

Legal Approaches to Data Transfer and Traceability in CRM Value Chains Internationally



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ABSTRACT

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China controls nearly 90% of the global supply of strategic rare earth elements, and its 2025 export restrictions exposed significant vulnerabilities in global critical raw material (CRM) supply chains. Although many jurisdictions have adopted traceability requirements to improve supply chain transparency, these measures increasingly conflict with national data sovereignty regulations, creating a legal trilemma involving transparency, data control, and international trade. This study examines the legal implications of divergent data sovereignty regimes for CRM traceability and evaluates the adequacy of existing international mechanisms governing cross-border data transfers. The research employs a normative legal method using statutory, conceptual, comparative, and analytical approaches to assess the compatibility of domestic regulatory frameworks with international trade obligations. The findings reveal three principal conclusions. First, existing international and domestic legal frameworks governing cross-border data transfers remain fragmented, generating regulatory inconsistencies that undermine the effectiveness, reliability, and interoperability of CRM traceability systems. Second, an effective international traceability framework requires harmonized legal standards that establish clear and proportionate rules, recognize the legal validity of digital traceability records, safeguard legitimate state interests in strategic data governance, and facilitate secure cross-border information exchange. Third, although the traceability trilemma cannot be completely resolved because transparency, data sovereignty, and international trade embody competing legal priorities, a balanced international legal framework aligned with World Trade Organization principles can reduce regulatory conflicts, strengthen legal certainty, prevent disguised trade restrictions, and promote trustworthy cooperation throughout the global CRM value chain.



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Introduction

Global critical raw material supply chains increasingly operate across multiple jurisdictions, requiring a single product to comply simultaneously with diverse national data governance frameworks. Throughout its cross-border journey, a battery or critical mineral may become subject to several distinct legal regimes regulating data sovereignty, traceability, and cross-border data transfers, thereby creating significant regulatory complexity. The movement of a lithium battery from

Chile to China, then the EU, then the United States shows this challenge clearly.¹ Each border brings new rules, new demands, and new risks. Every country in that path demands control of its own data. Each country also expects strong proof of responsible sourcing. At the same time, every country wants security in its trade systems. This is the core of the traceability trilemma.² The trilemma asks how we can respect data sovereignty, improve supply chain transparency, and protect trade security at the same time. Critical raw material (CRM) supply chain governance has attracted growing multidisciplinary attention, spanning resource economics, international trade law, and sustainability science.³

China has dominated rare-earth elements for many decades. It mines most global supply and refines nearly 90% of it. In April 2025, China imposed new export licensing rules on seven rare-earth elements. It claimed these controls were needed for national security reasons.⁴ The policy caused fast disruption in global trade flows. U.S.-bound shipments of rare-earth magnets dropped with long licensing delays. Many applications also faced a growing backlog inside China's system.⁵ The rules reached beyond China's borders and affected foreign exporters. Companies now needed Chinese approval to re-export goods with small Chinese-origin inputs. Shipments improved later in 2025, but U.S. firms stayed worried. China's strong refining position and control of key permits increased its leverage. In November 2025, China paused some controls for one year as a tactical step.⁶

The pause in China's controls reduces short-term pressure, but the main risk remains. Global supply chains still depend on a major power that can use its legal tools at any time.⁷ This dependence creates tension between three key priorities in trade. Countries want data sovereignty to protect their own production and resource information. They are cautious about sharing data that may expose

¹ Jing Li, Yibing Ding, and Yingjie Fu, "Accumulating Cross-Border M&A Experience and Its Impact on Enterprise Innovation: Evidence from China," *Economic Modelling* 158 (2026): 107529, <https://doi.org/10.1016/j.econmod.2026.107529>.

² Eloy Gil-Cordero, Belén Maldonado-López, and Pablo Ledesma-Chaves, "Cross-Border Marketing in Tourist SMEs in the Alentejo-Algarve-Andalusia Euroregion," *Cities* 172 (2026): 106912, <https://doi.org/10.1016/j.cities.2026.106912>.

³ Sean T Sithole, Daniel Tevera, and Mulugeta F Dinbabo, "Feeding Hope: Zimbabwean Migrants in South Africa and the Evolving Landscape of Cross-Border Remittances," *Global Food Security* 44 (2025): 100843, <https://doi.org/10.1016/j.gfs.2025.100843>.

⁴ Cornel Anyisile Kibona and Joel Matiku Joshua, "Mapping Economic Linkages between River Basin Management and Cross-Border Trade Performance in Tanzania," *Social Sciences & Humanities Open* 13 (2026): 102507, <https://doi.org/10.1016/j.ssaho.2026.102507>.

⁵ Meng Chen, "Developing China's Approaches to Regulate Cross-Border Data Transfer: Relaxation and Integration," *Computer Law & Security Review* 54 (2024): 105997, <https://doi.org/10.1016/j.clsr.2024.105997>.

⁶ Shujie Yao et al., "Technology Breakthrough Borders: Impact of Cross-Border Green Patents on Firms' Environmental Performance," *International Review of Economics & Finance* 107 (2026): 105060, <https://doi.org/10.1016/j.iref.2026.105060>.

⁷ Chen, "Developing China's Approaches to Regulate Cross-Border Data Transfer: Relaxation and Integration."

strategic assets.⁸ At the same time, companies and regulators need supply chain transparency for responsible and lawful sourcing. Without clear information, ESG compliance and public trust become uncertain. Trade security adds another layer of pressure for states and firms.⁹ They must protect sensitive knowledge and key technologies from misuse. The limits on data sharing can disrupt trade flows and reduce visibility.¹⁰ Other governments have tried to reduce these risks through diversification efforts. In November 2025, the United States agreed to support new mineral projects in Uzbekistan. Concerns about transparency have also grown in many sectors of CRM value chain. In 2019, Volvo Cars used blockchain to trace cobalt in its electric vehicle batteries. This system helped the company verify responsible sources across its global value chain.¹¹

The implementation of Digital Product Passports (DPP) for CRM in battery value chains faces significant legal conflicts across jurisdictions, requiring cross-border cooperation principles to address jurisdiction, enforcement, and mutual recognition challenges.¹² Traceability in critical mineral supply chains encounters persistent challenges in standardization, verification, and establishing effective cross-jurisdictional frameworks that accommodate multi-country operations. Self-sovereign identity technologies using decentralized identifiers and verifiable credentials can manage DPP while balancing decentralization, trust, and stakeholder data control.¹³

DPP can enhance circular economy principles for CRM by maintaining detailed provenance tracking throughout the material lifecycle, particularly for electric vehicle battery reuse and recycling. A digital twin model employing Product-Process-Resource Asset Network architecture enhances traceability capabilities during battery end-of-life disassembly and recycling phases.¹⁴ Natural language

⁸ zJanika Leoste et al., "Professional Development of Educational Researchers in Cross-Sector and Cross-Border Mobility: Evidence from a Reflexive Study of the EdTech Talents Project," *Higher Education, Skills and Work-Based Learning* 16, no. 8 (2026): 85–101, <https://doi.org/10.1108/HESWBL-08-2025-0364>.

⁹ Himadree Phookan and Revti Raman Sharma, "Cross-Border Interpersonal Knowledge Sharing within the MNE: Does Intra-MNE Competition Hinder or Facilitate It?," *Journal of Knowledge Management* 29, no. 4 (2025): 1229–47, <https://doi.org/10.1108/JKM-07-2024-0847>.

¹⁰ Ye Zhou, Wenbo Zhang, and Tianhao Ma, "Geopolitical Risks and Cross-Border Allocation of Bank Capital," *Economics Letters* 265 (2026): 113012, <https://doi.org/10.1016/j.econlet.2026.113012>.

¹¹ Geng Deng and Weiwei Liu, "Unpacking the Role of Corporate Culture in Cross-Border M&As: Evidence from China and Machine Learning Insights," *Journal of Asia Business Studies* 20, no. 3 (2026): 629–47, <https://doi.org/10.1108/JABS-08-2025-0476>.

¹² Emmanuel Kwesi Arthur, Sofía De-León Almaraz, and Tamás Solymosi, "Connecting Europe through Hydrogen: Cost Allocation Analysis of Cross-Border Pipeline Coalitions under Varying Subsidy Policies," *Energy Policy* 218 (2026): 115492, <https://doi.org/10.1016/j.enpol.2026.115492>.

¹³ Chen Pan et al., "Tracing Chinese Provincial CO2 Emissions in Cross-Border Production – An Accounting Base for Decarbonizing Production Chains," *Energy* 322 (2025): 135509, <https://doi.org/10.1016/j.energy.2025.135509>.

¹⁴ Sheng Zhang and Henry Gao, "Bridging the Great Wall: China's Evolving Cross-Border Data Flow Policies and Implications for Global Data Governance," *Computer Law & Security Review* 59 (2025): 106208, <https://doi.org/10.1016/j.clsr.2025.106208>.

processing technologies can be applied across battery lifecycle phases, with a proposed technical language processing framework improving data extraction and standardization in digital passport systems. Data space architectures in supply chains must balance security requirements, data sovereignty concerns, and effective data sharing among participants through shared but governed infrastructures.¹⁵

Blockchain technology combined with self-sovereign identity principles enables supply chain actors to certify and share traceability data while maintaining granular control over access permissions.¹⁶ Blockchain implementation in sustainable supply chains requires careful consideration of governance, policy, and technical challenges to enhance transparency without compromising sensitive business data. Threat modeling analysis of traceability systems reveals cybersecurity vulnerabilities including adversarial access risks and potential exploitation scenarios that require mitigation strategies.¹⁷

Despite advances in technical traceability and DPP analyses for CRM, International trade law studies has only recently begun to examine how data governance conflicts intersect with supply chain due diligence obligations. It leaves critical gaps in understanding how compliance frameworks must evolve.¹⁸ Current research studies the UNCRMTP and lessons from the conflict-of-laws White Paper. However, guidance on applying these lessons to Recommendation 51 is limited. Recommendation 49 sets general traceability principles, but literature does not show how Rec 51 builds enforceable rules. Few studies examine harmonizing these regulations with DEPA, RCEP, IPEF, or other multilateral agreements.¹⁹ The scope, roadmap, and practical mechanisms for an “International Traceability Law” are still unclear.²⁰

Current research does not show how legal lessons in traceability can form international laws. These laws should balance data sovereignty, supply chain

¹⁵ Franziska Klügl and Hildegunn Kyvik Nordås, “Cross-Border Data Flows and AI Adoption: Agent-Based Model Simulations,” *Structural Change and Economic Dynamics* 75 (2025): 676–88, <https://doi.org/10.1016/j.strueco.2025.10.009>.

