efficiency also create incentives for adoption.

↓ **Figure 2. Multi-level analytical framework for the adoption of traceability systems.**

Source: Prepared by the authors.

Traceability systems – encompassing infrastructure, CoC controls, verification processes and data governance – operate at the interface between these drivers and market outcomes. While certain barriers shape the pace and scope of adoption, its effectiveness depends on institutional, technical and market responses. The framework thus positions traceability as an intermediary mechanism, linking global sustainability imperatives with firm-level practices and market performance.



2.

Trade-related drivers & the evolving policy landscape

| 2.1 Sustainability trends & the need for traceability

The environmental impacts of production and consumption largely occur upstream within global supply chains (UNCTAD, 2021; Wiedman & Lenzen, 2018; Lenzen et al., 2012), as do most human rights abuses (Castaldi et al., 2023; Lafarre and Rombouts, 2022; Bright et al., 2020). As consumers and firms make purchasing decisions geographically removed from where production impacts occur, mechanisms are required to make those impacts visible to end users. Traceability and transparency are widely recognized as providing this information linkage, acting as key drivers of responsible and sustainable supply chains (García-Torres et al., 2024; WEF, 2020) and of the implementation and monitoring of sustainability objectives (UN General Assembly, 2025 and 2015; UNECE, 2022; UNEP, 2019 and 2021).

4 GHG emissions are commonly classified under the GHG Protocol into three scopes: Scope 1 covers direct emissions from sources owned or controlled by an entity; Scope 2 covers indirect emissions from purchased energy; and Scope 3 includes all other indirect emissions occurring upstream and downstream across the value chain.

5 For developing countries, traceability is also a means to demonstrate that a significant share of domestic emissions is driven by demand from foreign buyers. This aligns with evidence that since the early 2000s, production of emissions-intensive goods has been concentrated in the Global South, while final consumption has largely occurred in the Global North, thus strengthening the case for international assistance in implementing Nationally Determined Contributions (Meng et al., 2023).

There are several interrelated trends prompting the adoption of traceability at scale. For instance, circular economy models depend on the recovery, reuse, and recycling of materials across product life cycles. This requires knowledge of material composition (e.g., chemicals) and prior processing (European Commission, 2020; Ellen MacArthur Foundation, 2017). However, such information can be lost once products leave the manufacturing stage, limiting the feasibility of closed-loop systems and building a business case for traceability. Traceability systems can help address this gap by enabling material identification, sorting, and verification of recycled content, as is the case of plastics (Gazeau et al., 2024).

Climate action further reinforces the need for traceability. Both national climate plans (known as Nationally Determined Contributions, or NDCs) and corporate climate commitments increasingly depend on measuring and reducing greenhouse gas (GHG) emissions. As most emissions occur outside a firm's direct operations, Scope 3⁴ accounting requires identifying suppliers, production locations, energy sources, and upstream production processes (GHG Protocol, 2011).⁵ In this context, traceability is not a mitigation technology, but the information infrastructure that makes mitigation measurable across supply chains. With traceability, supply chain emissions can be mapped and verified against corporate low-carbon product claims and science-based targets (SBTi, 2021).

Furthermore, consumer demand has become an increasingly powerful driver of traceability, as sustainability and ethical claims shift from marketing levers to core competitiveness drivers. Recent global surveys show that, while price remains a key determinant of purchasing decisions, a substantial share of consumers prioritize sustainably sourced products and are often willing to pay a premium for it (PWC, 2024). In addition, recent studies demonstrate that transparency and traceability information significantly enhance consumer trust and influence purchasing decisions (Nguyen & Nguyen, 2025).

| 2.2 From voluntary to mandatory

The traceability turn

These trends and their case for traceability have gradually translated into governance instruments that operationalize sustainability objectives within global supply chains. Among the most prominent are VSS. These standards range from organic labels and forest certifications to recycled content and responsible sourcing schemes. They are typically adopted by lead firms and implemented throughout their supply chains to build trust and demonstrate commitment. While these standards are present in virtually all sectors, they were pioneered and remain particularly prominent in agri-food and textiles (ITC, 2025a).

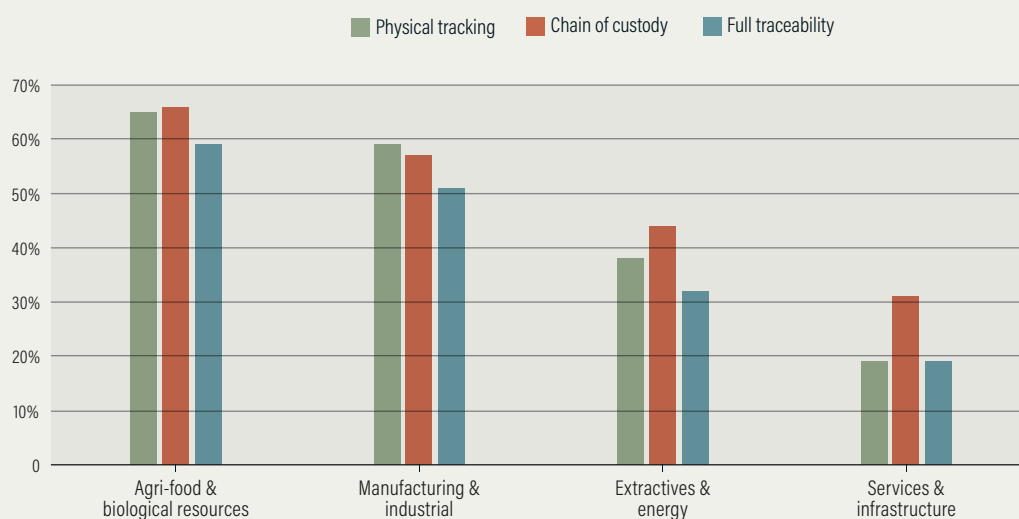
VSS exhibit a strong traceability footprint, incorporating provisions for physical product tracking, CoC systems, or both. A review of 371 standards for this study reveals that nearly half of them include provisions for full traceability (47 per cent). While 59 per cent of agri-food standards have full traceability provisions, this percentage is lower in other sectors, where provisions often focus on either the actions (physical tracking) or systems and documentary trails (CoC) supporting traceability (Figure 3). Of the 199 VSS integrating full traceability, around 80 per cent are administered by private entities, including standard owners and non-governmental organisations (NGOs), highlighting their central role in operationalizing sustainability.⁶

While being voluntary in nature and not formally tied to regulations, VSS are becoming de facto requirements for market access. Their adoption has increased dramatically in recent years, as shown by the steep increase in the certified harvested areas of agricultural commodities such as cocoa, cotton, and coffee – typically produced in developing countries. These now range from 10 per cent to 30 per cent of all harvested areas (ITC, 2025a).

In addition, VSS are increasingly serving as the technical blueprint for a new generation of mandatory due diligence regulations. By imposing strict sustainability standards on imported goods, these frameworks may limit market access for developing country exporters. These regulations frequently include traceability elements as a means of risk assurance, claim verification or quality safeguard. For instance, the EU Deforestation Regulation (EUDR) requires operators and traders to provide geolocation coordinates of the land where high-risk commodities such as oil palm and rubber were produced (European Union, 2023).⁷

6 Differences across sectors are minimal as VSS integrating traceability that are administered by private entities vary between 72 per cent (Services and Infrastructure) and 79 per cent (Manufacturing and industrial).

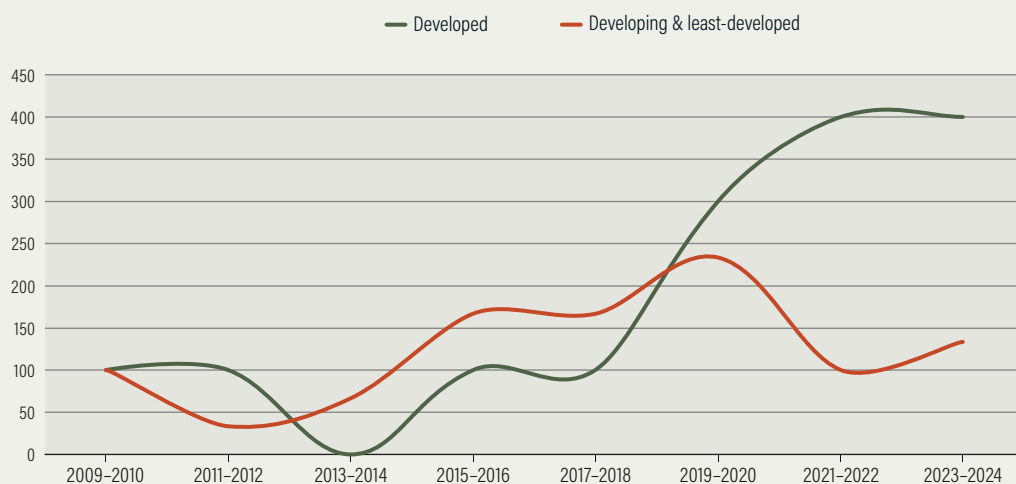
7 Additional examples can be found in UNCTAD (2025a), Table 1.



← **Figure 3. Voluntary sustainability standards embedding traceability, by sector and type of requirement**

Source: UNCTAD analysis of International Trade Centre StandardsMap data (2026).

Note: Percentages represent the share of VSS integrating traceability out of all VSS within each sector. Full traceability refers to standards including both physical tracking and CoC. Standards covering multiple sectors are included in all relevant categories and may be double-counted.



← **Figure 4. Environmental measures notified to the World Trade Organisation mentioning traceability**
Indexed count
(2009–2010, base year)

Source: UNCTAD analysis of WTO Environmental Database data (2026).

Note: The analysis covers 45 measures notified between 2009 and 2024. Relevant measures were identified using the keywords “traceability”, “chain of custody” and “geolocation”. To avoid double-counting, duplicate notifications of the same measure in the same year or under multiple WTO agreements were excluded.

8 The decline in new notifications after 2019–20 may partly reflect broader changes in WTO notification practices during and following the COVID-19 pandemic, rather than a reduced policy focus on traceability or environmental measures.

9 Distinct policy approaches also emerge: While developing countries tend to emphasize commodity-specific requirements intended to secure the integrity of exports (e.g. quality standards for cocoa, agave syrup, and organic seals), developed countries prioritize horizontal market access schemes focused on safety and environmental responsibility (e.g., genetically modified organism labelling, extended producer responsibility (EPR) schemes). In the Global South, the implementation of such measures often serves as a signalling tool to maintain market reputation and prevent the dumping of low-quality goods, even where domestic infrastructure and enforcement capacity is limited.

10 Additional examples were reported to the authors during key informant interviews with industry practitioners but are not yet reflected in published literature.