¹⁶ Renhui Fu et al., “The Cost of Cross-Border Listing: Evidence from the Holding Foreign Companies Accountable Act,” *Economics Letters* 266 (2026): 113039, <https://doi.org/10.1016/j.econlet.2026.113039>.

¹⁷ Yuhuilin Chen and Miao Wang, “The Effects of Cross-Border Acquisitions on Acquirers’ Environmental Performance: The Mediating Role of Overseas Market Expansion and Green Innovation,” *Finance Research Letters* 100 (2026): 110007, <https://doi.org/10.1016/j.frl.2026.110007>.

¹⁸ Huiling Song et al., “Is It Wise for Cross-Border e-Commerce Platforms to Bear Estimated Imported Charges on Behalf of Consumers?,” *International Journal of Production Economics* 295 (2026): 109938, <https://doi.org/10.1016/j.ijpe.2026.109938>.

¹⁹ Hua-Tang Yin and Kai Tang, “Unlocking AI Growth in Emerging Economies: The Role of Cross-Border Venture Capital,” *Pacific-Basin Finance Journal* 98 (2026): 103189, <https://doi.org/10.1016/j.pacfin.2026.103189>.

²⁰ Pradnya B Patil and M Sangeetha, “A Comprehensive Performance Analysis of a Hyperledger Fabric-Powered Blockchain Network for Cross-Border Fund Transfers,” *Procedia Computer Science* 233 (2024): 723–32, <https://doi.org/10.1016/j.procs.2024.03.261>.

transparency, and trade security.²¹ Guidance is limited on turning technical standards into policy recommendations using frameworks like Rec 49. There is little information on designing governance models that meet national control and business transparency needs. Supply chain security in CRM industries also requires better study. Research is almost nonexistent on linking international standards, trade agreements, and sustainability programs. A unified system for recognition across borders remains unclear.²² Furthermore, developing practical solutions requires clearer legal and technical guidance for global cooperation. Expert's consensus increasingly recognizes that fragmented regulatory environments inhibit effective international governance of digital trade in high-risk commodity sectors. The objectives of this research are²³

This study analyzes how divergent national data sovereignty frameworks generate legal and operational barriers that restrict the cross border transfer of information required to ensure effective traceability throughout critical raw material value chains.²⁴ It evaluates the legal adequacy of existing international data transfer mechanisms in facilitating traceability data exchange while accommodating competing national sovereignty interests.²⁵ The study further examines the necessity and feasibility of establishing an international legal framework capable of reconciling the competing objectives of data sovereignty, supply chain transparency, and trade security within digital traceability systems for critical raw materials.²⁶

This research contributes to the development of the normative and legal foundations of International Traceability Law as an emerging field situated at the intersection of international trade law, data governance, and sustainable supply chain regulation.²⁷ The study clarifies the legal obligations governing traceability for industries that depend on critical raw materials, including battery manufacturing, electronics, and the circular economy, while promoting greater

²¹ Hassan Haidar, "Closing the Global Loop: A Battery Deposit Mechanism for Cross-Border EV Battery Recycling," *Journal of Cleaner Production* 572 (2026): 148917, <https://doi.org/10.1016/j.jclepro.2026.148917>.

²² Hussain G Rammal, Elizabeth L Rose, and João J Ferreira, "Managing Cross-Border Knowledge Transfer for Innovation: An Introduction to the Special Issue," *International Business Review* 32, no. 2 (2023): 102098, <https://doi.org/10.1016/j.ibusrev.2022.102098>.

²³ Yuanfeng Cai and Timothy J Lee, "Sustaining Mobile Payment Habits Abroad: Merchant Warmth, Competence, and the Socio-Technical Foundations of Cross-Border Continuance," *Journal of Retailing and Consumer Services* 93 (2026): 104881, <https://doi.org/10.1016/j.jretconser.2026.104881>.

²⁴ Hiroshi Miyashita, "Human-Centric Data Protection Laws and Policies: A Lesson from Japan," *Computer Law & Security Review* 40 (2021): 105487, <https://doi.org/10.1016/j.clsr.2020.105487>.

²⁵ Liam Curren and Jane Kaye, "Revoking Consent: A 'Blind Spot' in Data Protection Law?," *Computer Law & Security Review* 26, no. 3 (2010): 273–83, <https://doi.org/10.1016/j.clsr.2010.03.001>.

²⁶ Zhi Tang et al., "Cyber-Physical Internet Enabled Two-Echelon Routing with Dynamic Order Consolidation Strategy in Cross-Border e-Commerce Logistics Systems," *Computers & Industrial Engineering* 219 (2026): 112232, <https://doi.org/10.1016/j.cie.2026.112232>.

²⁷ David Erdos, "Dead Ringers? Legal Persons and the Deceased in European Data Protection Law," *Computer Law & Security Review* 40 (2021): 105495, <https://doi.org/10.1016/j.clsr.2020.105495>.

legal certainty for cross border commercial activities. It also formulates principles that support the mutual recognition of national traceability systems, reduce regulatory fragmentation, and strengthen international regulatory cooperation.²⁸ Furthermore, the study identifies legal pathways that enable resource rich developing countries to participate in global traceability networks while preserving sovereign authority over strategic data. Finally, it addresses governance challenges associated with critical raw material supply chains by examining legal responses to corruption, environmental degradation, conflict financing, and human rights risks through a coherent international regulatory framework.²⁹

Research Method

This research uses qualitative methods to examine international legal frameworks and regulations. Qualitative methods are well-suited to analyzing complex regulatory documents. They allow detailed review of legal texts, policy papers, and frameworks. The study analyzes how countries regulate CRM supply chains. This approach helps understand conflicts between different national rules. It also examines compliance mechanisms, legal principles, and regulatory requirements.³⁰ Countries are divided into three categories based on supply chain roles. The first category focuses on mineral exploration and extraction in resource-rich nations. The second category focuses on production and processing in manufacturing countries. The third category focuses on users and consumption in major market economies. Indonesia represents the mineral exploration category in this research. Its nickel mining share rose from 34 percent to 52 percent between 2020 and 2023. Its refined nickel share increased from 23 percent to 37 percent. China represents the production-focused category, contributing to global refining capacity. In 2024, China and Indonesia together accounted for 90 percent of global nickel additions. The European Union represents the user-focused category. EU demand for rare-earth metals is projected to increase six-fold by 2030. By 2050, demand is expected to increase seven-fold. Lithium demand in the EU shows even faster growth, reaching twenty-one-fold by 2050.³¹

Data was collected using systematic keyword searches in Google Scholar. Keywords included critical raw materials, supply chain traceability, and data sovereignty. Additional terms covered blockchain, digital product passports, and regulatory compliance. Official government documents, legal texts, and

²⁸ Jawahitha Sarabdeen and Immanuel Azaad Moonesar, "Privacy Protection Laws and Public Perception of Data Privacy," *Benchmarking: An International Journal* 25, no. 6 (2018): 1883–1902, <https://doi.org/10.1108/BIJ-06-2017-0133>.

²⁹ Tongtong Sun and Qiang Fu, "Digital Trade, Financial Accessibility, and Cross-Border Capital Flows," *Finance Research Letters* 93 (2026): 109641, <https://doi.org/10.1016/j.frl.2026.109641>.

³⁰ Tobias Ide and Patrick A Mello, "QCA in International Relations: A Review of Strengths, Pitfalls, and Empirical Applications," *International Studies Review* 24, no. 1 (2022), <https://doi.org/10.1093/isr/viac008>.

³¹ Pablo Castillo-Ortiz, *Qualitative Comparative Analysis (QCA) as an Empirical Method for International Law1*, *Research Methods in International Law: A Handbook* (Edward Elgar Publishing Ltd., 2021), <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85129670050&partnerID=40&md5=088ed0e8c459206f934ebbb79122e3b5>.

international reports were included. Academic journal articles and conference papers provided additional scholarly insights. All laws were obtained from official government portals to ensure accuracy. Scholarly literature came from Scopus and Web of Science databases only. Legal texts analyzed include the EU Battery Regulation, Critical Raw Materials Act, and GDPR. Chinese laws analyzed include the Cybersecurity Law, Data Security Law, and rare-earth export controls. Indonesian laws include the Minerba Law, Personal Data Protection Law, and SIMBARA regulations. International frameworks include UNECE Recommendation 49, OECD Due Diligence Guidance, and UN resolutions.

The research applied the CRAAP test to ensure validity and reliability of sources. Currency was ensured by using materials from the last five years only. Relevance was checked by focusing on CRM supply chains and traceability issues. Authority was confirmed by selecting works of experts and peer-reviewed publications. Accuracy was verified through proper evidence and citations. Purpose was assessed to include only scientific and academic objectives. Commercial or politically biased sources were excluded. All government documents came from official portals to ensure authenticity. Doctrinal analysis was used to examine legal rules, principles, and frameworks. Document analysis reviewed scholarly articles, policy reports, and agreements. Only publicly available data was used for this research. No confidential or proprietary information was accessed. All sources were cited to acknowledge intellectual contributions. The researcher has no conflict of interest. This study was conducted for academic purposes only, without external funding.

The geography included only Indonesia, China, and the EU. The study focused on three supply chain categories: exploration, production, and consumption. Only CRM for batteries were analyzed. The principles proposed have not been tested in practice. Implementation may reveal practical challenges not anticipated in the research. Differences in administrative capacity may affect compliance and effectiveness. Developing countries may lack resources to implement traceability systems fully. Strategic circumvention by companies or states may undermine compliance. Enforcement mechanisms may not prevent deliberate non-compliance. Rapid technological changes may strengthen or obsolete legal solutions. Advances in AI, encryption, and quantum computing may affect data security assumptions. Publicly available documents may not reflect actual practice or enforcement gaps. Official regulations may differ from how rules operate on the ground.

Results and Discussion

National Data Sovereignty Frameworks and Cross-Border Barriers in CRM Traceability

Data sovereignty as a regulatory concept has evolved significantly in the past decade, reflecting broader tensions between economic nationalism and digital

interdependence.³² Experts distinguish between “hard” localization mandates and “soft” sovereignty instruments that permit conditional cross-border flows. Addressing the first research objective, this section analyzes how divergent national data sovereignty frameworks in Indonesia, China, and the European Union create legal and operational barriers to cross-border data flows necessary for CRM supply chain traceability.³³

Indonesia enforces strict data localization to control its nickel and critical minerals. The Minerba Law (No. 3/2020) and ESDM Regulation No. 11/2023 require full digital traceability of mineral production. All mining data must remain in Indonesia and be accessible to the government.³⁴ The Personal Data Protection Law (PDPL No. 27/2022) allows cross-border personal data transfers only with strong safeguards or equal protection abroad. Without these safeguards, explicit consent is needed for data transfer. MoCI Regulation No. 5/2020 requires private electronic operators to remove illegal content within 4–24 hours. Authorities also have wide powers to order content takedowns. At the same time, Indonesia signs international agreements like the September 2024 UK–Indonesia Critical Mineral MoU.³⁵

China treats data governance as a key part of national security and industry strategy. This is especially true for rare earths and critical minerals. The Cybersecurity Law of 2017 requires important data to be stored fully within China. This applies to both domestic and foreign-owned companies operating in China.³⁶ The Data Security Law of 2021 allows authorities to classify mining and refining data as “important” or “core.” These classifications are subject to strict export controls. In November 2025, China added export rules for five more rare earth elements. These measures strengthen Beijing’s control over data and material flows.³⁷ The rules prevent unrestricted sharing of supply-chain information with foreign partners. This system gives China significant leverage over downstream

³² Nicolo Zingales, “Between a Rock and Two Hard Places: WhatsApp at the Crossroad of Competition, Data Protection and Consumer Law,” *Computer Law & Security Review* 33, no. 4 (2017): 553–58, <https://doi.org/10.1016/j.clsr.2017.05.018>.

³³ Zharova Anna, “The Salient Features of Personal Data Protection Laws with Special Reference to Cloud Technologies. A Comparative Study between European Countries and Russia,” *Applied Computing and Informatics* 12, no. 1 (2016): 1–15, <https://doi.org/10.1016/j.aci.2015.07.001>.

³⁴ Darius Štītis and Marius Laurinaitis, “Treatment of Biometrically Processed Personal Data: Problem of Uniform Practice under EU Personal Data Protection Law,” *Computer Law & Security Review* 33, no. 5 (2017): 618–28, <https://doi.org/10.1016/j.clsr.2017.03.012>.

³⁵ Asli Deniz Helvacioğlu and Hanna Stakheyeva, “The Tale of Two Data Protection Regimes: The Analysis of the Recent Law Reform in Turkey in the Light of EU Novelties,” *Computer Law & Security Review* 33, no. 6 (2017): 811–24, <https://doi.org/10.1016/j.clsr.2017.05.014>.

³⁶ Ambuj Tewari, “MHealth Systems Need a Privacy-by-Design Approach: Commentary on ‘Federated Machine Learning, Privacy-Enhancing Technologies, and Data Protection Laws in Medical Research: Scoping Review,’” *Journal of Medical Internet Research* 25 (2023), <https://doi.org/10.2196/46700>.

³⁷ Gianclaudio Malgieri, “In/Acceptable Marketing and Consumers’ Privacy Expectations: Four Tests from EU Data Protection Law,” *Journal of Consumer Marketing* 40, no. 2 (2022): 209–23, <https://doi.org/10.1108/JCM-03-2021-4571>.

industries globally. Experts have analyzed China's approach as an "adaptive sovereignty" model that strategically calibrates data openness to serve industrial policy goals. This approach contrasts with liberal data governance models that treat free data flows as trade liberalization measures.³⁸

The European Union has created a strong data governance framework for CRM supply chains. It aims to enforce transparency and protect rights beyond EU borders. The Critical Raw Materials Act (2024) sets rules for responsible sourcing and traceability.³⁹ The Battery Regulation (2023/1542) requires digital product passports with CRM content data. The Data Act (2023) ensures relevant supply-chain data is accessible, auditable, and usable within the EU. These laws also limit access by non-EU public authorities. GDPR and the Data Governance Act set strict rules for cross-border transfer of personal data. Many producer countries, including China and Indonesia, do not meet these conditions.⁴⁰ The Corporate Sustainability Due Diligence Directive (CSDDD) requires companies to identify and reduce harms in CRM value chains. This creates strong demand for verifiable data that may conflict with local data rules. These linked rules show the tension between EU transparency and global data sovereignty.⁴¹

The adequacy of current multilateral and plurilateral frameworks for governing cross-border data flows in high-risk value chains has attracted considerable scholarly scrutiny.⁴² Current researches argue that present trade agreements fail to bridge the gap between national data sovereignty and functional traceability requirements. Turning to the second research objective, this section evaluates whether existing international data transfer mechanisms namely DEPA, RCEP, and IPEF provide legally adequate pathways for CRM traceability data exchange in the context of competing sovereignty frameworks.⁴³

The Digital Economy Partnership Agreement (DEPA) is a trade pact among Chile, New Zealand, Singapore, and South Korea. It helps smaller countries grow

³⁸ Maša Galič and Raphaël Gellert, "Data Protection Law beyond Identifiability? Atmospheric Profiles, Nudging and the Stratumseind Living Lab," *Computer Law & Security Review* 40 (2021): 105486, <https://doi.org/10.1016/j.clsr.2020.105486>.

³⁹ Long Wen, "Development Analysis of Cross-Border E-Commerce Logistics Based on Big Data Technology Under Safety Law Protection," *International Journal of Information Systems in the Service Sector* 14, no. 2 (2022), <https://doi.org/10.4018/IJISSS.290547>.

⁴⁰ Jojo Y C Mo, "Are Data Protection Laws Sufficient for Privacy Intrusions? The Case in Hong Kong," *Computer Law & Security Review* 30, no. 4 (2014): 429–38, <https://doi.org/10.1016/j.clsr.2014.05.006>.

⁴¹ Paul de Hert and Vagelis Papakonstantinou, "Framing Big Data in the Council of Europe and the EU Data Protection Law Systems: Adding 'Should' to 'Must' via Soft Law to Address More than Only Individual Harms," *Computer Law & Security Review* 40 (2021): 105496, <https://doi.org/10.1016/j.clsr.2020.105496>.

⁴² Ulrich Wuermeling, "Modernization of European Data Protection Law at a Turning Point," *Computer Law & Security Review* 28, no. 5 (2012): 587–88, <https://doi.org/10.1016/j.clsr.2012.08.004>.

⁴³ Bo Zhao and Yang Feng, "Mapping the Development of China's Data Protection Law: Major Actors, Core Values, and Shifting Power Relations," *Computer Law & Security Review* 40 (2021): 105498, <https://doi.org/10.1016/j.clsr.2020.105498>.

their digital economies. DEPA covers modern topics like AI and digital identities. It also promotes paperless trade and smooth electronic transactions. On 15 July 2023, the members signed a Protocol to strengthen the rules. This Protocol benefits New Zealand companies exporting digital products and services. It came into force on 20 March 2024. One key rule, Article 4.3, allows businesses to send information across borders electronically. This includes personal data, but only when needed for normal business activities.⁴⁴

The Regional Comprehensive Economic Partnership (RCEP) is a free trade agreement among 15 countries. It includes the 10 ASEAN nations plus China, Japan, South Korea, Australia, and New Zealand. RCEP started in 2013 after negotiations began in 2012. The member countries together have nearly half the world's population.⁴⁵ They account for about 30% of global GDP and over 25% of world exports. The agreement lowers tariffs and opens markets for goods and services. It also protects investments and simplifies trade rules. RCEP covers areas like e-commerce, intellectual property, competition, and support for small and medium enterprises. The deal keeps ASEAN at the center of regional trade. It helps smaller companies join global supply chains more easily. The agreement aims to provide fair benefits to all members. It also works to reduce economic gaps between the countries.⁴⁶

In May 2022, the United States launched the Indo-Pacific Economic Framework for Prosperity. Thirteen partner countries joined, including Australia, India, Japan, and South Korea. Together, these 14 countries represent about 40% of the world's GDP. The framework aims to make their economies stronger, greener, fairer, and more resilient.⁴⁷ IPEF has four main pillars: trade, supply chains, clean energy and infrastructure, and tax/anti-corruption. Countries can choose which pillars to join based on their priorities. The Supply Chain Agreement was signed in 2023 and is now in force. The Clean Economy Agreement, Fair Economy Agreement, and IPEF Partnership Agreement have also been completed. Negotiations on the Trade pillar are still ongoing. Australia has already ratified the Supply Chain Agreement and is working on the others.⁴⁸

⁴⁴ Dan Jerker B Svantesson, "Enter the Quagmire – the Complicated Relationship between Data Protection Law and Consumer Protection Law," *Computer Law & Security Review* 34, no. 1 (2018): 25–36, <https://doi.org/10.1016/j.clsr.2017.08.003>.

⁴⁵ Eren Can Ersoy, "Examining Turkish Law on Data Protection," *Computer Fraud & Security* 2019, no. 9 (2019): 9–11, [https://doi.org/10.1016/S1361-3723\(19\)30095-8](https://doi.org/10.1016/S1361-3723(19)30095-8).

⁴⁶ David Erdos, "Beyond 'having a Domestic'? Regulatory Interpretation of European Data Protection Law and Individual Publication," *Computer Law & Security Review* 33, no. 3 (2017): 275–97, <https://doi.org/10.1016/j.clsr.2017.03.010>.

⁴⁷ Steve Saxby, "The 2012 CLSR-LSPI Seminar on Privacy, Data Protection & Cyber-Security – Presented at the 7th International Conference on Legal, Security and Privacy Issues in IT Law (LSPI) October 2–4, 2012, Athens," *Computer Law & Security Review* 29, no. 1 (2013): 4–12, <https://doi.org/10.1016/j.clsr.2012.11.007>.

⁴⁸ Kunbei Zhang and Aernout H J Schmidt, "Thinking of Data Protection Law's Subject Matter as a Complex Adaptive System: A Heuristic Display," *Computer Law & Security Review* 31, no. 2 (2015): 201–20, <https://doi.org/10.1016/j.clsr.2015.01.007>.