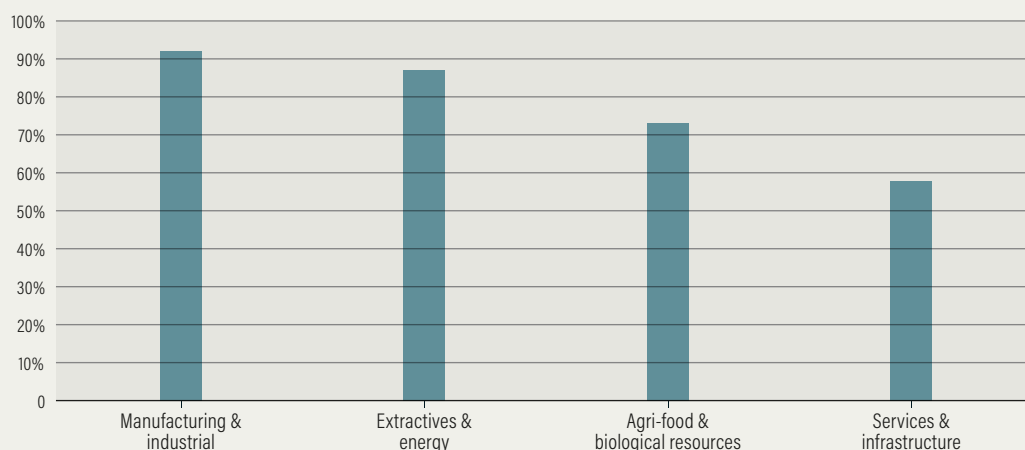
This trend reflects a broad shift within the multilateral trading system. In fact, as traceability moves from voluntary best practice to a legal prerequisite for market access, both developed and developing countries are enacting due diligence legislation and support measures for compliance with new, traceability-related requirements. This is reflected in a notable increase in the number of environmental measures notified to the World Trade Organisation (WTO) that cover traceability (Figure 4).⁸ Notified measures are unevenly distributed across developed countries (34 per cent) and developing and least-developed countries (66 per cent), highlighting that this shift is not a Global North phenomenon.⁹

Taken together, these trends point to a co-evolution of public and private standards shaping global traceability uptake. Private schemes have historically functioned as “laboratories” for traceability tools and verification systems that regulators are now codifying into mandatory due diligence frameworks (Sarmiento et al., 2025; UNCTAD, 2024a). At the same time, VSS are aligning their standards with new regulatory requirements (World Bank, 2025).¹⁰ As a result, companies face a dual layer of expectations: compliance with regulatory requirements alongside alignment with private certification schemes. While VSS offer tools and expertise to help companies navigate due diligence, certification alone is generally not accepted as a proof of regulatory compliance (UNCTAD, 2025a).

As traceability requirements proliferate across both VSS and due diligence regulations, traceability systems are becoming the essential architecture for sustainable supply chains. Digital tracking tools, CoC protocols and data verification mechanisms are no longer optional add-ons but the operational backbone enabling companies to demonstrate compliance and gain or maintain access to green markets. Together with traditional business considerations, such as risk management and resource planning, these dynamics are reshaping investment decisions and the organisation of global supply chains (Xue et al., 2025; Stranieri et al., 2017; Heyder et al., 2010).

| 2.3 Adoption challenges

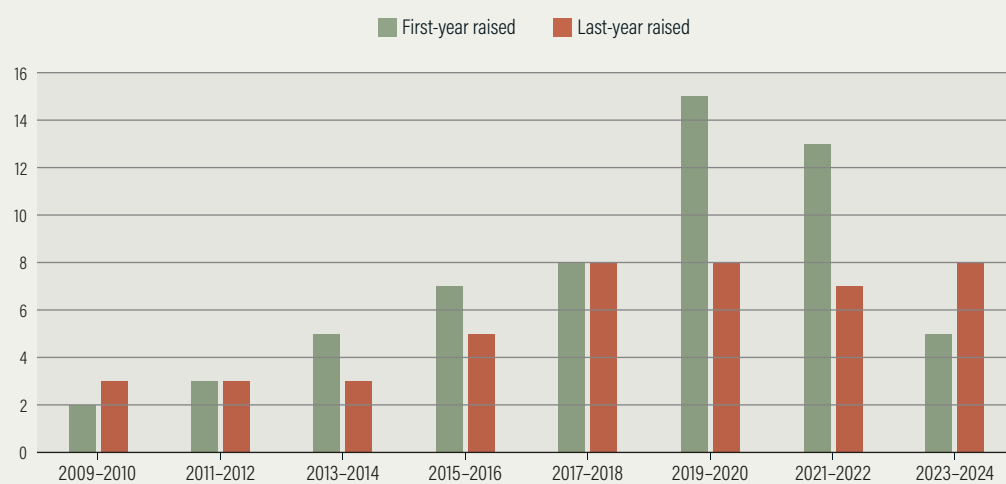
Despite growing policy momentum, adoption remains uneven. Indeed, traceability-related compliance is resource-intensive. It involves significant investment, ranging from specialized equipment and software to skills development, requiring upfront capital and specialized knowledge that companies may lack (Kashyap et al., 2026; WEF, 2020). These barriers are particularly acute in developing countries, where limited technical and financial capacity constrains corporate action. In South Asia and East Africa, for instance, local companies often struggle to adopt digital traceability systems due to gaps in resources and skills. These challenges are exacerbated by weak digital infrastructure, unreliable energy supplies and high borrowing costs (SMEP 2025a and 2025b).



← **Figure 5. Share of traceability-embedding voluntary sustainability standards requiring third-party verification, by sector**

Source: UNCTAD analysis of International Trade Centre StandardsMap data (2026).

Note: Percentages represent the share of VSS mandating third-party verification out of all VSS integrating full traceability (physical tracking and CoC). Standards covering multiple sectors are included in all relevant categories and may be double-counted.



← **Figure 6. Traceability-related concerns raised by members at the World Trade Organisation (2009–2024)**

Source: UNCTAD analysis of WTO Trace Concerns Database data (2026).

Note: Traceability-related concerns were identified through a keyword search using “traceability”, “chain of custody”, “geolocation”, and references to high-profile regulatory initiatives such as the EU Deforestation Regulation (EUDR).

Furthermore, tracking products and generating supporting documentation at each stage adds complexity, requiring coordination and collaboration within and across company boundaries. Certification and verification are also major cost drivers, particularly when third parties are involved. Indeed, most VSS incorporating traceability require independent third-party verification, with shares ranging from 57 per cent in services and infrastructure to over 90 per cent in manufacturing and industrial sectors (Figure 5). This entails activities such as testing, inspection and audits, increasing operational costs.

Fragmentation of digital systems and lack of interoperability further constrain implementation (Adamashvili et al., 2025; WEF, 2021, 2025a, 2025b). End-to-end, fully integrated platforms remain limited, resulting in fragmented efforts. At the same time, enabling frameworks, such as standards and data governance rules, are not evolving at the same pace. The lack of standardization often hinders information exchange, resulting in low interoperability and the creation of “data silos”, where data and metrics in different formats have limited or no utility.

While traceability underpins transparency, credibility, and market access, implementation challenges remain and can disproportionately affect MSMEs in developing countries. This is reflected in the number of concerns raised at the WTO, where several countries have questioned the design and impact of traceability-related measures on trade. These concerns grew substantially over the last decade, from just 2 new concerns in 2009–2010 to a peak of 15 in 2019–2020 (Figure 6). While the number of new concerns has slowed since that peak, the number addressed remained consistently high through 2023–2024.¹¹ This suggests that traceability is no longer a “new” trade policy issue but a persistent concern subject to regular scrutiny by WTO members.

¹¹ The decline in new concerns (“First year raised”) after 2019–20 may partly reflect broader changes in WTO committee activity during and following the COVID-19 pandemic, rather than a reduced policy focus on traceability and environmental measures. Conversely, addressed concerns (“Last year raised”) remained relatively high after 2019–20, indicating persistent policy interest.

| 2.4 Policy & market responses

Addressing the adoption challenges outlined in [Section 2.3](#) requires coordinated responses across institutional, technical and market dimensions. Multi-stakeholder action, supported by international cooperation, can help address key constraints, ranging from regulatory and technological fragmentation to capacity gaps and limited access to finance. These dimensions are closely interconnected, with progress in one area reinforcing outcomes in others. Together, they shape systemic “convergence” and determine whether firms in developing countries can effectively participate in sustainable markets.

Institutional and regulatory coherence

The need for coherence to prevent “compliance fatigue” has been driven by the expansion of traceability requirements across standards and regulations ([Chapter 2](#)). In this context, fragmentation arises from the overlap of voluntary and mandatory standards and from the legal friction between differing regimes (UNCTAD, 2025a).

Multi-stakeholder initiatives are seeking to reduce this fragmentation through harmonized frameworks and protocols. Ongoing efforts focus on benchmarking, equivalence assessments, and mutual recognition agreements (MRAs), aimed at reducing the administrative burden on companies while maintaining disclosure integrity. For example, the Social & Labor Convergence Program and the Consolidated Mining Standard Initiative are operationalizing harmonized assurance frameworks for site-level verification, while the Global Dialogue on Seafood Traceability and the UN Transparency Protocol (UNTP) have established unified data protocols to provide a single, benchmarked proof of origin (GDST, 2026; SLCP, 2026; UNECE, 2026; CMSI, 2024).

↓ **Image 3.** Guidance documents supporting benchmarking, equivalence assessments and MRAs to facilitate interoperability and reduce reporting burdens.



Technical interoperability & data governance

At the technical level, traceability systems depend on the structured exchange of information across supply chain actors. While international standards such as the ISO 22005 provide general guidance, they often lack the granularity needed for automated data exchange (e.g., machine-readable data structures) (UNCTAD, 2024b; ISO, 2020 and 2007). Consequently, technical silos emerge from a lack of universally accepted semantic standards and common data formats (Farina et al., 2025).

Recent policy initiatives, such as the EU Ecodesign for Sustainable Products Regulation (ESPR) and the EU Battery Regulation, are introducing DPPs to store and share product information across the value chain (European Parliament and Council, 2024 and 2023). This includes material sourcing, recycled content, carbon footprint, and performance characteristics. At the same time, industry-driven frameworks such as the GS1 Global Traceability Standard translate traceability principles into standardized data structures, enabling interoperability across systems (GS1, 2017). These standards also provide the necessary architecture for integrating emerging technologies, such as blockchain and artificial intelligence.

Traceability also requires data governance frameworks to manage access rights, security, and legal liability, enabling trusted data exchange while protecting confidentiality. One emerging initiative in this space is the UNTP, which provides a decentralized protocol for digitally-verifiable data claims (Box 2). Initiatives of this type allow supply chain actors to share authenticated sustainability claims in a verifiable format, supporting due diligence requirements while enabling companies to retain control over commercially sensitive information.

Box 2. The United Nations Transparency Protocol



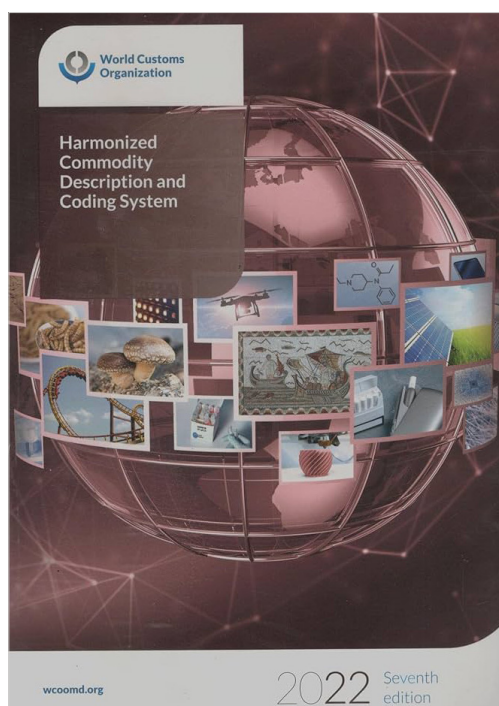
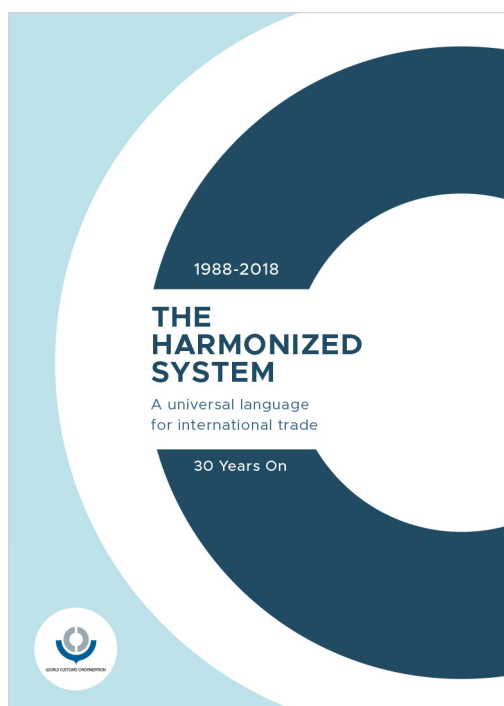
Developed by the United Nations Economic Commission for Europe (UNECE) and the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT), the United Nations Transparency Protocol (UNTP) is a global, open-source digital protocol designed to address key transparency challenges facing global supply chains, such as high data fragmentation, limited systems integration and interoperability, and unverified sustainability claims.

The UNTP functions as a common technical language that allows business systems or traceability platforms to exchange sustainability data. It comprises standards for product data, facility data, traceability data, conformity data, and identity data, enabling transparency to “emerge” in a bottom-up manner through the voluntary disclosures of actors who independently implement the protocol.

As a result, the UNTP transforms sustainability assertions into digitally verifiable data claims. These claims function as secure digital assets that can accompany a product via, e.g., DPPs, providing the authenticated evidence required for modern sustainability due diligence. To protect commercial interests, the protocol also includes “selective redaction” tools.

By providing this interoperability backbone, the UNTP aims to reduce the risk of greenwashing and lower compliance costs by reducing duplicative data requests across proprietary systems.

↑ Source: UNECE (2026).



← **Image 4.** World Customs Organization publications on the HS. Consistent classification of goods under the HS can support trade in enabling technologies and inputs relevant to traceability, while reducing uncertainty associated with tariff and NTMs.

Market conditions, capacity & trade

In addition to regulatory coherence and technical interoperability, a conducive environment includes effective law enforcement, well-developed markets for inputs, and the availability of investment incentives and capital. In many developing countries, however, financial markets remain illiquid and borrowing costs high, limiting firms' ability to invest in digital systems and compliance infrastructure (UNCTAD, 2025b). In these circumstances, blended finance instruments and public-private partnerships are emerging as mechanisms to mobilize finance and knowledge critical for sustainability-related investment (SMEP, 2025c). Similar models may prove relevant for mobilizing investment in traceability systems where private incentives are insufficient.

Where markets are undeveloped and key technological inputs undersupplied, trade can facilitate access to environmental goods and enabling technologies (Belleli and Xu, 2024; ITC, 2025b; UNCTAD, 2025c, 2025d and 2024c). In fact, access to digital technologies and related services through trade remains a critical enabling condition for traceability, especially in developing countries. Through imports, firms can access critical solutions, ranging from digital devices and sensors to cloud computing and data storage services that may not be readily available domestically.¹²

¹² It should be noted, however, that the effectiveness of these imported technologies depends on the presence of reliable digital infrastructure, including broadband connectivity and reliable power supplies (UNCTAD, 2024b).

However, trade flows are shaped by tariff and non-tariff measures (NTMs), such as technical standards and health and safety measures, which may act as barriers to technological diffusion. Indeed, while NTMs increasingly incorporate sustainability objectives, they can also raise compliance costs and limit the ability of firms, especially MSMEs, to benefit from global markets (UNCTAD, 2023). While evidence is limited, the effects of traceability-related NTMs on trade are mixed and depend on the sector, type of measure and trade partners' economic profile (Bispo et al., 2026). Potential issues may also arise from the erroneous or inconsistent classification of goods and technologies under frameworks such as the Harmonized System (HS) (**Box 3**).

Box 3. Traceability technologies in the Harmonized System: the case of radio frequency identification

Many traceability-enabling technologies are embedded within existing six-digit HS codes. However, as the case of RFID technologies shows, none of these codes uniquely or exclusively identify RFID technologies but cover broader groups of electronic equipment.

Target goods	Description	Purpose	Code	Description
Readers	Electronic devices that scan RFID tags or barcodes and transmit the captured information to digital systems.	Automated data collection at key points such as warehouses, plants and border crossings.	847160	Units of automatic data processing machines; input or output units, whether or not containing storage units in the same housing.
			847190	Magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, not elsewhere specified or included.
			851762	Communication apparatus (excluding telephone sets or base stations); machines for the reception, conversion and transmission or regeneration of voice, images or other data, including switching and routing apparatus.
Tags	Small identification devices or printed labels attached to products, packaging or assets that store a unique code.	Automatic identification and tracking of goods throughout the supply chain.	852352	Semiconductor media; smart cards, whether or not recorded, excluding products of Chapter 37.
			852359	Semiconductor media; other than smart cards, whether or not recorded, excluding products of Chapter 37.

As these codes are used interchangeably to track and regulate trade in RFID technologies, this can cause erroneous applications of tariffs and NTMs and a bias in trade statistics. In addition to dual use, the lack of granular classification can also result in foregone tax revenues if tariff reductions intended for traceability equipment inadvertently apply to a broader set of consumer goods.

The extent to which traceability-enabling technologies are identified and considered in future updates of the classification and adequately reflected in national tariff lines will determine how trade policy facilitates or constrains access to these goods. At the same time, approaches such as the use of “ex-outs” within existing classifications can provide more immediate paths for tariff reform without waiting for HS updates or affecting broader product categories.

↑ Source: UNCTAD analysis on the World Customs Organization's HS classification, 2022 edition.



← **Image 5.** Leather processing represents a critical node for traceability, providing opportunities to capture and verify information relevant to CoC systems and sustainability claims.

© H. Pacini (UNCTAD), 2022.

3.

Sector perspectives

Priority actions for implementing traceability solutions vary significantly by sector (UNECE, 2025; WEF, 2020). Over time, industries have developed different traceability approaches in response to sector-specific challenges, from input sourcing and processing to product use and end-of-life. In practice, these are operationalized through four recognised CoC models – book-and-claim, mass balance, segregation and identity preservation – which determine how information supports verifiable sustainability claims. These models differ in how they account for material use and integrity, as well as in the stringency of the information underpinning sustainability claims (**Box 4**).

The choice of CoC model varies across sectors depending on differences in product fungibility, processing complexity, and risk exposure. Bulk commodities, such as cotton in textiles and recycled polymers in plastics, typically rely on mass balance, whereas higher-risk sectors, including pharmaceuticals and conflict minerals, tend to apply stricter segregation or identity preservation systems. As regulatory requirements for sustainability claims and circularity increase, sectors are gradually moving toward stricter forms of material verification (UNECE, 2026; Ellen MacArthur Foundation, 2017; Olsen & Borit, 2013).

Against this backdrop, this chapter assesses the deployment of CoC models and the readiness of different sectors to adopt and scale traceability systems. Drawing on SMEP Programme traceability interventions (Annex 1), it compares dynamics across four sectors with strong traceability incentives – plastics, LABs, textiles, and leather – and illustrates system flows and prevailing traceability architectures (**Figure 7**). The chapter then examines sector-specific hotspots – critical nodes where traceability has the greatest leverage on systems integrity and claims verification – as well as gaps, adoption challenges, and emerging industry ambitions through four case studies.¹³

¹³ These case studies, prepared by independent experts, provide focused insights into traceability systems across sectors. They follow a common structure but reflect different priorities and are not intended as exhaustive assessments.

The four main CoC models are summarized as follows (from least to most stringent):

1. **BOOK-AND-CLAIM (CREDIT SYSTEM)**

Separates sustainability attributes from the physical product, allowing certificates or credits to be traded independently. It does not ensure physical traceability of the material in the final product. For example, in carbon markets, sustainability claims are traded as credits without physical traceability of the underlying activity.

2. **MASS BALANCE (MB)**

Accounting-based model in which certified and non-certified materials can be physically mixed, provided that the quantity certified does not exceed the certified input. It ensures proportional integrity. For example, under the EU renewable Energy Directive, certified and non-certified feedstocks for biofuels can be mixed as long as certified output and input match.

3. **SEGREGATION (SG)**

Allows certified material from different sources to be physically mixed but excludes non-certified material, ensuring that the final product contains only certified inputs, though not from a single origin. It maintains material integrity. Under the GOTS, certified organic fibres are kept physically separate from non-certified materials throughout processing, ensuring that final products contain only certified inputs.

4. **IDENTITY PRESERVATION (IP)**

Ensures that a certified material from a specific source is kept physically separate from all other materials throughout processing, transport and manufacturing, so that the final product can be linked to a specific origin. It maintains full physical separation and source identity. For example, under the EU Batteries Regulation (2023/1542), critical raw materials such as lithium and cobalt remain traceable to specific mines or suppliers.



↑ Source: UNECE (2026); Roundtable on Sustainable Palm Oil (2023); Forest Stewardship Council (2020); ISO (2020).

| 3.1 Plastics: a regulatory-driven quest for recycled content

The plastics value chain is characterised by fragmented recycling systems where traceability fails at aggregation and transformation stages. Overall, the system reflects a predominance of mass balance and non-traceable flows, with limited implementation of formal CoC or traceability standards, resulting in fragmented data continuity across the value chain (Figure 7).