UNECE Recommendation No. 49 focuses on “Transparency at Scale” in supply chains. It aims to make global trade more sustainable and trustworthy. The recommendation promotes fair trade, environmental protection, and respect for human rights. It also gives honest companies equal opportunities and opens markets for green products.⁴⁹ Sharing reliable sustainability information should be faster, cheaper, and accurate. All data must be easy to verify and compatible with global systems.⁵⁰ Information should be clear, digital, and protect business secrets and privacy. It must stay under the control of the data owner. The recommendation encourages sharing product information only with those who need it. It also supports tracking materials throughout the supply chain. A common digital format helps compare products and companies easily. The approach promotes a circular economy by reusing materials and reducing waste.⁵¹

Feasibility and Necessity of an International Traceability Framework

The systemic fragility of global CRM value chains has been extensively discussed in recent supply chain resilience literature.⁵² Geopolitical constraints and strategic export controls have demonstrated structural weaknesses that bilateral arrangements cannot address. The third research objective is addressed across this section and Sections 3.8 and 3.9, which together build the normative and structural case for a new international legal instrument.⁵³ Global supply chains link many countries with different rules, economies, and politics. Agreements between only two countries usually cannot fix major weaknesses in these chains. When a shock occurs, like a pandemic or trade war, cooperation is slow and difficult. Many parts are specially made, so switching suppliers is costly and time-consuming.⁵⁴

Efforts by just two countries, like the US-China trade war, often fail to solve supply chain problems fully. Different data rules in every country create additional challenges for companies. Following all these rules is expensive and creates

⁴⁹ Michiel Rhoen, “Rear View Mirror, Crystal Ball: Predictions for the Future of Data Protection Law Based on the History of Environmental Protection Law,” *Computer Law & Security Review* 33, no. 5 (2017): 603–17, <https://doi.org/10.1016/j.clsr.2017.05.010>.

⁵⁰ Mireille Hildebrandt and Laura Tielemans, “Data Protection by Design and Technology Neutral Law,” *Computer Law & Security Review* 29, no. 5 (2013): 509–21, <https://doi.org/10.1016/j.clsr.2013.07.004>.

⁵¹ Toptchiyska Denitza, “The Rule of Law and EU Data Protection Legislation: Some Controversial Issues in Light of the New EU General Data Protection Regulation,” *The ORBIT Journal* 1, no. 1 (2017): 1–16, <https://doi.org/10.29297/orbit.v1i1.16>.

⁵² Lufeng Lin, Yinglong Zheng, and Yongqian Tu, “The New Environmental Protection Law, ESG Investment, and Corporate Innovation Performance,” *International Review of Economics & Finance* 98 (2025): 103916, <https://doi.org/10.1016/j.iref.2025.103916>.

⁵³ Qian Wang et al., “Environmental Regulations and Bond Pricing: A Quasi-Natural Experiment Based on the New Environmental Protection Law,” *Research in International Business and Finance* 77 (2025): 102921, <https://doi.org/10.1016/j.ribaf.2025.102921>.

⁵⁴ Nianling Wang, Jiacheng Song, and Zichen Chao, “New Environmental Protection Law, Polluting Enterprises and Capital Structure: A Dynamic Analysis,” *International Review of Financial Analysis* 107 (2025): 104615, <https://doi.org/10.1016/j.irfa.2025.104615>.

complex paperwork.⁵⁵ Each country interprets regulations differently, leaving businesses unsure about compliance. Rules on “important” or “sensitive” data are unclear, and penalties for mistakes are high. Companies often respond by delaying data sharing or avoiding some markets entirely. These restrictions make it hard for the executive authorities to track inventory, forecast demand, or coordinate with partners globally. Some companies, like Volvo, now join blockchain networks for responsible sourcing to improve transparency in supply chain.⁵⁶

Experts now see transparency as part of national security, not a threat. A country’s sovereignty depends on its people, land, and recognized government. Security means protecting laws, values, and the way of life. Today, sovereignty faces new challenges from other states, sanctions, or pressure. Large companies and private groups can also limit a state’s control. Global technology, the internet, and transnational organizations make full independence harder. Nations must control with openness to remain safe and free. “Digital sovereignty” shows how states try to protect their data and online space. It reflects efforts to stay independent while facing outside pressures and risks.⁵⁷

DPPs act like IDs that travel with products. They show what a product contains, where materials come from, and how it was made. DPPs also provide environmental information and guidance for repair, reuse, or recycling.⁵⁸ The European Union will soon require DPPs for batteries, electronics, and textiles. Other countries, including China, Australia, and the United States, are planning similar systems.⁵⁹ DPPs give consumers, companies, and authorities easy access to reliable product information. This encourages greener choices and circular business models like repair and recycling. Developing countries need support with training and technology to avoid trade barriers. Legal cases show companies can be held responsible for suppliers’ actions even if links are indirect. In 2013, the Rana Plaza collapse in Bangladesh killed over 1,100 garment workers. Danish authorities found PWT Group violated OECD Guidelines for failing safety checks on its

⁵⁵ Ece Bas Suzel, “Adult Protection in Turkish and Swiss Civil Law,” *The Journal of Adult Protection* 27, no. 5 (2025): 262–82, <https://doi.org/10.1108/JAP-03-2025-0011>.

⁵⁶ Yuming Xiong et al., “Does Environmental Regulation Inhibit Rent-Seeking by Heavy-Polluting Firms? Evidence from China’s New Environmental Protection Law,” *Pacific-Basin Finance Journal* 98 (2026): 103127, <https://doi.org/10.1016/j.pacfin.2026.103127>.

⁵⁷ Kailong Mei and Zihao Zhang, “Environmental Regulation, Green Investment and Corporate Green Governance: Evidence from China’s New Environmental Protection Law,” *Finance Research Letters* 76 (2025): 106979, <https://doi.org/https://doi.org/10.1016/j.frl.2025.106979>.

⁵⁸ Sicong Yan et al., “New Environmental Protection Law, Polluting Enterprises and Corporate Green Technological Innovation,” *Finance Research Letters* 77 (2025): 107008, <https://doi.org/https://doi.org/10.1016/j.frl.2025.107008>.

⁵⁹ Yanling Wang et al., “How Does Privacy Protection Affect the Innovation Performance of Artificial Intelligence Corporations: Empirical Evidence from the Personal Information Protection Law,” *International Review of Economics & Finance* 107 (2026): 104991, <https://doi.org/https://doi.org/10.1016/j.iref.2026.104991>.

supplier. Similarly, German authorities told Adidas to improve its complaint system after workers faced anti-union actions and unpaid wages.⁶⁰

DPPs act like digital IDs for products from factory to recycling. They show what materials the product contains and where they come from. DPPs also explain how products were made and their environmental impact. They provide guidance on repair, reuse, and recycling.⁶¹ The European Union will soon require DPPs for batteries, electronics, and textiles. Other countries, including China, Australia, and the United States, are planning similar systems. DPPs give consumers, companies, and authorities access to trustworthy product information. This helps people make greener choices and encourages circular business models. It is also important to support developing countries with training and technology. This ensures DPP rules do not create trade barriers and benefit everyone. Past cases show companies can be responsible for harm caused by suppliers. In 2013, the Rana Plaza collapse in Bangladesh killed over 1,100 workers.⁶² Danish authorities found PWT Group violated OECD Guidelines for not checking its supplier properly. Even though PWT was a minor buyer, it was held accountable. In another case, Germany asked Adidas to improve its complaint system. Workers at an Indonesian sub-contractor faced unpaid wages and anti-union actions.⁶³

Data sovereignty means a country control how information must be protected within its borders. Governments can block certain data from leaving the country to ensure security. Many developing countries worry that big tech firms from rich nations take their data unfairly.⁶⁴ This often creates concerns about economic and digital control. Companies sometimes resist these rules to protect business secrets or avoid extra costs. Enforcing international data rules is difficult because violations are hard to punish. Linking computer systems across countries is also technically complex. These challenges make global data governance a major legal and policy issue.⁶⁵

⁶⁰ Ni Zhang and Hongjun Han, "The New Environmental Protection Law, Political Connections and Corporate ESG Performance," *International Review of Financial Analysis* 102 (2025): 104110, <https://doi.org/https://doi.org/10.1016/j.irfa.2025.104110>.

⁶¹ Zhiwei Yang, Jiahui Yang, and Wei Wang, "Labor Protection Policy and Firm Markup: Evidence from the Implementation of the China Social Insurance Law," *Finance Research Letters* 82 (2025): 107623, <https://doi.org/https://doi.org/10.1016/j.frl.2025.107623>.

⁶² Yunhai Zhao et al., "Environmental Protection Tax Law and Corporate Financial Fraud: Evidence from Listed Firms in China," *International Review of Financial Analysis* 96 (2024): 103537, <https://doi.org/https://doi.org/10.1016/j.irfa.2024.103537>.

⁶³ Ana Beduschi, "Data Protection in the Era of Agentic Artificial Intelligence," *Computer Law & Security Review* 61 (2026): 106342, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106342>.

⁶⁴ Konrad Kollnig et al., "Privacy in Chinese IOS Apps and Impact of the Personal Information Protection Law," *Computer Law & Security Review* 55 (2024): 106041, <https://doi.org/https://doi.org/10.1016/j.clsr.2024.106041>.

⁶⁵ Chiara Gallese, "Predictive Policing and Predictive Justice: Ethics, Data Protection, and the AI Act," *Computer Law & Security Review* 61 (2026): 106282, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106282>.

Legal Principles toward International Traceability Law

The design of international regulatory frameworks for novel governance challenges draws on a well-developed body of international law scholarship concerning the relationship between principles, rules, and enforcement mechanisms.⁶⁶ In particular, the literature on “global administrative law” offers useful structural insights into how non-state actors can be held to accountability standards across jurisdictions. Developing an international traceability law for CRMs needs clear legal building blocks. A set of principles should guide cross-border traceability rules. The principle of legality requires laws to be clear, accessible, and not retroactive. Businesses must understand what is allowed, forbidden, and the penalties for violations.⁶⁷ The principle of proportionality requires measures to be the least restrictive possible. Authorities must consider product or actor circumstances and explain restrictions carefully.⁶⁸ Functional equivalence ensures digital records, signatures, and product identifiers have equal legal value. This allows electronic traceability to be recognized in cross-border trade. Functional sovereignty emphasizes a state’s control over data, resources, and compliance.⁶⁹ At the same time, it allows participation in shared, interoperable systems.