Figure 7. Comparison of mechanisms to operationalise traceability in plastics, lead-acid batteries, textiles, and leather

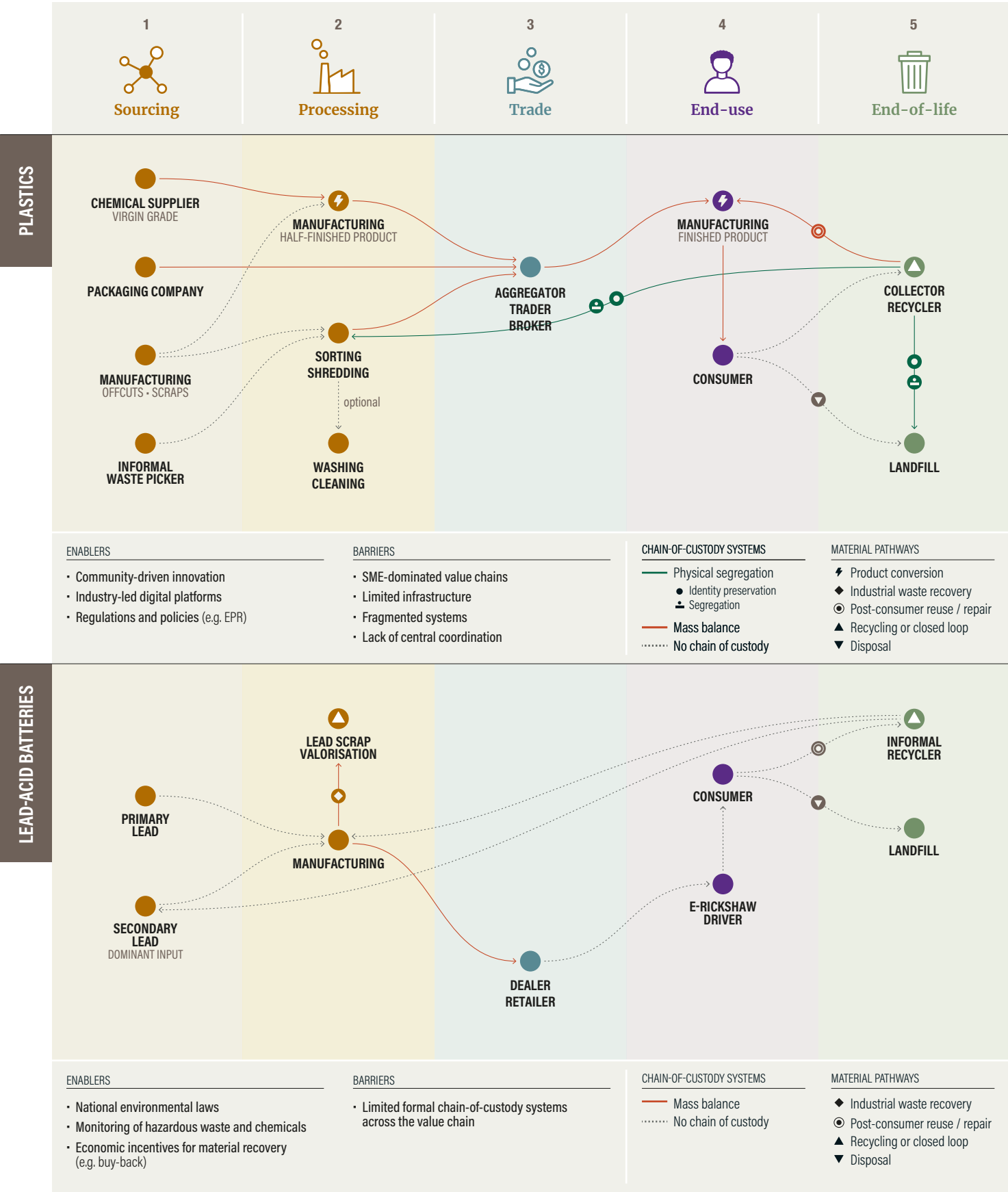
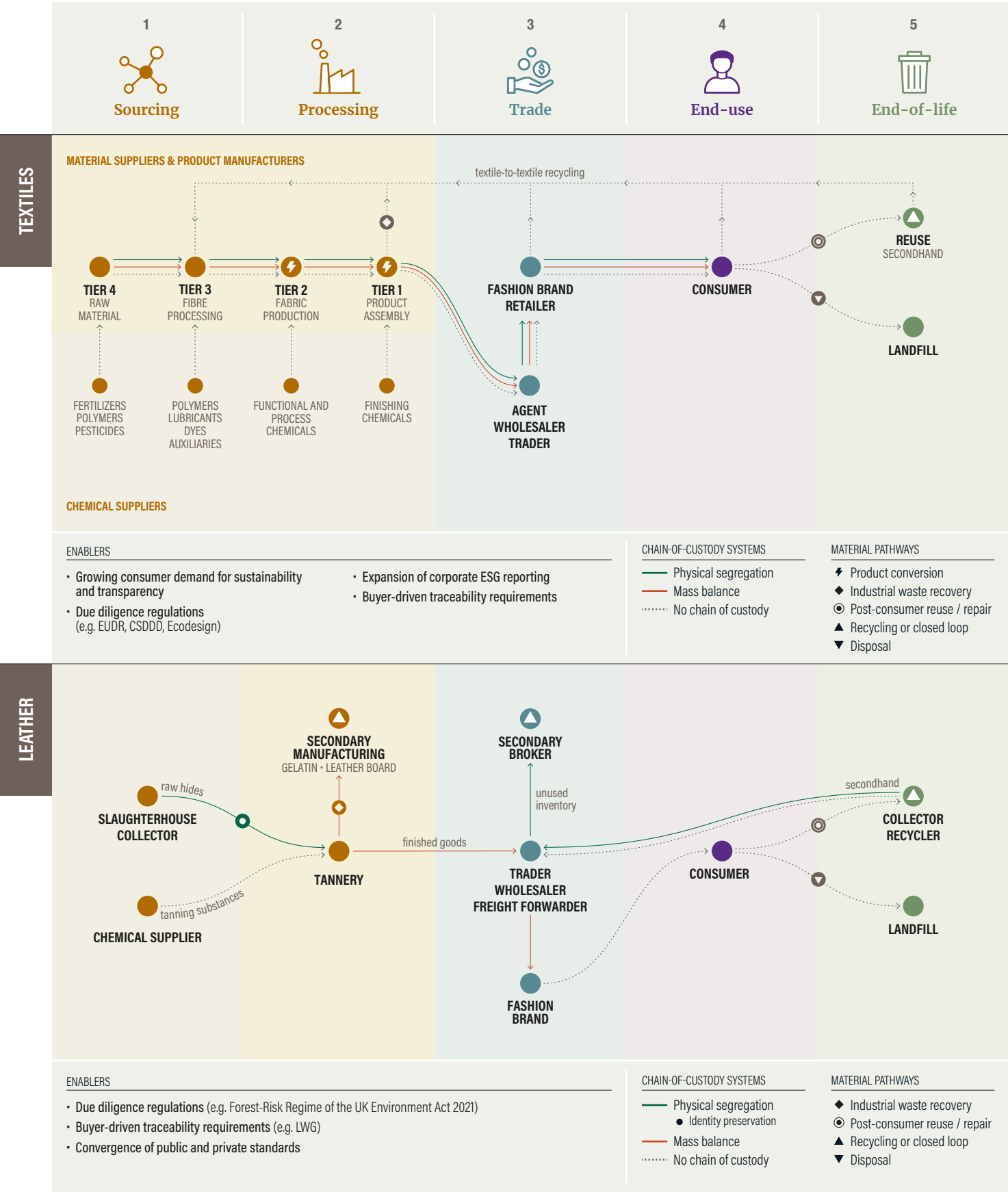


Figure 7. (cont.) Comparison of mechanisms to operationalise traceability in plastics, lead-acid batteries, textiles, and leather



Hotspots & gaps

Traceability hotspots are primarily at stages where materials are transformed, aggregated, or reintroduced into production, as these points determine material identity, quality, and downstream claims. The first hotspot is the sorting and shredding stage, where plastics from households, markets, industrial offcuts, and informal collection streams are consolidated and processed. At this stage, polymer segregation and initial quality decisions occur. A second hotspot exists at trade and aggregation nodes, where recyclates are mixed, blended, or reclassified. A third hotspot appears at the product conversion stage, where recycled content enters manufacturing.

Despite progress, significant gaps remain throughout the system. Information is frequently lost during sourcing due to informal collection practices. Processing stages often lack standardised recording of transformations, contamination levels, or batch composition. Trade transactions between aggregators and brokers are commonly informal, reducing CoC continuity. At the end of life, disposal pathways such as landfill, open dumping, or leakage are untracked, limiting visibility into recovery rates and circular outcomes.

Industry ambition

Traceability in the plastics sector is increasingly driven by external regulatory, market, and buyer pressures that require greater transparency across material flows. Emerging sustainability-related product regulations, particularly in large export markets, are pushing the industry toward measurable recycled content, improved recyclability, and clearer product information. For example, the EU Packaging and Packaging Waste Regulation aims to make all packaging recyclable by 2030 and increase recycled plastic content, while introducing stronger lifecycle requirements and labelling obligations (European Commission, n.d.; European Union n.d.). In parallel, buyer requirements from multinational brands increasingly demand proof of recycled content, origin, and compliance with sustainability targets (OECD, 2024). According to the Global Commitment 2025 Progress Report, beverage brands, among the largest signatories, have driven a near tripling of post-consumer recycled content use since 2018 (Ellen Macarthur Foundation, 2025).

Concrete mechanisms are emerging to operationalise traceability. For example, signatories to the Ellen MacArthur Foundation's Global Commitment are required to report annually on packaging volumes, recycled content (Ellen Macarthur Foundation, n.d., Ellen Macarthur Foundation, 2025), and progress against circularity targets, creating a structured demand for data on material flows. The Global Plastic Action Partnership supports the development of national data frameworks and dashboards to improve visibility of plastic flows across value chains (Global Plastic Action Partnership, n.d., World Economic Forum, 2025). Industry certification schemes such as ISCC+ are increasingly used to verify recycled content through mass balance approaches (ISCC, 2025).

Traceability is also becoming essential for the implementation and credibility of emerging policy and market-based instruments, such as extended producer responsibility (EPR) schemes and plastic credit mechanisms. These systems rely on the ability to track material flows and verify recovery or recycling activities. As such, traceability underpins both regulatory compliance and the integrity of financial and environmental claims within the plastics value chain.

The industry is moving towards digital traceability approaches, including standardised identifiers, product-level data, and interoperable systems. Standards such as GS1 Digital Link are gaining relevance by enabling packaging to be linked to dynamic traceability information through product identifiers (GS1, 2017). The greatest development potential lies in processing and trade stages, where materials are aggregated, transformed, or mixed, and traceability often breaks down. These points offer opportunities for improved segregation, documentation, and digital data capture. A clear signal of mainstreaming is the emerging DPP framework under the ESPR, which links products to lifecycle information and supports verification of recycled content and compliance (IEA, 2025a).

Ongoing international and regional policy processes are likely to further reinforce this dynamic. At the global level, negotiations under the Intergovernmental Negotiating Committee on plastic pollution are expected to increase the need for robust traceability systems to support monitoring, reporting, and verification under a future international instrument. Similarly, emerging regional initiatives, such as the East African Community single-use plastics draft Bill, are likely to embed traceability-related requirements, further expanding demand for interoperable systems across jurisdictions.

Adoption challenges

Despite these signals, implementation remains uneven due to fragmented infrastructure, inconsistent standards, and misaligned incentives across the value chain. At the firm level, high costs and low technological readiness disproportionately affect MSMEs and informal actors. While some 20 million informal plastic waste pickers are estimated to recover waste from landfill for reprocessing in the Global South (Gutberlet, 2023), investment in the digital tools required for data capture is often constrained by lack of financing and competing operational priorities. Innovation in this space, however, is emerging through models like GIVO, which digitizes informal transactions to produce traceability data from the source (Box 5).

Box 5. Plastic waste value chains enabled through digital infrastructure



The **GIVO-Warwick project**, a collaboration between the University of Warwick and GIVO Africa supported by the SMEP Programme, demonstrates how digital tools can strengthen transparency and traceability in plastic recycling value chains while bridging formal and informal sectors.

The project enhances plastic waste management through digital systems that track waste materials from community collection to processing and reuse. At the core of the model are digitally enabled, decentralized GIVO collection centres. These centres function as community hubs where plastic waste is collected, aggregated, and prepared for recycling. Waste collectors use mobile phone-based tools linked to the GIVO Technology Platform to exchange collected plastic for points redeemable as cash or vouchers. At the same time, the system records and monitors materials as they enter and move through reverse supply chains. The collected plastics are then processed into recycled materials such as eco-panels and protective equipment.

The GIVO platform captures several layers of traceability data. At the supplier level, it records information on collection centres and participating waste collectors. At the material level, it documents the types and quantities of plastics recovered and converted into recyclates. At the process level, it generates insights on environmental performance, GHG emissions, and compliance with recycling standards.

This case shows that digital tools can simultaneously address plastic waste and help close critical data gaps around informal sectors. By generating reliable information on material flows across informal and formal sectors, the intervention strengthens transparency in recycling value chains and supports verification of recycled-content claims. However, their effectiveness depends on inclusive design that integrates informal waste collectors, viable markets for recyclates, and alignment with infrastructure and policy frameworks, including standards, EPR schemes, and incentives for recycling.

↑ Sources: SMEP (2026); Oyinlola et al. (2022); Schröder et al. (2023).

GIVO-Warwick project



To learn more about the project, scan the QR code.

Systemic barriers are equally significant. The highly fragmented value chain results in discontinuities in data and CoC documentation. Data governance also remains weak, with unclear data ownership and confidentiality concerns permeating supply chains. Furthermore, the risk of fraud or misrepresentation of recycled content increases where verification mechanisms are limited or auditing capacity is low.

From a developing country perspective, structural issues such as inadequate waste management infrastructure, weak enforcement capacity, and limited policy coherence further slow adoption (Oyinlola, 2022). While international buyers increasingly demand traceable and verifiable recycled content, local market incentives may remain insufficient to justify investment. As a result, traceability adoption remains concentrated in export-oriented or donor-supported initiatives. A SMEP-supported project in Nigeria provides a practical example of how mobile technologies, digital platforms and data systems can be used to overcome some of these challenges in circular plastic supply chains (Box 5).



← Image 6. GIVO-Warwick collection centre equipped with solar roof panels. The centre serves as a decentralized hub for the collection, aggregation and digital tracking of plastic waste.

© H. Pacini (UNCTAD), 2024.



← Image 7. Electric bike used for plastic waste collection within the GIVO-Warwick project. By linking waste collection activities to digital monitoring systems, the initiative helps generate verifiable information on material flows from collection to recycling.

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| 3.2 Lead-acid batteries

Intrinsically circular, institutionally opaque supply chains

LABs power the majority of South Asia's electric three-wheeler fleet, underpinning a large segment of low-cost urban mobility and informal employment. The sector demonstrates high intrinsic circularity as used lead-acid batteries (ULABs) are systematically collected and recycled into new batteries. However, this circularity operates outside formal traceability frameworks, resulting in limited transparency over environmental performance, occupational safety and health risks, and material provenance (SMEP, 2025d).

In most developing countries, the LAB sector still operates as a circular but undocumented ecosystem. LABs are often recycled informally, driven by economic incentives such as high demand for batteries and the relative ease of LAB remanufacturing, rather than formal tracking systems designed for regulatory compliance. Most opportunities for product traceability are currently missed (Figure 7; Box 6). While environmental clearance requirements and hazardous waste monitoring frameworks are in place, enforcement capacity remains constrained, and informal recycling continues to dominate reverse flows (SMEP, 2024). However, some degree of oversight is found in countries such as Nigeria and India, where EPR schemes and digital "battery passports" are used to verify the CoC in processing and trade (IEA, 2025b; CPCB, 2024; NESREA, 2024).

Box 6. Traceability "touchpoints" and missed opportunities in the ULAB's value chain of Bangladesh



Battery manufacturing relies on two principal sources of lead. Primary lead bars are imported and supplied directly to manufacturers. These flows are commercially documented but not accompanied by sustainability certifications or CoC verification. Secondary, domestically recycled lead accounts for most production. It reaches manufacturers through two main channels: (a) informal recycling facilities supplying directly to manufacturers; (b) informal recycling facilities supplying aggregators or traders, who then sell to manufacturers.

Processing is undertaken by a mix of large formal manufacturers, foreign-owned facilities, and numerous informal producers. Material segregation may occur internally. However, it is rarely documented, audited, or verified. There is no batch-level tracking, recycled content accounting, or third-party certification.

Distribution and trade occur through dealers, sub-dealers, and retail battery shops. A defining structural feature of the sector is the embedded buy-back mechanism, as the return of a used battery provides a 40–50 percent credit toward a new purchase. This economic incentive ensures high recovery rates in the absence of a formal EPR system. However, transactions are undocumented and not digitally recorded, meaning that collection volumes are not systematically traceable, nor is lead leakage into the environment.

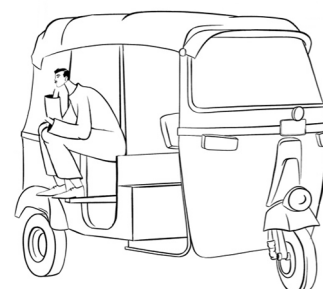
LABs used in e-rickshaws typically have a lifespan of six to nine months, resulting in high turnover and strong reverse flow intensity. No tracking or registration occurs during the use phase. Once a battery reaches the end of its lifespan, it is either recycled at informal recycling facilities (most likely) or refurbished and resold after minor repair (less likely). Although this creates a physically segregated, ULAB-only lead stream that is inherently circular, the lack of digital "check-ins" including documentation and certification at the collection points remains the primary obstacle to proving a verified CoC.

↑ Sources: Prepared by authors based on Kundu, Plambeck and Wang (2025) and SMEP interventions in Bangladesh.



← **Image 8.** Electric three-wheelers are commonly powered by LABs in Bangladesh, creating a steady supply of used batteries that sustains the country's informal recycling sector.

© E. Henshilwood (SouthSouthNorth), 2026.



↑ **Image 9.** Standard Bangladeshi three-wheeler

© L. Barcellos, UNCTAD 2024.



↑ **Image 10.** Man handling lead from informally recycled LABs. Informal recycling activities can create significant traceability gaps by limiting documentation of material provenance and processing practices.

© H. Pacini (UNCTAD), 2024.

Hotspots & gaps

In this context, the principal traceability hotspot lies within informal recycling facilities. At the point of manual battery breaking, information on origin and handling conditions is lost. Lead is recast into generic bars without documentation, breaking any potential CoC. Process losses (which often spread lead into the environment) are not tracked. The aggregator layer represents a second hotspot. Traders consolidate scrap volumes but do not provide standardized documentation, reducing visibility over material provenance.

The retail buy-back mechanism constitutes a key traceability gap. High recovery rates coexist with minimal data capture. Acid management presents an additional environmental and health risk, as improper disposal can contaminate soil and water systems. Cross-border movements of scrap batteries and secondary lead may introduce further governance challenges under international obligations, such as those associated with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention, 2003 and 1989).

Overall, the sector is economically circular but institutionally opaque. Material recovery is driven by price incentives rather than regulated tracking, constraining transparency and alignment with sustainability norms.

Industry ambition

Across the LAB sector, industry actors are increasingly investing in traceability. Global coalitions such as the Global Battery Alliance (GBA) are advancing frameworks for carbon footprinting and due diligence, including the Battery Passport, which is beginning to shape industry practice (Global Battery Alliance, 2025). Regional and national industry associations are also developing shared standards, certification schemes, and voluntary codes of conduct that reflect a growing recognition of environmental and social accountability as competitiveness drivers. Leading manufacturers and recyclers are participating in collective platforms designed to digitize battery lifecycle data and enable transparent reporting to buyers, regulators, and investors.



↑ Image 11. Woman without personal protective equipment handling lead-acid batteries for recycling

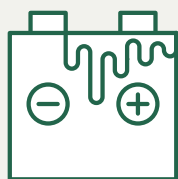
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Development potential is strongest in digital registration systems linking manufacturers, dealers, and recyclers; the integration of buy-back mechanisms into formal EPR frameworks; and standardized battery identification through QR-based product passports. Over time, shared reverse logistics infrastructure may further support the development of integrated traceability systems.

Adoption challenges

Barriers to traceability adoption occur at both the systemic and firm levels. At the systemic level, enforcement capacity is constrained by limited inspection resources and fragmented institutional coordination. No centralized digital battery registry currently exists. Standardized identification protocols are absent, and data governance systems remain underdeveloped (SMEP, 2025d, 2024). At the firm level, informal recyclers face limited access to affordable finance for upgrading to environmentally sound smelting technologies. Compliance increases operating costs relative to non-compliant competitors, discouraging voluntary formalization. In addition, most manufacturers are domestic-oriented and have limited commercial incentives to demand certified inputs as they do not export their batteries (Box 7).

Box 7. Strengthening governance and traceability in lead-acid battery recycling



The SMEP research project **Development of Business Models and Policy Interventions to Reduce Informal ULAB Recycling in Bangladesh**, implemented by Pure Earth in collaboration with Georgetown University, examines the environmental and governance risks linked with the rapid growth of electric mobility. In this context, electric three-wheelers are commonly powered by lead-acid batteries (LABs).

In Bangladesh, a large share of ULABs is collected and recycled through informal channels. These practices often involve unsafe smelting techniques that release toxic lead into the environment. Research indicates that up to 80 per cent of ULABs in Bangladesh are recycled informally, generating harmful lead pollution (UNCTAD, 2024; Pure Earth, 2021). The persistence of informal recycling is driven by strong economic incentives for lead recovery, limited capacity within the formal recycling sector, weak enforcement of environmental regulations, and the absence of effective systems for tracking material flows.

The SMEP-funded research focused on analysing the economic incentives and operating models of battery recyclers. Findings show that informal operators are able to offer higher prices for ULABs because they avoid compliance and environmental safeguarding costs. This creates a structural advantage over formal recyclers and encourages the diversion of batteries into unsafe channels. The research highlights the importance of improving transparency and traceability across the battery life cycle to reduce diversion and support environmentally sound recovery of valuable materials.

Used lead-acid battery solutions



To learn more about the project, scan the QR code.

Traceability not only improves visibility over battery flows but also provides evidence for policy action, as reflected in the project's contribution to the National Lead-Free Bangladesh Strategy and Multi-Year Action Plan (2026-2035). However, it is not sufficient on its own. Effective solutions require governance frameworks that combine formal collection and take-back systems, EPR schemes, enabling import-export tariff structures, economic incentives, common standards, stronger enforcement, and capacity-building to strengthen the formal sector and support safer and more regulate recycling (UNCTAD, 2024; Pure Earth, 2024).

↑ Sources: SMEP (2026); UNCTAD (2024); Pure Earth (2021) and (2024).

| 3.3 Textiles & apparel

Multi-tier and fragmented production networks

Textile and apparel value chains are among the most complex globally, involving multiple production tiers and geographically dispersed production networks. Traceability in this sector is closely linked to profitability and risk management. Yet, it remains limited due to fragmented supply chains – particularly at sourcing and processing stages, where physical segregation, mass balance and non-traceable flows coexist (Figure 7).