Harmonized data models, shared vocabularies, and unique identifiers support CRM traceability. Verifiable credential frameworks help systems work across different legal environments. Rule-based mechanisms, such as Rule-Based Access Control (RuBAC), manage data access. It enables predefined, automated “if-then” rules to determine who may access which data elements under what conditions, balancing transparency needs with commercial confidentiality and national security. Federated oversight and regional coordination let states control their own data. Trust frameworks also support harmonization across borders. Compliance mechanisms ensure traceability rules are enforceable internationally.⁷⁰

The proposed legal framework for international CRM traceability must follow UNECE Recommendation 49. This recommendation sets key requirements for

⁶⁶ Yue Li and Zhongwen Deng, “Can Environmental Regulation Inhibit Enterprises’ Greenwashing? Evidence from Implementing the New Environment Protection Law,” *Finance Research Letters* 81 (2025): 107476, <https://doi.org/https://doi.org/10.1016/j.frl.2025.107476>.

⁶⁷ Walter Britto Gaspar, Fernando Naegele, and Daniel Dore Lage, “A Wild Data Controller Appeared! Opacity in Personal Data Protection Documentation of Pokémon Mobile Games,” *Computer Law & Security Review* 62 (2026): 106346, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106346>.

⁶⁸ Wenlong Li and Jiahong Chen, “From Brussels Effect to Gravity Assists: Understanding the Evolution of the GDPR-Inspired Personal Information Protection Law in China,” *Computer Law & Security Review* 54 (2024): 105994, <https://doi.org/https://doi.org/10.1016/j.clsr.2024.105994>.

⁶⁹ Xin Zhang and Chenxiao Shi, “How Does Environmental Protection Tax Law Affect Corporate Investment Preferences?,” *Finance Research Letters* 72 (2025): 106498, <https://doi.org/https://doi.org/10.1016/j.frl.2024.106498>.

⁷⁰ Haoran Li and Mingyu Lu, “Implementation of the New Environmental Protection Law, Patient Capital, and Corporate Sustainable Development,” *Finance Research Letters* 86 (2025): 108365, <https://doi.org/https://doi.org/10.1016/j.frl.2025.108365>.

trust, quality, and interoperability in sustainability data. It requires that data be high-quality, verifiable, interoperable, accessible, and privacy-preserving. Data must also be digitized, understandable, and under the control of its owner. Aligning with Rec. 49 ensures CRM traceability records are accurate and complete. Records must also be independently verifiable by regulators or auditors. Interoperability requires following regional and international technical standards. This allows CRM data to move smoothly across borders and platforms. Recommendation 49 also stresses that transparency cannot compromise privacy or business confidentiality. Privacy-preserving design is therefore a central legal requirement. The framework must support self-sovereignty for value chain actors. Companies must keep control over their own product, facility, and company information. At the same time, regulators must access the data needed to meet sustainability goals.⁷¹

In addition to UNECE frameworks, the legal structure must follow international digital and trade agreements. DEPA Module 4, Article 4.3 requires parties to allow cross-border data transfers for business needs. Each party may still apply its own regulatory rules for information flows. The IPEF Supply Chain Agreement adds mechanisms supporting traceability objectives.⁷² Its Supply Chain Council creates sector-specific action plans for critical goods. The Supply Chain Crisis Response Network provides channels for sharing information during disruptions.⁷³ RCEP covers 16 countries, nearly half the world's population, and 30% of global GDP. It aims to lower trade barriers and improve market access in Asia-Pacific economies. The study proposes four layers for an International Traceability Law. The foundational layer sets principles reconciling data sovereignty, transparency, and trade security. The operational layer covers technical and procedural elements across borders. It includes standards, protocols, verification models, and mutual recognition agreements. The enforcement layer ensures obligations are upheld through disputes, monitoring, sanctions, and cooperation.⁷⁴

The capacity-building layer supports countries with limited technical or institutional ability. It provides guidance, assistance, and phased implementation methods for effective adoption. This four-layer framework constitutes the study's direct answer to the central research question: international legal frameworks can

⁷¹ Rebecca Valek et al., "Addressing Risks of Violence to Children and Adolescents Through Oregon's Extreme Risk Protection Order Law," *Academic Pediatrics* 26, no. 3 (2026): 103179, <https://doi.org/https://doi.org/10.1016/j.acap.2025.103179>.

⁷² Yufeng Chen, Longshan Liu, and Xiaojuan Yuchi, "Carbon Risk and Cost of Equity Capital: Evidence from a Quasi-Natural Experiment Based on China's New Environmental Protection Law," *Finance Research Letters* 96 (2026): 109780, <https://doi.org/https://doi.org/10.1016/j.frl.2026.109780>.

⁷³ Weiping Han and Bo Zhang, "Environmental Protection Law, Green Investment, and Corporate Greenwashing Behavior," *Finance Research Letters* 86 (2025): 108915, <https://doi.org/https://doi.org/10.1016/j.frl.2025.108915>.

⁷⁴ Tanja Kammersgaard Christensen, "Pre-Installed Cameras in Vehicles—New Technology from a Data Protection Law Perspective," *Computer Law & Security Review* 53 (2024): 105980, <https://doi.org/https://doi.org/10.1016/j.clsr.2024.105980>.

reconcile the traceability trilemma by structuring obligations around differentiated but interoperable layers that simultaneously protect sovereignty, guarantee transparency, and preserve security.⁷⁵

The Trilemma as a Structural Challenge

The traceability issues in CRM value chains comes from three competing goals. These are data sovereignty, supply chain transparency, and trade security. Optimizing one goal often limits the others. Data sovereignty rules increase supply chain risks and complicate cross-border operations.⁷⁶ Strict data transfer laws raise costs and create security challenges. Similar structural tensions appear in the Mundell-Fleming Trilemma or “Impossible Trinity” in monetary policy.⁷⁷ The trilemma concept has been applied widely in international law, particularly in analyzing trade-offs between market integration, regulatory autonomy, and democratic governance.⁷⁸ Experts have also applied “game-theoretic” models to similar collective action problems in international environmental and trade regimes. It shows that fixed exchange rates, free capital flows, and independent monetary policy cannot all exist together.⁷⁹

Globalization Trilemma also mirrors this traceability challenge. It demonstrates that democracy, national sovereignty, and global economic integration cannot fully coexist.⁸⁰ Arrow’s impossibility theorem further shows that no voting system satisfies all rational-choice rules. In traceability, these trade-offs are inevitable and cannot be fully avoided. On April 4, 2025, China’s Ministry of Commerce and Customs issued Announcement 18. It imposed export controls on medium and heavy rare earth materials for national security. These controls act like a “one-shot

⁷⁵ Piotr Rataj et al., “Sharing IP Addresses with Law Enforcement Authorities: Data Protection in Cybersecurity-Related Public-Private Partnerships,” *Computer Law & Security Review* 61 (2026): 106316, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106316>.

⁷⁶ M R Leiser, “From the Law of Everything to a System That Works: Why Recalibrating Personal Data Enables, Rather than Undermines, Digital Protection (A Response to Professor Nadezhda Purtova),” *Computer Law & Security Review* 60 (2026): 106256, <https://doi.org/https://doi.org/10.1016/j.clsr.2025.106256>.

⁷⁷ Xinwei Gao, Na Liu, and Yujie Hua, “Environmental Protection Tax Law on the Synergy of Pollution Reduction and Carbon Reduction in China: Evidence from a Panel Data of 107 Cities,” *Sustainable Production and Consumption* 33 (2022): 425–37, <https://doi.org/https://doi.org/10.1016/j.spc.2022.07.006>.

⁷⁸ Piotr Rataj, “Botnet Defense under EU Data Protection Law,” *Computer Law & Security Review* 56 (2025): 106080, <https://doi.org/https://doi.org/10.1016/j.clsr.2024.106080>.

⁷⁹ Emmanouil Bougiakiotis, “One Law to Rule Them All? The Reach of EU Data Protection Law after the Google v CNIL Case,” *Computer Law & Security Review* 42 (2021): 105580, <https://doi.org/https://doi.org/10.1016/j.clsr.2021.105580>.

⁸⁰ Dr David Erdos, “Identification in Personal Data: Authenticating the Meaning and Reach of Another Broad Concept in EU Data Protection Law,” *Computer Law & Security Review* 46 (2022): 105721, <https://doi.org/https://doi.org/10.1016/j.clsr.2022.105721>.

bazooka,” strong but limited in effectiveness. Overuse of such controls may force permanent supply chain diversification.⁸¹

Volvo Cars implemented global traceability of cobalt in its batteries using blockchain in 2019. The system covers China, South Korea, and Sweden, partnering with Circulor and Oracle. It digitally tracked recycled cobalt across multiple refiners and manufacturing sites over a 3,500 km journey. This ensured no cobalt of unknown origin entered the supply chain. However, technical traceability does not remove legal barriers to cross-border data sharing.⁸² GDPR requires personal data to be modifiable or erasable, but blockchains make this technically impossible. Organizations may face penalties up to €20 million or 4% of global revenue. Blockchain nodes can operate across jurisdictions, complicating compliance. The Digital Product Passport is legally required under EU Regulations 2024/1781 and 2024/1305. Controlled access to information is regulated by Article 10 and specific levels set by Article 4. Self-Sovereign Identity (SSI) gives users control over credentials with their consent, unlike centralized identity systems. Participants need verifiable credentials recognized in the data space to engage effectively. DPPs must be interoperable across industries and borders using harmonized standards. Traditional supply chains rely on centralized databases and auditors, creating single points of failure and cyber risks. Blockchain’s decentralized design fosters trust through transparent, independently verifiable transactions. Assuming technology alone solves legal and political conflicts reflects “techno-solutionism,” a flawed approach for CRM traceability governance.⁸³

The traceability seems unsolvable when one goal reduces the others. Zero-sum thinking assumes that one person’s gain is another’s loss. This mindset treats resources as limited and social relations as competitive. Digital sovereignty is important for managing supply chains and protecting data. Research shows risks to digital sovereignty can be reduced using distributed ledger technology. Sovereign AI and cloud systems keep data inside national borders. This reduces foreign access and avoids vendor lock-in. Companies often use hybrid clouds to balance security and efficiency. Federated governance distributes decision-making to those closest to the data.⁸⁴ This model allows faster innovation and maintains compliance with rules. It also helps scale data governance as data volumes and

⁸¹ Miranda Mourby, “The ‘DPIA+’: Aligning Data Protection with UK Equality Law,” *Computer Law & Security Review* 59 (2025): 106212, <https://doi.org/https://doi.org/10.1016/j.clsr.2025.106212>.

⁸² Xijin Zhou and Deqin Lin, “Impact of the Environmental Protection Law on Corporate Biodiversity Risk Attention - An Empirical Analysis Based on Data of Chinese Listed Companies,” *Finance Research Letters* 86 (2025): 108663, <https://doi.org/https://doi.org/10.1016/j.frl.2025.108663>.