Hotspots & gaps

Traceability hotspots are concentrated at sourcing and processing stages, where buyer-supplier relationships span multiple tiers.¹⁴ Shared challenges arise in fibre blending (tier 3), dyeing and finishing (tier 2), subcontracting (tier 1), and chemical inputs supply across all tiers. Most companies lack systematic traceability approaches (Textile & Fashion, 2030) and production processes are where tracking most frequently breaks. Contributing factors include limited digital interconnectedness across suppliers, material and chemical mixing that eliminates traceability markers and limited regulation.

Outsourcing is widespread in the Global South, where material ownership may differ from process ownership. As a result, subcontractors are frequently missing from official supplier lists, limiting visibility. The dominant CoC models, physical segregation and mass balance, also have shortcomings. Certification schemes such as the Recycled Claim Standard (RCS) and the Organic Content Standard (OCS) focus on raw materials and fibre origin, while downstream processes such as dyeing and finishing are covered separately or inconsistently through frameworks such as Zero Discharge of Hazardous Chemicals (ZDHC). Only a limited number of standards, notably the Global Organic Textile Standard, provide integrated requirements spanning the entire value chain.

Reverse flows involve recycling post-industrial waste, wastewater reuse, recovering fabric off-cuts, and secondhand markets for apparel and footwear. Each recycling pathway brings distinct traceability challenges such as informal waste handling networks with no visibility of the actors involved. Fibre content in post-consumer waste is often inaccurately labelled, and reuse flows have minimal traceability once garments leave primary retail channels. Today, most recycled fibres used in textiles come from recycled Polyethylene Terephthalate (PET) bottles (Textile Exchange, 2025), supported by established CoC systems, most commonly mass balance.

¹⁴ Textile supply chains are often described in tiers: Tier 1 covers final garment or product assembly; Tier 2 includes fabric and yarn production, dyeing, and finishing; Tier 3 involves fibre processing; and Tier 4 refers to raw material production, such as fibre cultivation or fossil-based feedstocks.



← **Image 12.** Wastewater treatment facility at Fakir Knitwear, Dhaka, where SMEP, Fakir Group, H&M and Primark collaborate to reuse wastewater. Monitoring wastewater treatment and reuse generates verifiable information on chemical use, environmental performance and resource efficiency.

© H. Pacini (UNCTAD), 2025.



← **Image 13.** Examples of industry initiatives advancing traceability to support circular production, sustainability claims and due diligence in textile value chains.

© Cascale, 2026; Ellen MacArthur Foundation, 2026.

Industry ambition

Industry actors are increasingly advancing traceability to reduce risk and support the transition to low-carbon and circular production models. These ambitions are being articulated through industry-led alliances and coalitions such as the Textile Exchange, Cascale, and the Ellen MacArthur Foundation's Make Fashion Circular initiative (EMF, 2023; Cascale, 2024a; Textile Exchange, 2026). Through shared frameworks, targets and metrics, these platforms position traceability as enabling infrastructure – supporting credible sustainability claims and forming the foundation for effective human rights and environmental due diligence. Complementary initiatives such as the private-sector-led ZDHC extend traceability to chemical inputs and processes, enabling compliance with restricted substances requirements in textile manufacturing and wastewater treatment (ZDHC, 2024).

In parallel, industry actors are investing in shared digital platforms designed to operate across jurisdictions, such as the the Cascale Higg Index suite of standardised tools and datasets (Cascale, 2024b). Such collective infrastructure reflects a growing recognition that traceability challenges cannot be addressed effectively through fragmented or purely bilateral solutions.

At the same time, a rapidly evolving regulatory landscape influences and reinforces these efforts. Key policy drivers for traceability include the EU's initiatives ESPR (European Union, 2024a) and the Corporate Sustainability Due Diligence Directive (European Union, 2024b), as well as the Uyghur Forced Labor Prevention Act 2022 in the United States (US Customer and Border Protection, 2026). While regulations create global momentum and potential for new business models, current frameworks lack harmonization and can act as barriers to trade ([Chapter 2](#)). For instance, there is no unified definition of traceability, nor clarity on the levels required. Perspectives from the Global South are often underrepresented, which risks placing further administrative burdens on suppliers.

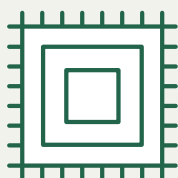
Power imbalances between the Global North and Global South continue to challenge effective traceability implementation. However, serious efforts exist to address them (Worldly, 2026).

Adoption challenges

The structural characteristics of the sector, including multi-tier supply chains and diverse raw materials, limit traceability adoption. Different fibres, ranging from synthetics (mostly polyester) to cotton and wool, have distinct traceability conditions, with visibility declining at lower tiers. Synthetic fibres, for example, lack unified raw material certification at tier 4 and have minimal upstream traceability beyond tier 3. The only exception is recycled polyester from PET bottles, which benefits from established CoC systems. Cotton and cellulosic fibres often rely on mass balance at tier 3, which limits origin tracing and physical tracking compared to segregation models used in organic fibres.

Adoption is also limited by the financial capacity of firms, especially in the Global South where sound management of sustainability-related risks is most needed. Most environmental and social impacts occur in developing countries in tiers 2 and 3 (Quantis, 2018), where implementing traceability is labour-intensive and expensive. In addition, the sector lacks harmonized standards, particularly terminology. For instance, broad terms like “packaging” often absorb disparate activities, such as ironing, branding, and sizing, which occur in different locations. Without precise process descriptions, data exchange becomes unreliable because IT systems across the value chain interpret terms differently. The issue is exacerbated in emerging reverse supply chains such as textile recycling, where fragmented waste streams, uncertain fibre composition and informal collection networks make traceable textile-to-textile (T2T) recycling particularly challenging. Emerging digital solutions are beginning to address these issues by improving visibility of waste streams, as illustrated by the SMEP-supported Reverse Resources platform (Box 8).

Box 8. Digital traceability for textile-to-textile recycling: the Reverse Resources platform



Scaling T2T recycling remains a major challenge for the global textile sector. Less than 1 per cent of textile waste is recycled into new textiles, while most recycled fibres still originate from plastic bottles (EMF, 2017; Textile Exchange, 2025; Boston Consulting Group, 2025). Progress is constrained by limited information on fibre composition, fragmented material flows, and competition with secondhand clothing markets.

The SMEP-supported **Reverse Resources platform** demonstrates how digital traceability can address these barriers by improving visibility over textile waste flows. The intervention focuses on post-industrial textile waste from garment manufacturing in major hubs such as Bangladesh and Pakistan, where waste streams are poorly documented and managed through intermediary networks. The platform acts as a digital marketplace that maps and tracks textile waste flows while linking waste generators, intermediaries and recyclers through verified transactions.

The platform captures traceability data. At the supplier level, it records information such as geographic location and brand affiliation. At the product and material levels, it documents waste types, fibre compositions, volumes, and handling practices such as segregation and sorting. It maintains end-to-end CoC records and supports sustainability metrics, enabling verification of recycled-content claims and alignment with emerging regulatory requirements such as DPPs.

This case highlights the role of digital traceability in organising fragmented waste streams and enabling local T2T recycling markets in developing countries. The platform is built around a clear business case, with traceability emerging as a by-product of participation rather than a reporting burden. The case also highlights the importance of inclusive tool design and deployment, as informal actors remain central to textile waste management.

↑ Sources: Reverse Resources (2025); SMEP (2026); Boston Consulting Group (2025); Textile Exchange (2025); Ellen MacArthur Foundation (2017).

Textile waste traceability



To learn more about the project, scan the QR code.



← **Image 14.** Tagged raw hides awaiting processing. Recording origin and supplier information at the point of sourcing is essential for maintaining traceability throughout the leather value chain.

© M. Rahman
(LeatherTrace), 2026.

| 3.4 Leather

Cross-industry linkages and duplicative compliance

The leather value chain connects commodity markets such as livestock production with low-tech, labour-intensive manufacturing across highly distributed supply networks. Through trade, these activities function as critical drivers of socio-economic development in many developing countries (SMEP, 2025b). Traceability addresses a wide range of risks, from deforestation linked to cattle production to chemical safety in tanning. At the same time, the sector involves multiple intermediaries, including collectors, traders, secondary manufacturers, and apparel brands, which can fragment information flows across the CoC. As a result, traceability challenges arise across the product life cycle, from the point of origin of raw hides to the end of life of consumer goods (Figure 7).

Hotspots and gaps

In the leather supply chain, traceability begins at the sourcing stage when raw hides are sold by slaughterhouses or collectors to tanneries. Initial arm's-length transactions of this kind are critical for successful tracking and verification at subsequent stages. Before hides are aggregated or split into different batches, their origin and legality must be clearly recorded (e.g., farm, supplier, date) through physical identification.¹⁵ Downstream data credibility depends on getting this early linkage right.

The use of tanning agents and other chemicals in processing introduces additional traceability challenges, including restricted substance management. Tracking these elements requires detailed and auditable data captured at the point of use. The difficulty is that standards and data requirements are rarely consistent across certification schemes and buyers, making it hard to maintain a clean, reliable record that satisfies all actors in the chain. As a result, non-traceable flows tend to prevail.

A significant traceability gap emerges when industrial by-products (e.g., offcuts, shavings) are converted into secondary products (e.g., gelatine, leather board). At this stage, inputs are frequently pooled, reclassified, and processed for different end-markets, making it difficult to maintain clear traceability of their original source. As a result, CoC often shifts from identity-preservation to mass balance, unless strict segregation and auditing controls are applied. Trade nodes are also frequent information-loss points because materials are aggregated and documentation is re-issued without persistent, standardized lot or item identifiers.

¹⁵ While this represents the highest level of ambition, the approaches and practices being implemented to achieve it remain uneven across regions and materials.

At the consumer use level, traceability is often limited to the point of sale, with end-of-life pathways (reuse, recycling) lacking interoperable product identifiers. Such fragmentation constrains the verification of recycled-content and related circularity claims, thus pushing leather businesses toward administrative claim models. In some cases, reverse flows of secondhand goods back to wholesalers, traders or brands for repurposing are tracked through physical segregation.

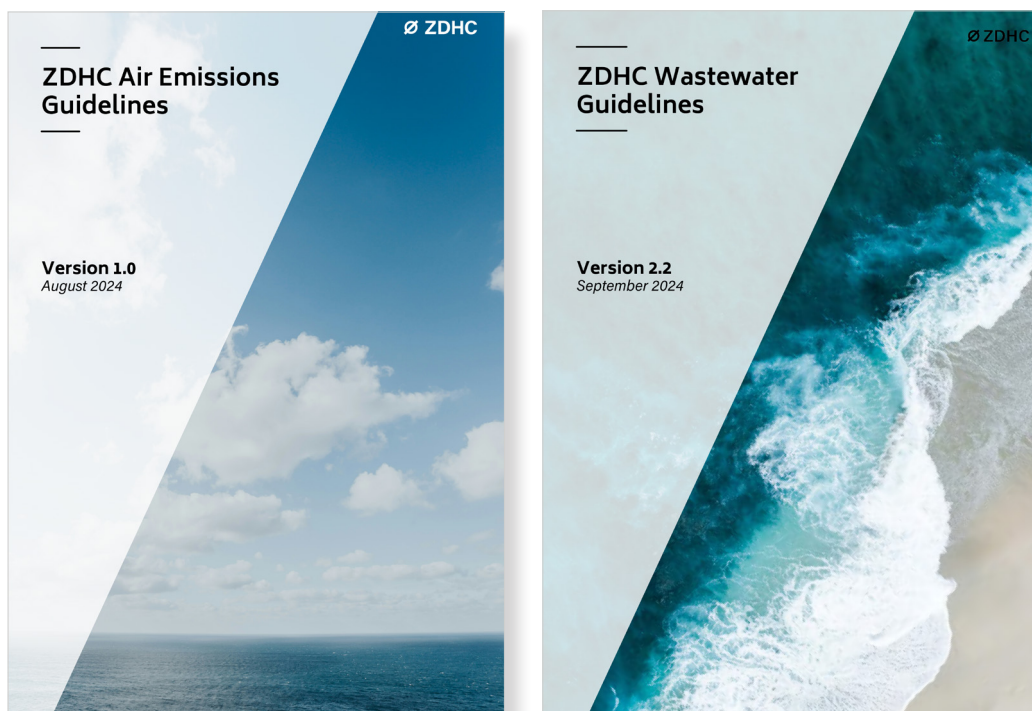
Industry ambition

The leather industry is moving away from a narrow compliance approach and transitioning towards more transparent and circular production systems.

Across the industry, associations such as the International Council of Tanners, the International Union of Leather Technologists and Chemist Societies are shaping good practice in leather processing and testing (IULTCS, 2026). Alongside these, sector initiatives such as the Leather Working Group, the Sustainable Leather Foundation (SLF), and COTANCE's Leather Traceability Cluster demonstrate increasing commitment to strengthen environmental governance and traceability (Sustainable Leather Foundation, 2024; COTANCE, 2024; Leather Working Group, 2024). For example, the LWG now treats chemical management as a mandatory audit component, aligning with frameworks such as the ZDHC (Leather Working Group, 2026a; ZDHC, 2025).

Industry efforts are also driven by emerging regulatory pressures, including more stringent chemicals regulation under the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulation (European Union, 2006) and due diligence requirements linked to deforestation, and product transparency (Leather Working Group, 2026b). At the same time, some players are positioning leather within broader circular economy and low-impact production debates through improved by-product use, resource efficiency, traceable sourcing, and data systems supporting repair, reuse, recycling, and recycled-content verification (Leather Working Group, 2025).

Traceability supports industry ambition by linking hides and skins to origin data for sustainability due diligence (Leather Working Group, 2025); enabling auditable chemical and process management (ZDHC, 2024); reducing duplication and improving comparability across certifications (COTANCE, 2024); and supporting circularity and responsible sourcing with data-backed claims (UNECE, 2022).



← Image 15. Examples of ZDHC guidance documents supporting chemical and environmental management in leather manufacturing.

© ZDHC, 2026.



← **Image 16.** Digital traceability in practice: scanning a QR code to access material information in the LeatherTrace Bangladesh project.

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↑ **Image 17.** Finished leather hides marked with engraved identification codes that enable traceability throughout the leather value chain in a SMEP-supported pilot in Pakistan.

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Adoption challenges

For many leather producers in developing countries, traceability is becoming a “de facto” market access condition, yet the capacity to comply remains uneven and costly. At the tannery level, challenges include the cost of implementing traceability systems (e.g., digitised intake and dispatch records, chemicals and production data), as well as limited technical capacity and digital literacy. Similar constraints also affect other actors, especially collectors, who frequently struggle to access to technology, infrastructure, and organisational capacity (Thakur et al., 2020; Uba et al., 2026).

Traceability systems require investment in equipment, software, staff time, and training. These are often prohibitive for micro, small and medium-sized enterprises (MSMEs), particularly when squeezed margins and fluctuating orders strain liquidity and threaten business continuity. These constraints are amplified in clustered production settings, where subcontracting and informal service provision can fragment data capture and weaken the continuity of the CoC (OECD, 2018).

Wider systemic challenges further compound the tannery-level barriers. Firstly, the fragmentation of traceability expectations across markets – which stems, in part, from the absence of harmonized, interoperable minimum datasets and common identifiers – forces leather producers to routinely report similar data in different formats (e.g., for audits). This “duplicative compliance” architecture increases transaction costs, discourages standard operating procedures within tanneries, and weakens comparability across supply chains (OECD, 2018).

A second challenge concerns data governance and the political economy of information. In fact, traceability requires disclosure of commercially sensitive data (e.g., sourcing routes, processing parameters), creating concerns over data ownership and misuse. In these circumstances, there is often uncertainty about who can view or use the disclosed data, and what safeguards are in place to guarantee against a misuse of that data and the loss of competitiveness which may flow from it. This can discourage commercial actors from adopting traceability systems (**Chapter 2**).

Finally, the fragmentation of digital traceability approaches remains a major constraint. In practice, leather supply chains often face a proliferation of buyer-specific platforms, certification interfaces, proprietary tools, and reporting requests that do not rely on the same identifiers, data fields, or verification processes (Euroleather, 2023). This weakens interoperability, raises transaction costs, and makes it difficult to sustain a continuous digital CoC across the entire value chain (Leather Working Group, 2024). The sector is responding with initiatives such as the COTANCE Leather Traceability Cluster, which aims to align the requirements of private schemes to facilitate mutual recognition while contributing to European standardisation discussions (COTANCE, 2024).

Complement private standard-setting, national initiatives such as Leathertrace's policy blueprint for digital traceability in Bangladesh are critical for reducing duplication and strengthening institutional coordination, thus creating the enabling conditions for interoperable and scalable traceability systems (Box 8). While this initiative illustrates a policy-driven approach to advancing traceability, a parallel SMEP-supported pilot led by WWF-Pakistan offers further insights into how traceability can be developed in close collaboration with public institutions (Box 9).

Box 9. Digital traceability pilots in Bangladesh and Pakistan's leather sectors



The SMEP Programme has supported two complementary traceability pilots in the leather sectors of Bangladesh and Pakistan. In Bangladesh, where buyer requirements drive adoption, the **LeatherTrace Bangladesh: Traceable and Circular Leather Production (TCLP)** project developed an integrated e-traceability solution combining end-to-end product tracking with environmental analysis. Using a cluster-based approach and working with 16 organizations, including eleven tanneries and five footwear and leather-goods manufacturers, the system traces raw hides from slaughterhouses through tanning and processing to finished products, including exports. The approach is tailored to local conditions while meeting international compliance requirements.

In Pakistan, WWF-Pakistan piloted a digital traceability toolkit in partnership with public institutions and industry actors. The intervention established the country's first digital system for tracing hides from suppliers through slaughterhouses and tanneries to finished leather. Collaboration with a state-operated slaughterhouse, a leading tannery and a global brand ensured alignment with existing systems and practical usability.

LeatherTrace Bangladesh



To learn more about the project, scan the QR code.

Both systems capture supplier-, process- and product-level CoC data, including facility registration, hide identification through digital and physical codes, raw-material origin data aligned with EUDR requirements, and processing stages within tanneries. The tools are designed to progressively integrate environmental and social compliance information, supporting alignment with DPP and emerging regulatory frameworks.

Key lessons show that there is no single pathway to leather traceability. A compliance-oriented model in Bangladesh and an infrastructure-first approach in Pakistan can both succeed when tailored to local conditions and co-developed with industry and public actors. In contexts with limited formalization, establishing basic digital infrastructure is often the critical first step.

Pakistan leather sector



To learn more about the project, scan the QR code.

Both pilots equip policymakers to support scale-up and regulatory alignment. In Pakistan, collaboration with national bodies, including the Pakistan Tanners Association and the Trade Development Authority of Pakistan, supports uptake and export readiness. In Bangladesh, stakeholders are developing a policy blueprint to embed traceability into trade frameworks in collaboration with the Ministries of Commerce and Industry (LeatherTrace, 2026a). Strong interest from industry and policymakers signals readiness to scale as regulatory and market demands accelerate.

↑ Sources: SMEP (2026 and 2025b); WWF-Pakistan (n.d.); LeatherTrace (2026a)



← **Image 18.** Handling coloured textile fibres during processing. Fibre blending and processing stages are critical traceability hotspots, where information on fibre composition and chemical inputs may be lost.

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4.

Synthesis of findings & actionable guidance

| 4.1 Traceability archetypes

The sectoral analysis presented in Chapter 3 shows that different traceability approaches follow distinct sectoral “archetypes”, shaped by adoption drivers, implementation challenges, and supply chain characteristics. In plastics, traceability reflects a regulatory-driven “quest” for recycled content, as large industry players increasingly demand verification of post-consumer recycled materials in response to emerging regulations such as the EU Packaging and Packaging Waste Regulation. In contrast, LABs rely on an established circular model driven primarily by price signals but operate through highly informal, poorly documented collection and recycling systems, lacking formal traceability frameworks.¹⁶

In the leather sector – also increasingly shaped by regulations – traceability is emerging as a tool for due diligence and to consolidate vital linkages between livestock production, fashion, and petrochemicals. However, this also creates instances of “duplicative compliance” when different expectations and standards apply across supply chains. Finally, in textiles and apparel sector, traceability adoption is driven by demand for verified sustainability claims but constrained by the complexity of multi-tier and geographically dispersed production networks. **Table 1** summarizes the main patterns observed across the four sectors. While not exhaustive, these archetypes highlight how different structural conditions shape traceability adoption.

¹⁶ However, it should be noted that this does not apply to batteries other than lead-acid ones.

Table 1. Lessons from the sector analysis: emerging traceability “archetypes”

Sector/archetype	Core features	Traceability challenges	Dominant models
Plastics A regulatory-driven quest for recycled content	Strong regulatory pressure to incorporate and verify post-consumer recycled content Fragmented waste collection and recycling systems Multiple material flows, including reverse logistics	Verification of recycled content Loss of information at aggregation and transformation stages	Mass balance, with limited physical segregation
Lead-acid batteries Intrinsically circular, institutionally opaque supply chains	High material recovery driven by economic incentives (e.g. lead value) Widespread informality and weak institutional oversight Well-established reverse logistics (e.g. lead buy-back)	Lack of formal documentation and opaque material flows (e.g. collection, recycling)	Predominantly non-traceable flows Limited use of formal CoC systems in more advanced contexts (e.g. India)
Textiles & apparel, including for reuse recycling Multi-tier and fragmented production networks	Highly complex, multi-tier, and geographically dispersed upstream supply chains Multiple raw materials (e.g. fibres) and heavy reliance on subcontracting	Loss of traceability upstream (tiers 2–4) due to material mixing, subcontracting Loss of traceability downstream due to fragmented waste streams, and informal collection	Mix of physical segregation and mass balance Certification-based systems
Leather Cross-industry linkages and “duplicative compliance”	Value chain spans multiple industries (livestock, chemicals, fashion) Multiple intermediaries Increasing regulatory scrutiny (e.g. due diligence, deforestation)	Fragmented data across supply chains where different standards apply Information loss at major trade nodes due to material aggregation and ineffective documentation Challenges in tracking chemical use and downstream flows	Combination of physical segregation and mass balance Administrative verification

↑ Source: Prepared by authors based on cited literature in and insights from the sector case studies.

Traceability development is shaped by different incentive structures, ranging from regulatory-related to market-driven. While compliance with public and private standards can function as an incentive, its ultimate incidence depends on the spatial organisation and trade intensity of the sector. For example, buyer requirements are a primary driver of adoption in export-oriented sectors such as textiles. A similar dynamic is observed in the leather sector, where due diligence regulations and private certifications are converging, making traceability a de facto condition for market access.