⁸³ Valentin Rupp and Max von Grafenstein, “Clarifying ‘Personal Data’ and the Role of Anonymisation in Data Protection Law: Including and Excluding Data from the Scope of the GDPR (More Clearly) through Refining the Concept of Data Protection,” *Computer Law & Security Review* 52 (2024): 105932, <https://doi.org/https://doi.org/10.1016/j.clsr.2023.105932>.

⁸⁴ Katerina Demetzou, Gabriela Zafir-Fortuna, and Sebastião Barros Vale, “The Thin Red Line: Refocusing Data Protection Law on ADM, a Global Perspective with Lessons from Case-Law,” *Computer Law & Security Review* 49 (2023): 105806, <https://doi.org/https://doi.org/10.1016/j.clsr.2023.105806>.

complexity increase. The principle of subsidiarity gives lower authorities some independence from higher bodies. The Union can act collectively only when individual actions are insufficient. Subsidiarity reflects a margin of appreciation for local decision-making.⁸⁵

The Sovereignty-Transparency Conflict

China controls about 90% of global rare earth refining, creating a supply bottleneck. Rare earths mined elsewhere often must be sent to China for processing. These materials are essential for many defense technologies, including fighter jets, submarines, missiles, radar, drones, and smart bombs.⁸⁶ National security concerns justify strong data sovereignty rules.⁸⁷ In 2010, China cut rare earth exports to Japan over a territorial dispute, causing global prices to spike. During the U.S.-China trade war, Beijing again threatened to use rare earths strategically. Developing countries' natural resource revenues can strengthen institutions, support social programs, and fund industries. BRICS nations treat certain data as strategic resources to support national development.⁸⁸ Sustainable energy systems generate massive amounts of valuable data, from smart meters to environmental monitoring. If such data is mainly processed in developed countries, developing nations may not receive fair economic benefits, worsening inequality.

Starting in 2027, EU batteries over 2 kWh must carry digital passports with detailed provenance, carbon, and recycling data. The U.S. Inflation Reduction Act ties EV tax credits to supply chains free of "foreign entities of concern" and to higher domestic critical mineral use. Lack of supply-chain transparency enables human rights abuses, conflict funding, and environmental harm.⁸⁹ The connection between opacity and harm has been extensively discussed in the extractive industries literature and has informed mandatory human rights due diligence

⁸⁵ Massimo Marelli, "The Law and Practice of International Organizations' Interactions with Personal Data Protection Domestic Regulation: At the Crossroads between the International and Domestic Legal Orders," *Computer Law & Security Review* 50 (2023): 105849, <https://doi.org/https://doi.org/10.1016/j.clsr.2023.105849>.

⁸⁶ Zihao Li, "Affinity-Based Algorithmic Pricing: A Dilemma for EU Data Protection Law," *Computer Law & Security Review* 46 (2022): 105705, <https://doi.org/https://doi.org/10.1016/j.clsr.2022.105705>.

⁸⁷ Luiz Stephany Holanda-Filho, João Pedro Prado Benevides Pires, and Rafaela Ponte Lisboa, "Similarities and Singularities of the Data Protection Laws of the South American Countries," *Computer Law & Security Review* 61 (2026): 106308, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106308>.

⁸⁸ Zhilong Guo, Jie Hao, and Lewis Kennedy, "Protection Path of Personal Data and Privacy in China: Moving from Monism to Dualism in Civil Law and Then in Criminal Law," *Computer Law & Security Review* 52 (2024): 105928, <https://doi.org/https://doi.org/10.1016/j.clsr.2023.105928>.

⁸⁹ Jawahitha Sarabdeen, Emna Chikhaoui, and Mohamed Mazahir Mohamed Ishak, "Creating Standards for Canadian Health Data Protection during Health Emergency – An Analysis of Privacy Regulations and Laws," *Heliyon* 8, no. 5 (2022): e09458, <https://doi.org/https://doi.org/10.1016/j.heliyon.2022.e09458>.

legislation across multiple jurisdictions.⁹⁰ The UN Guiding Principles on Business and Human Rights provide the foundational normative framework within which traceability obligations should be understood.⁹¹

Circular economies for batteries require end-to-end material passports. Effective recycling depends on knowing chemistry, impurities, and provenance at the batch level. Current lithium recycling yields remain below 5% due to heterogeneous black-mass and missing data. Regulators should limit mandatory disclosure to data required to prove responsible sourcing. Key elements include origin, mine ID, recycled content, and CO₂ footprint. More detailed documentation, audits, and corrective plans are also needed. Sensitive data, like ore grades, refining yields, customer lists, and deposit geolocation, must remain protected. Zero-knowledge proofs, homomorphic encryption, and secure multi-party computation can verify compliance without exposing underlying data.⁹²

Trade Security in an Era of Weaponized Supply Chains

China's dual-use export controls on rare earth elements show supply chain weaponization. EU assessments under the Critical Raw Materials Act also highlight these chokepoints. Without supply diversification, the EU risks serious strategic vulnerabilities. The new Strategic Projects advance the implementation of the Critical Raw Materials Act. The Act aims for European extraction, processing, and recycling to meet 10%, 40%, and 25% of demand by 2030. The "new geopolitics" shows a shift from energy dependence to mineral supply vulnerabilities.⁹³ Control over extraction, processing, and distribution gives significant leverage to states. This tactic continues historical precedents, turning rare earths into economic chokepoints. It signals Beijing's intent to reward allies while penalizing rivals.

In CRM value chains, refining and separation innovations are closely protected. Detailed traceability can reveal intellectual property to competitors or state actors. The intersection of trade secret protection and supply chain disclosure obligations creates a layered legal tension that standard IP frameworks are not designed to resolve.⁹⁴ A "regulatory sandbox" approach may be needed to pilot disclosure regimes without irreversibly compromising competitive position. Shared platforms

⁹⁰ Mathias Bartholdy, "Positioning Synthetic Data under EU Data Protection Law," *Computer Law & Security Review* 61 (2026): 106310, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106310>.

⁹¹ Wenyue Wu and Yiming Zhao, "Big Data Grace: Implementations of the Feature Engineering and Data Science Algorithms for Environmental Protection Law," *Alexandria Engineering Journal* 125 (2025): 256–64, <https://doi.org/https://doi.org/10.1016/j.aej.2025.03.121>.

⁹² Alissa Brauneck et al., "Federated Machine Learning, Privacy-Enhancing Technologies, and Data Protection Laws in Medical Research: Scoping Review," *Journal of Medical Internet Research* 25 (2023), <https://doi.org/https://doi.org/10.2196/41588>.

⁹³ Uta Neumann et al., "German Law on Protection of Children with DSD: First Data on Care after Enactment," *Endocrine Connections* 15, no. 6 (2026), <https://doi.org/https://doi.org/10.1530/EC-26-0194>.

⁹⁴ Tuulia Karjalainen, "The Battle of Power: Enforcing Data Protection Law against Companies Holding Data Power," *Computer Law & Security Review* 47 (2022): 105742, <https://doi.org/https://doi.org/10.1016/j.clsr.2022.105742>.

like blockchain or IoT may increase this risk. Supply chains face barriers like data silos, cybersecurity gaps, and interoperability problems. These challenges make electronic data transfers more vulnerable to leaks. The U.S.-Uzbekistan agreements address these risks by promoting alternative sourcing. Signed in September 2024, the agreements expanded in 2025 with \$1 billion for joint exploration. They focus on uranium, copper, tungsten, and rare-earth minerals. The MOU, part of the C5+1 Critical Minerals Dialogue, protects Central Asian ecosystems. It also ensures U.S. access to geological data and processing technologies.⁹⁵

Supply chain traceability data in the CRM sector is a dual-use asset. The same detailed data enables OECD-aligned due diligence. It includes mine locations, volume flows, smelter identities, and certification flags. The data can also be misused for industrial espionage or geopolitical targeting. Security experts may classify parts of the dataset for national-security reasons. But hiding information creates gaps that enable smuggling and sanctions evasion. International agreement is needed on which data may be redacted safely. Redacted data should not violate due-diligence obligations.⁹⁶

The Kimberley Process Certification Scheme (KPCS) reduced conflict diamonds in global trade. It used mandatory peer-reviewed reporting and shared watch lists. The OECD Due Diligence Guidance helps companies and governments track minerals from conflict areas. It targets tantalum, tin, tungsten, and gold that funded armed groups in Central Africa. The EU–Canada Minerals Security Partnership and other 2023 initiatives promote CRMs cooperation. The U.S.–Japan–Korea Trilateral Critical Minerals Arrangement strengthens international supply chain security. Australia and the EU also work together across exploration, processing, recycling, and innovation. The Cold War Coordinating Committee for Multilateral Export Controls offers a historical analogy. Seventeen Western nations agreed on common controls and mutual end-use verification. They still protected national cryptography and intelligence systems. Full secrecy, however, creates its own security risks.⁹⁷

Why Existing Mechanisms Fail: Structural Analysis

A typical electric-vehicle battery value chain spans four or more countries. Lithium may be extracted in Chile, refined in China, and made into cells in South Korea. Vehicle assembly and data generation often happen in the EU. For n countries to mutually recognize traceability systems, $n(n-1)/2$ agreements are

⁹⁵ Miliane dos Santos Fantonelli et al., "Organization and Management of Sensitive Personal Health Data in Electronic Systems in Countries with Implemented Data Protection Laws, Lessons to Brazil: A Brief Systematic Review," *Computer Law & Security Review* 51 (2023): 105872, <https://doi.org/https://doi.org/10.1016/j.clsr.2023.105872>.

⁹⁶ Elif Küzeci and Oguzhan Yesiltuna, "General Data Protection Par Ricochet: The GDPR's Impact on Turkish Data Protection Law," *Computer Law & Security Review* 62 (2026): 106368, <https://doi.org/https://doi.org/10.1016/j.clsr.2026.106368>.