In contrast, in the LABs sector, economic incentives such as price signals for lead recovery drive circularity through well-established buy-back mechanisms. Manufacturers focused on domestic markets face weaker incentives to formalize traceability, as they are less exposed to mandatory and voluntary export market requirements. In this context, compliance may increase operating costs relative to non-compliant competitors, thereby discouraging voluntary formalization.

Despite incentive specificities dictated by their trade orientation, the four sectors also share challenges where policy action can be aligned. Across all sectors, business informality emerges as a major source of information gaps and breaks in the CoC. Informal transactions tend to permeate key traceability hotspots, from sourcing to end-of-life. For example, in plastics, information is frequently lost at the sourcing stage due to informal collection practices. In batteries (LABs), important levels of informality are observed in collection and recycling, undermining the tracking of secondary material flows.

Limited access to finance for investment is an issue in both the plastics and batteries sectors, where companies struggle to acquire new technologies to verify recycled content and shift to environmentally sound smelting, respectively. Similarly, in the leather sector, high upfront investment costs are a barrier to the adoption of software and equipment that enables credible traceability (e.g., routine lot identification). This also requires specialized skills, whose supply can be limited.

At the systemic level, all sectors struggle with the high fragmentation and limited harmonization of standards, which hamper system interoperability and act as cost multipliers. While standards increasingly co-evolve and there is evidence of harmonization efforts, further development is needed to enable interoperability at scale. Key challenges include unevenly used terminology (textiles), lack of standardized identification and data governance protocols (batteries) and inconsistent data requirements across certification schemes (leather).

Some issues are observed more frequently in developing countries, where weak institutional capacity and policy coherence affect traceability uptake. For example, traceability may not be adequately embedded in policy frameworks or laws covering key CoC hotspots (e.g., mixing of materials and chemicals in textiles). Even when traceability is reflected in policies, regulatory frameworks can be fragmented (leather) and the enforcement capacity of government agencies weak (batteries, plastics). This results in an unpredictable business environment and a lack of conducive framework conditions.

Cross-sector traceability synergies also emerge from the sector analysis, particularly around plastics. For instance, most recycled fibres used in textiles come from recycled PET bottles (Ellen MacArthur Foundation, 2017). Recycled PET is also emerging as an investment pivot in packaging, with its market valued at USD 13 billion in 2025 and projected to grow at a compound annual growth rate (CAGR) of 8 per cent over the next decade (Fortune Business Insights, 2026). Similarly, polyester is mixed with natural fibres such as cotton and bamboo in sustainable textile-grade blends (SMEP, 2025a). These linkages can multiply the benefits of traceability investments, enabling actors with shared objectives to institutionalize synergies through co-investment or de-risking mechanisms.

| 4.2 Recommendations

The sector analysis, coupled with findings in [Chapters 1](#) and [2](#), points to a process of “unlocking convergence”, not only at the sectoral level, but also across jurisdictions, public and private regimes, and technical systems, where traceability has become a cornerstone of sustainability compliance. Beyond compliance, traceability can also enhance trade facilitation and competitiveness by improving information flows, reducing transaction costs, bridging formal and informal markets, and enabling access to high-value markets. While incentives for adoption may differ across markets and industries, trade acts as a key transmission mechanism, aligning corporate practices and expectations as sustainability-related regulations and VSS increasingly embed traceability elements.

Overall, traceability adoption unlocks more visible and transparent supply chains, but involves multifaceted challenges that require coordinated and comprehensive policy approaches. Effective policy action must prioritize the needs of developing countries and involve the full spectrum of stakeholders, working collaboratively to address adoption barriers at key trade-related intersections, such as the nexus of environmental, economic development and public health policy.

Based on the analysis presented in **Chapters 2, 3, and 4**, a number of recommendations can be identified to support the adoption of digital traceability at scale:

Governments

Promote the adoption of digital traceability at stages in the supply chain where it has the greatest leverage, such as pre-tannery trade in leather and sorting and aggregation in plastics, by:

- Introducing mandatory traceability requirements through sector-specific platforms and roadmaps, including incentives to help overcome integration costs.
- Supporting business formalization at key supply chain nodes (e.g., plastics recycling), creating an enabling environment for investment in traceability systems.
- Supporting compliance and certification costs through concessional finance (e.g., low interest loans), skills development, and subsidies for technology investment (e.g., tax exemptions).
- Providing tailored capacity-building services such as training and skills development to enhance technological readiness and digital literacy.
- Investing in digital (e.g., broadband, data systems) and quality infrastructure (e.g., testing labs) required to demonstrate compliance with traceability-related standards.
- Supporting the development and adoption of DPPs and related product-level identification systems, in line with emerging regulatory frameworks, to enable interoperable traceability across product life cycles.
- Facilitating access to traceability-enabling technologies and services through trade policy, including duty-free treatment for critical equipment and measures to ease access to relevant software/digital solutions (e.g., cross-border data flows).
- Leveraging and formalizing existing market-based incentives (e.g., buy-back schemes in batteries, collection systems in plastics) under EPR frameworks to strengthen traceable material flows.

Support alignment of standards and conformity assessment procedures to reduce “duplicative compliance” and enable interoperability, by:

- Integrating VSS into national and regional policy instruments, such as due diligence regulations and procurement schemes.
- Institutionalizing industry-led protocols, standards, and platforms that proved successful for enhancing interoperability and reducing the verification burden, such as the GS1; integrate them as verification means or assurances in due diligence processes.
- Negotiating and concluding MRAs around conformity assessment procedures at a bilateral, regional or plurilateral level.
- Engaging in multilateral discussions, such as at the WTO Technical Barriers to Trade (TBT) Committee, or at informal dialogues, on reducing regulatory fragmentation and integrating VSS into trade policies.
- Facilitating multistakeholder consultations at the national level, involving both national and international stakeholders from the private sector, standard-setting bodies, and international organisations (such as ISO, UN/CEFACT).

Multilateral agencies and donors

Translate market signals into actionable support through evidence, dialogue, technical assistance, and investment promotion, by:

- Supporting investment in traceability and measurement, reporting and verification (MRV) infrastructure in developing countries, including interoperable digital systems and verification capacity, to enable firms to meet emerging market access requirements.
- Promoting the integration of developing country perspectives into policy development processes, including voluntary standards and due diligence regulations (e.g., EU Green Deal for textiles), through phased roadmaps and trade-related technical assistance.
- Facilitating multi-stakeholder dialogue to promote alignment around public and private standards and due-diligence regulations, including through WTO committees and plurilateral discussions (e.g., WTO Trade and Environmental Sustainability Structured Discussions).
- Addressing market failures constraining adoption, such as data fragmentation and high upfront investment costs, through transparency initiatives (e.g., UNTP) and innovative financing and de-risking models (e.g., SMEP).¹⁷
- Designing and funding trade-related technical assistance programmes that address key bottlenecks to traceability adoption, in coordination with existing initiatives, including:
 - a. Policy and regulatory capacity-building that assists developing country governments in designing regulatory frameworks, enforcing regulations, and participating effectively in international standard-setting processes;
 - b. Digital literacy, technical skills, and technology adoption support for SMEs and informal sector actors, including on a shared basis;
 - c. Ecosystem-level interventions that address shared infrastructure gaps, strengthen testing and certification capacity, and foster the emergence of local traceability solution providers.
- Supporting the update and expansion of the HS classification to better reflect traceability-enabling technologies presently captured under broad, non-specific HS codes. This can be facilitated by the World Customs Organisation involving national customs authorities.

¹⁷ Coordination between various initiatives aimed at transparency is essential to avoid duplication and minimise burden for firms. Also, data gathering initiatives and data repositories must connect seamlessly to country-based centralized systems and local private-sector driven efforts (for e.g. the GIVO-Warwick initiative) and be based on commonly agreed upon and harmonised protocols.

Supply chain actors

International buyers, suppliers, business support organisations

Invest in digital traceability systems to meet regulatory requirements and buyer expectations, while supporting frameworks and standards for convergence and interoperability, by:

- Exploring co-investment schemes (e.g., buyer-supplier) in digital systems and upskilling initiatives. This reduces upfront costs, shares risks, and facilitates access to finance.
- Contribute to industry-led platforms and shared data infrastructure to support standards development, interoperability, and the exchange of verified supplier information (e.g., Global Traceability Framework for Beef and Leather and the UNTP).
- Reducing “duplicative compliance” through better coordination between international buyers and standard-setting bodies to ensure consistency in requirements (e.g., terminology).
- Adapting expectations to the specific contexts and realities of producers in developing countries. Requirements can be gradually strengthened over time through phased roadmaps.

Standard-setting bodies and solution providers

Support alignment, mutual recognition, and integration of traceability-related standards, while ensuring that developing country perspectives are reflected, by:

- Engage with regulators and peers to harmonize standards and align requirements (e.g., verification methods); support the recognition of VSS as credible tools in due diligence regulations and sustainability provisions of free trade agreements.
- Aligning existing standards with the traceability requirements of mandatory due diligence legislation.
- Involving non-traditional stakeholders, such as business support organisations from developing countries, in consultations to develop new or updating existing standards with a view to better reflect developing country perspectives and needs.
- Promoting inclusive, low cost and scalable traceability standards by embedding technical assistance and adequate transition periods, and by targeting feasible “entry points” (e.g., basic physical segregation, simplified mass-balance models).

These actions can support a gradual transition toward interoperable, scalable, and inclusive traceability systems across supply chains, enhancing the ability of developing countries to seize opportunities in sustainable trade while strengthening digital capabilities.

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Annex 1

Traceability projects in the Sustainable Manufacturing and Environmental Pollution Programme

Sector	Country	SMEP Project	Lead partner	Description
Plastics	Nigeria	GIVO-Warwick project Digitally enabled traceability for africa's circular economy 	GIVO Africa Warwick University	GIVO Africa is a circular economy company that leverages the use of technology to collect, process and upcycle plastic waste into valuable goods. The project focuses on digitally tracking and monitoring waste collection centres to enable data-driven solutions to plastic waste management and optimising the plastic management supply chain.
Used lead-acid batteries	Bangladesh	Used lead-acid battery solutions Business model solutions for lead-acid batteries in the e-mobility sector 	Pure Earth Georgetown University	Research and testing of business and micro-finance models to shift battery collection and recycling from the informal to the formal sector, while encouraging policies that promote the uptake of higher-quality lead and lithium batteries.
Textiles	Bangladesh Pakistan	Textile Waste Traceability Using data to revolutionise textile waste management and recycling 	Reverse Resources	Through the Reverse Resources Software-as-a-Service digital traceability platform, the project aims to grow the demand for T2T recycling and provide verifiable data.
Leather	Bangladesh	LeatherTrace Bangladesh Traceable and circular leather production 	University of Northampton	Developed a first-of-its-kind traceability pilot in Bangladesh that enables hides to be traced from slaughterhouse to final product.
	Pakistan	Pakistan Leather Sector Traceability, cleaner production and circularity 	WWF-Pakistan	Designed and testing a pioneering traceability pilot in Pakistan, enabling end-to-end tracking of hides from slaughterhouse to finished product.



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