⁹⁷ Jackie Davis and Lisa L Losada-Rojas, "State of Safety: A Systematic Assessment of State-Level Nighttime Pedestrian and Cyclist Protection Laws," *Journal of Safety Research* 97 (2026): 565–80, <https://doi.org/https://doi.org/10.1016/j.jsr.2026.05.002>.

needed. In a four-country chain, this creates six separate bilateral instruments. Each agreement has its own technical standards, audit rules, data-sharing clauses, and dispute mechanisms. Bilateral talks reflect differences in economic power, market size, and technology control. Investment choices often depend on quick access to foreign markets. Host countries compete by offering permissive traceability and data-sharing rules.⁹⁸

Regional trade agreements like DEPA, RCEP, and IPEF try to address the traceability trilemma. The structural limitations of regional trade frameworks in addressing global commons problems have been analyzed through both institutionalist and functionalist lenses. The “Spaghetti bowl” effect of overlapping regional agreements creates compliance complexity that undermines rather than reinforces governance coherence.⁹⁹ They include rules on data flows, supply chain transparency, and digital security. However, they face limits in balancing data sovereignty, transparency, and trade security. Their regional focus does not match the global nature of CRM value chains. This gap reduces their ability to enforce traceability across the entire chain. By design, these frameworks can favor “insider” members over outsiders.¹⁰⁰ This creates barriers for non-members and shifts CRM flows toward specific blocs. Despite this, the agreements have increased intra-bloc trade flows. They clarify non-discrimination principles and support wider adoption of standards.¹⁰¹

The soft law paradox in CRM value chains comes from tension between flexibility and accountability. Voluntary instruments like guidelines and certifications encourage innovation and broad adoption without strict rules.¹⁰² Yet their non-binding nature allows inconsistency and evasion, weakening trust in supply chain data. Voluntary standards often fail to ensure robust CRM traceability

⁹⁸ Johannes Barth, Thomas Bauer, and Bertrand Sonnery-Cottet, “The ‘Jardé’ Law: The Shambles Threatening to Kill off Clinical Research in France. How to Reconcile Clinical Research with Data Protection, Informed Consent and Scientific Rigor?,” *Orthopaedics & Traumatology: Surgery & Research* 106, no. 8, Supplement (2020): S181–82, <https://doi.org/https://doi.org/10.1016/j.otsr.2020.09.001>.

⁹⁹ Jawahitha Sarabdeen, “E-Consumers- a Critical Legal Analysis of Consumer Protection Laws,” *Social Sciences & Humanities Open* 13 (2026): 102685, <https://doi.org/https://doi.org/10.1016/j.ssaho.2026.102685>.

¹⁰⁰ Md. Abu Issa Gazi et al., “The Relationship between CRM, Knowledge Management, Organization Commitment, Customer Profitability and Customer Loyalty in Telecommunication Industry: The Mediating Role of Customer Satisfaction and the Moderating Role of Brand Image,” *Journal of Open Innovation: Technology, Market, and Complexity* 10, no. 1 (2024): 100227, <https://doi.org/https://doi.org/10.1016/j.joitmc.2024.100227>.

¹⁰¹ Pushpender Kumar and Anupreet Kaur Mokha, “Electronic Customer Relationship Management (E-CRM) and Customer Loyalty:,” *International Journal of E-Business Research* 18, no. 1 (2022), <https://doi.org/https://doi.org/10.4018/IJEER.293292>.

¹⁰² Pasquale Del Vecchio et al., “A Structured Literature Review on Big Data for Customer Relationship Management (CRM): Toward a Future Agenda in International Marketing,” *International Marketing Review* 39, no. 5 (2021): 1069–92, <https://doi.org/https://doi.org/10.1108/IMR-01-2021-0036>.

due to weak adoption, incentives, and oversight.¹⁰³ They cannot fully meet the trilemma's demand for transparent, verifiable data while respecting sovereignty and security. UNECE Recommendation 49 is technology-neutral regarding physical data carriers such as QR codes and RFID tags. It does not explain how sustainability information should be encoded or accessed.¹⁰⁴ The recommendation also does not cover the design or production of these devices. While it may define core terms and verify open-source tools, general software development is outside its scope. Storage solutions for product or value chain data are also not included. Soft law's main weakness is the lack of penalties, letting non-compliant firms benefit without consequences.¹⁰⁵

The Case for Recommendation 51 and International Traceability Law

Multiple factors like geopolitical tension, climate urgency, technology growth, and ESG investments align interests. The conditions for successful international institutional design such as convergence of interests, epistemic communities, and political windows have been theorized extensively in regime theory.¹⁰⁶ The emergence of CRM traceability as a shared concern among otherwise competing states may represent precisely such a window of opportunity. This alignment increases demand for unified CRM traceability frameworks.¹⁰⁷ Climate imperatives make this need even stronger. The green transition will require four times more CRM supply by 2040. Electric vehicles, batteries, and renewable energy drive this growing demand. The Global Traceability Standards (GS1) shows how interoperability can work. It standardizes data exchange to verify origins and ESG compliance without proprietary barriers. The Montreal Protocol phased out ozone-depleting substances with timed production cuts. It used technology transfer funds to support innovation. This approach achieved a 99% reduction in controlled emissions. It also encouraged alternatives like HCFC substitutes.¹⁰⁸

¹⁰³ Yahia Baashar et al., "Customer Relationship Management Systems (CRMS) in the Healthcare Environment: A Systematic Literature Review," *Computer Standards & Interfaces* 71 (2020): 103442, <https://doi.org/https://doi.org/10.1016/j.csi.2020.103442>.

¹⁰⁴ Mudjahidin Mudjahidin et al., "Structural Model for Analyzing the Impact of Social CRM on Customer Relationship Performance in Automotive Manufacturing Company," *Procedia Computer Science* 234 (2024): 861–68, <https://doi.org/https://doi.org/10.1016/j.procs.2024.03.073>.

¹⁰⁵ Teck-Yong Eng, Fenfang Lin, and Lin-Chih Wu, "Strengthening CRM Performance through Customer Knowledge: The Role of Technological Capability in SMEs," *European Business Review* 38, no. 3 (2026): 403–28, <https://doi.org/https://doi.org/10.1108/EBR-06-2025-0204>.

¹⁰⁶ Obaid Mobarak Al-Shuridah, "Determinants of CRM Implementation Success: A Cross-National Analysis," *Journal of Asia Business Studies* 20, no. 2 (2026): 361–85, <https://doi.org/https://doi.org/10.1108/JABS-10-2024-0614>.

¹⁰⁷ Roghayeh soleimani et al., "Integrating Customer Relationship Management and Organizational Capabilities for Hospital Resilience: A Framework for Disaster Preparedness and Recovery," *Progress in Disaster Science* 28 (2025): 100488, <https://doi.org/10.1016/j.pdisas.2025.100488>.

¹⁰⁸ José Sevilla-Ruiz et al., "Studying the Impact of CRM (Citizen Relationship Management) Tools on the Resilience of Spanish Municipalities," *Heliyon* 12, no. 6 (2026): e44821, <https://doi.org/10.1016/j.heliyon.2026.e44821>.

Recommendation 49 provides a recognized foundation for end-to-end traceability in mineral value chains. It was developed through an open, multi-year UN/CEFACT process. Governments, industry, and civil society all participated in its creation. One core strength is its design as a bridge between technical standards and regulatory needs. It requires using the UN/CEFACT Traceability Call for Implementation templates. It also mandates mass-balance or segregated chain-of-custody models in high-risk CRM corridors. Certain data attributes must be exchanged, including country of origin and unique batch identifiers. Carbon footprint information is included where applicable. These requirements can become enforceable under national law or future international conventions. Taken together, Sections 3.3, 3.8, and 3.9 establish that: (i) existing bilateral and regional mechanisms are structurally inadequate; (ii) the geopolitical, technological, and sustainability conditions creating demand for a unified framework are converging; and (iii) a legally feasible pathway exists through building on UNECE Recommendation 49 toward a binding Recommendation 51. This directly answers the third research objective.¹⁰⁹

Toward a legal framework for the traceability in CRM value chains, states must keep full control over sensitive data in their territory. They must allow limited cross-border data flows needed for global supply-chain traceability. Traceability requirements should match the legitimate regulatory purpose and avoid full disclosure of the entire value chain. States recognize each other's certified traceability systems if they achieve similar results in responsible sourcing and security checks. All approved systems must use strong cybersecurity and integrity protections for legal recognition. Timelines and obligations are adjusted to each country's institutional and technological capacity. Traceability systems are run by hybrid governance bodies including industry, civil society, communities, and government equally. Trusted participation depends on decentralized digital identity systems, ideally self-sovereign identity using W3C verifiable credentials and decentralized identifiers.¹¹⁰

UNECE has a strong record in creating neutral, consensus-based standards. These standards connect public and private stakeholders across different regions. UNECE's authority is valuable even in a fragmented geopolitical environment. Its standards are non-binding and do not need formal ratification. The traceability framework must comply with WTO law from the start. This includes the TBT Agreement and core non-discrimination rules. Traceability rules should focus on process and production methods. They must be clearly non-product-related and avoid arbitrary discrimination. UNCITRAL can complement UNECE standards with supporting legal infrastructure. Global principles in Rec 51 should match

¹⁰⁹ Aman Kumar and Amit Shankar, "Role of Generative AI-Enabled Customer Relationship Management Solutions in Achieving Agility," *Journal of Business & Industrial Marketing* 48, no. 8 (2025): 1593–1614, <https://doi.org/10.1108/JBIM-06-2024-0433>.

¹¹⁰ Edyta Gołab-Andrzejak, "AI-Powered Customer Relationship Management – GenerativeAI-Based CRM – Einstein GPT, Sugar CRM, and MS Dynamics 365," *Procedia Computer Science* 246 (2024): 1790–99, <https://doi.org/https://doi.org/10.1016/j.procs.2024.09.683>.

regional legal traditions and data rules. Enforcement capacity must also be considered when applying these principles.¹¹¹

The UNCRMTP establishes a decentralized, verifiable linked data system for CRM supply chains. It enables secure tracking without relying on a central authority. Unlike traditional API-based systems, UNCRMTP uses a web-like linked data model. Each participant publishes machine- and human-readable credentials with unique identifiers. These identifiers can be resolved through trusted identity anchors. The system stores digital records with CRM-specific data, including composition, origin, extraction methods, and environmental metrics. The DPP uses a "need-to-know" access model with role-based permissions. This approach respects data sovereignty and limits shared information to verified excerpts.¹¹²

Beijing announced a series of adjustments to trade measure on rare-earth export controls in November 2025. The pause lasts one year, until November 10, 2026. It followed high-level U.S.-China negotiations in Busan and bilateral commitments.¹¹³ This move signals a careful adjustment of risks in CRM value chains. China's 2024-2025 regulatory changes included the Ministry of Finance's CSDS (Trial). Stock exchanges also require SSE 180, STAR 50, SZSE 100, and ChiNext firms to report ESG data by 2026. These rules show a shift toward "double materiality" disclosures. They align with ISSB and EU CSRD standards. The focus is on governance, environmental impact, and supply chain risks.

Most mineral-rich states in the Global South lack sufficient financial resources. This highlighted how traceability and transparency requirements imposed by Northern-led regulatory frameworks can function as de facto non-tariff barriers, disadvantaging producers who lack the technical infrastructure for compliance.¹¹⁴ Capacity-building provisions in international agreements have had mixed success in addressing this asymmetry. They also have limited digital infrastructure and skilled personnel. These gaps make deploying blockchain-based or interoperable

¹¹¹ Cristina Ledro, Anna Nosella, and Ilaria Dalla Pozza, "Unlocking the Power of Artificial Intelligence in Customer Relationship Management: A Comprehensive Analysis of Critical Success Factors," *Journal of Retailing and Consumer Services* 91 (2026): 104754, <https://doi.org/https://doi.org/10.1016/j.jretconser.2026.104754>.

¹¹² Siti Hasnah Hassan, Noor Mohamed Mohamed Haniba, and Noor Hazlina Ahmad, "Social Customer Relationship Management (s-CRM) among Small- and Medium-Sized Enterprises (SMEs) in Malaysia," *International Journal of Ethics and Systems* 35, no. 2 (2018): 284–302, <https://doi.org/https://doi.org/10.1108/IJOES-11-2017-0192>.

¹¹³ Pushpender Kumar, Anupreet Kaur Mokha, and Subash Chandra Pattnaik, "Electronic Customer Relationship Management (E-CRM), Customer Experience and Customer Satisfaction: Evidence from the Banking Industry," *Benchmarking: An International Journal* 29, no. 2 (2021): 551–72, <https://doi.org/https://doi.org/10.1108/BIJ-10-2020-0528>.

¹¹⁴ Vicente Guerola-Navarro et al., "Customer Relationship Management (CRM) and Innovation: A Qualitative Comparative Analysis (QCA) in the Search for Improvements on the Firm Performance in Winery Sector," *Technological Forecasting and Social Change* 169 (2021): 120838, <https://doi.org/https://doi.org/10.1016/j.techfore.2021.120838>.

traceability systems difficult.¹¹⁵ Mineral-producing developing countries face major challenges in infrastructure, human capital, and funding. Governments often worry that Northern-led traceability initiatives transfer control over subsoil data.¹¹⁶ Such transfers occur without providing fair benefits to the producing states. The principle of common but differentiated responsibilities (CBDR) could address these concerns. It is already recognized in climate and biodiversity regimes. It should be applied explicitly in CRM traceability governance.¹¹⁷

Without industry support, even strong legal frameworks risk remaining theoretical. Companies worry traceability data could reveal proprietary sourcing strategies and costs. Contract terms or geological knowledge may also be exposed. Public reporting could require aggregated, anonymized, or pseudonymized data only. Full, detailed datasets should remain accessible to regulators under strict non-disclosure rules. Legal privileges, like those in banking supervision or competition-law leniency, could protect raw data.¹¹⁸ Frameworks such as iTSCI or the Cobalt Industry Responsible Assessment Framework still see low uptake. Second- and third-tier suppliers rarely participate fully in these programs. Meanwhile, growing ESG-linked investment creates strong incentives for compliance. Pure top-down regulation may impose technically difficult or overly costly obligations.¹¹⁹

Global supply chains are often opaque, and national regulations differ widely. These differences create strong incentives for companies to bypass rules. The main enforcement tool is linking market access to verifiable traceability compliance. Private companies can support this by including traceability performance in ESG frameworks. Mandatory public disclosure of traceability data can create reputational pressure on firms. Trade disputes over traceability need fast, expert-led resolution mechanisms. Traditional WTO panels are too slow and politicized for these issues.

¹¹⁵ Cristina Ledro et al., "Artificial Intelligence in Customer Relationship Management: A Systematic Framework for a Successful Integration," *Journal of Business Research* 199 (2025): 115531, <https://doi.org/https://doi.org/10.1016/j.jbusres.2025.115531>.

¹¹⁶ Joe Hazzam et al., "Digital Marketing Capabilities and SME Performance: The Influence of Market Orientation and the Complementarity Effect on Customer Relationship Management Capabilities," *Journal of Research in Marketing and Entrepreneurship* 28, no. 1 (2026): 1–21, <https://doi.org/https://doi.org/10.1108/JRME-02-2025-0029>.

¹¹⁷ Zhan (Myra) Wang and Garth Harris, "From Tools to Trusted Allies: Understanding How IoT Devices Foster Deep Consumer Relationships and Enhance CRM," *Journal of Research in Interactive Marketing* 20, no. 1 (2026): 11–29, <https://doi.org/https://doi.org/10.1108/JRIM-10-2024-0484>.

¹¹⁸ Werner J Reinartz, "Customer Relationship Management: Past, Present, and Future," *International Journal of Research in Marketing* 43, no. 1 (2026): 8–27, <https://doi.org/https://doi.org/10.1016/j.ijresmar.2025.12.001>.

¹¹⁹ Rashed Al Karim et al., "The Nexus between CRM and Behavioural Loyalty in Hotel Sector: The Mediating Role of Relationship Quality (Trust and Satisfaction)," *Global Knowledge, Memory and Communication* 75, no. 5 (2026): 2394–2413, <https://doi.org/https://doi.org/10.1108/GKMC-03-2024-0169>.

Implications and Future Trajectories for International Traceability Law

This nascent field goes beyond existing branches of international economic law. It creates a distinct space for governing global supply chains through mandatory, verifiable information flows. International traceability law is highly interdisciplinary at its core.¹²⁰ It works at the intersection of trade law, data governance, environmental law, human rights law, and technology regulations. Traceability systems for active pharmaceutical ingredients face similar tensions. EU and WHO rules aim to prevent falsified medicines. These rules require disclosure but must respect data sovereignty. The field balances transparency, compliance, and legal protections across borders.

Data is no longer only ancillary to trade in goods. In high-risk value chains, such as cobalt, lithium, or rare-earth elements, traceability data forms part of the good itself. This challenges the traditional distinction between trade in goods (GATT) and trade in services (GATS).¹²¹ Certain data flows are neither services supplied electronically nor simple transmissions. They are digitally embodied attributes of physical products. The trilemma shows contradictions of strict digital sovereignty in global value chains. Even strict jurisdictions, like China with its Critical Mineral Traceability Standard, rely on data generated abroad. The EU, with its Battery Regulation and Digital Product Passport, faces the same reliance on foreign-generated data. Often this data comes from Indonesia and is processed by foreign-owned platforms. Governing CRM traceability systems resembles regulating large digital platforms under GDPR, DMA, and emerging EU rules like the AI Act and Data Act.¹²²

The proposed legal framework for resolving the traceability trilemma has global implications. Effective traceability is essential for moving CRM value chains toward a circular economy. The framework improves supply chain transparency, which supports accurate Scope 3 carbon accounting. It also helps companies implement decarbonization strategies more reliably. The framework strengthens compliance with emerging human rights and environmental due diligence obligations. It contributes to multiple Sustainable Development Goals in an

¹²⁰ Antoine Saadé and Ouidade Sabri, "GAI-Enabled CRM and Sales Unit Performance: A User-Level Pathway through Perceived Quality and Technology Acceptance, Moderated by Adoption Duration," *Journal of Innovation & Knowledge* 16 (2026): 101073, <https://doi.org/https://doi.org/10.1016/j.jik.2026.101073>.

¹²¹ Todd Morgan et al., "Customer Participation in Manufacturing Firms' New Service Development: The Moderating Role of CRM Technology," *Journal of Business & Industrial Marketing* 39, no. 4 (2023): 857–70, <https://doi.org/https://doi.org/10.1108/JBIM-03-2022-0142>.

¹²² Vinod Kumar et al., "Exploring the Relationship between GenAI-CRM and Market Effectiveness: The Moderating Role of Top Management Support and Technology Turbulence," *European Journal of Innovation Management* 29, no. 5 (2026): 1625–45, <https://doi.org/https://doi.org/10.1108/EJIM-06-2025-0827>.

integrated way. Responsible Consumption and Production is a key area supported by this framework.¹²³

The principles and mechanisms have not yet been tested in real-world CRM supply chains. Different administrative capacities may limit effective implementation and compliance. Non-cooperative actors could deliberately try to bypass the rules. Advances in AI may change how compliance is monitored or enforced. Homomorphic encryption and zero-knowledge proofs could strengthen technical safeguards. Quantum computing may make some current technical methods obsolete. These rapid changes create uncertainty for the framework's long-term effectiveness.

Conclusion

This study concludes that fragmented national data sovereignty regimes have become a fundamental legal obstacle to the establishment of effective international traceability systems for critical raw materials. Divergent regulatory approaches adopted by the European Union, China, and Indonesia impose inconsistent requirements for data localization, cross border data transfers, and digital traceability, thereby increasing compliance costs, reducing legal certainty, and weakening supply chain resilience. The absence of harmonized legal standards prevents seamless information exchange across jurisdictions and limits the effectiveness of existing traceability mechanisms. The study further concludes that the development of International Traceability Law requires a coherent legal framework founded on the principles of legality, proportionality, functional equivalence, and functional sovereignty. Such a framework should recognize the legal validity of digital traceability records, facilitate secure cross border data exchange, respect legitimate national interests in strategic data governance, and maintain consistency with international trade obligations. At the same time, the framework should incorporate differentiated implementation mechanisms that enable developing mineral producing countries to participate effectively without undermining their sovereign rights over critical resources. International traceability framework extends beyond regulatory compliance by strengthening supply chain transparency, supporting sustainable resource governance, enhancing environmental and human rights due diligence, and improving the resilience of global critical raw material value chains. Although complete reconciliation between data sovereignty, transparency, and unrestricted international trade remains unattainable, a balanced legal framework can provide the normative foundation for trusted international cooperation and the future development of International Traceability Law.

¹²³ Cristina Ledro, Anna Nosella, and Andrea Vinelli, "Leveraging Artificial Intelligence for Sustainable Customer Relationship Management: A Critical Review and a Conceptual Framework," *Journal of Cleaner Production* 535 (2025): 147142, <https://doi.org/10.1016/j.jclepro.2025.147142>.

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