



Traceability Readiness in Bangladesh's RMG Supply Chain and the SME Exclusion Gap in EU Digital Product Passport Compliance

Areebah Ahsan¹ Sajib Chowdhury¹ Abdullah Wakib¹ Adonia Sama¹ Jalalul Islam²

BRAC Business School, BRAC University¹ IPE, Ahsanullah University of Science and Technology²

areebahahsan30@gmail.com, sajib.Chowdhury@g.bracu.ac.bd, abduhahwakib1610@gmail.com,
adoniasamadharma@gmail.com, efazislam2002@gmail.com

ABSTRACT

Bangladesh's ready-made garment (RMG) sector exports over USD 19.71 billion annually to the European Union (EU). Under the EU Ecodesign for Sustainable Products Regulation (ESPR), these exports will soon require Digital Product Passport (DPP) compliance. However, institutional initiatives, such as the May 2026 BGMEA-AWARE™ Memorandum of Understanding, focus primarily on large, Tier-1 exporters with existing digital capabilities. This focus leaves small and medium-sized enterprise (SME) subcontracting factories without a viable compliance pathway, creating an SME Exclusion Gap. Using an exploratory qualitative case study design (Yin, 2018), this paper evaluates traceability readiness across five purposefully selected RMG factories in Chittagong and Narayanganj using a 27-question cross-functional assessment and four operational datasets. The findings reveal a significant gap between external buyer pressure (averaging 3.8 out of 5) and internal technology capacity (averaging 2.4 out of 5, the lowest among all evaluated dimensions). While all five factories reported regular buyer compliance demands, past order cancellations, and financial constraints, operational data showed severe structural deficits: only 40% maintained formal chemical tracking, 40% could identify export shipments at the vessel level, and zero demonstrated high DPP awareness. To explain why demand-driven pressure fails to spur digital adoption, this study models a Six-Barrier Causal Chain: financial exclusion induces skills deficits, which prevent foundational data capture; this lack of structured data renders technology investments ineffective. Consequently, subsidizing software or blockchain licenses alone cannot close the compliance gap. To resolve this issue, the paper introduces a Minimum Viable Traceability (MVT) framework featuring four cost-tiered implementation steps, alongside a repeatable Traceability Readiness Score (TRS) tool. Ultimately, the SME Exclusion Gap is fundamentally an information infrastructure and operational capability challenge rather than a blockchain adoption hurdle; verified DPP compliance cannot occur without certified supplier records, structured procurement data, and digitized logistics documentation.

Keywords : *Digital Product Passport (DPP); Traceability Readiness; SME Exclusion Gap; RMG Supply Chain; Minimum Viable Traceability; Blockchain Adoption Barriers*

INTRODUCTION

On 10 May 2026, BGMEA Vice President Vidiya Amrit Khan and AWARE™ Founder Feico van der Veen signed a Memorandum of Understanding, pledging the compliance of the RMG sector in Bangladesh with the blockchain system. During the ceremony, Khan said: “The EU Digital Product Passport is soon in effect and our members must be ready for it.” There is a sense of urgency. The EU Ecodesign for Sustainable Products Regulation (ESPR) has entered into force on 18 July 2024 while delegated acts for textiles are expected around 2027, with mandatory compliance taking place around 18 months after, placing the compliance window for most product categories between 2028 and 2029 (European Commission, 2024; COSH!, 2026).

DPP compliance is not just a regulatory formality but a prerequisite for accessing markets, as Bangladesh's export earnings from the European Union (EU) amounted to USD 19.71 billion in FY2024–25 (BGMEA, 2025). This urgency is focused in the 2026 - 2028 period due to three converging pressures. First, in November 2026 Bangladesh will graduate from Least Developed Country status, losing duty free access from the EU and moving into a new tariff regime which will squeeze margins. Second, the US-Iran Hormuz Strait disruptions of 2025-2026 for slashing LNG imports from Qatar and UAE, the sources of 72% of Bangladesh's LNG requirements, resulted in catch-and-cancel emergency switches of raw materials which disrupted traceability chains in the middle. Third and most importantly, the research conducted on the state of Asian supply chains' readiness indicates that the factories in Bangladesh will have around 10 to 30% of the documentation the DPP will request, while European-based manufacturers (Portugal Clothing Factory, 2026) will have 60 to 80% of the documents. BGMEA–AWARE™ is targeted at the top 10% of the sector that is best prepared. This paper proposes that the remaining 90% is an uncovered structural risk. This structural risk is especially relevant because Bangladesh's export-oriented supply chain has more than 70% of its garment factories as small and medium-sized enterprises (SMEs) and many of these SMEs are subcontractors. They have been historically helping to increase the competitiveness of Bangladesh by providing production capacity to adjust and have much smaller financial and technological power to manage large compliance issues. This weakness has been apparent in past sectoral crises. The Rana Plaza tragedy completely transformed industry-wide safety standards, with compliance requirements significantly hampering smaller manufacturers' ability to meet international standards (Iqbal, 2026). Approximately USD 3.16 billion worth of clothing orders had been canceled or suspended by foreign purchasers during the

COVID-19 outbreak, impacting 1,142 factories and 2.26 million people. This exposed the fragility of many manufacturers, especially when it comes to unexpected events (Hossain, 2021).

The EU Digital Product Passport is not a human or public health issue, but is a similar structural issue. The lack of affordable and scalable traceability solutions is a concern for many SME manufacturers as it could make them vulnerable to being excluded from EU value chains, again jeopardising the production flexibility that has been the cornerstone of Bangladesh's competitiveness in the global apparel industry. With this background, this study has three contributions. It offers empirical and case study analysis of the traceability readiness in all size of RMG industries in Bangladesh. It provides a score, called the Traceability Readiness Score (TRS), that is replicable and tested. Moreover, it proposes an 18-month implementation roadmap, a subsidy mechanism and a Minimum Viable Traceability (MVT) framework with clear cost criteria for the SME subcontracting factories which have not been addressed by existing DPP initiatives.

2. Literature Review

2.1 The EU DPP Regulatory Framework and Bangladesh's Quantifiable Exposure

Supply chain traceability is defined as the ability to trace and verify the movement of goods and material inputs from the origin to the end consumer by digitally documented and auditable digital records (Saber et al., 2019). This definition will finally be put into effect through the EU Ecodesign for Sustainable Products Regulation (ESPR) which came into force on 18 July 2024. To achieve delegated acts expected for textiles around 2027 by the EU (European Parliament Research Service, 2024), all garments entering the market in the EU will require a Digital Product Passport (DPP): a digital record attached to a data carrier which will include information on fibre composition, compliance with MRSL/RSL standards, multiple-tier supplier verification checks, environmental footprint per garment and End-of-Life instructions. The key regulatory leap forwards is towards declared compliance to verified compliance. Some previous schemes such as OEKO-TEX, GOTS, BSCI, allowed for the use of periodic third party audits. In the DPP, the requirement is for ongoing product-level verification, where every data value is traceable back to some verifiable source online or digitally (Badhwar et al., 2023). In fact, more than 53% of the environmental claims identified in the European Commission's (2021) screening study of websites

for greenwashing in the EU single market were vague, misleading or unsupported, thus identifying the regulatory rationale for the DPP's move from declared to verified compliance.

The impact of this regulatory change on Bangladesh seems significantly focused and measurable. A decade-long trend of the country's RMG export shows a growth of structural dependence on EU markets together with structural growth. Total RMG exports grew from about USD 25.5 billion in FY2014–15 to USD 42.61 billion in FY2021–22, benefiting from the diversion of orders from China during its prolonged lockdown and pent-up demand in the West, after the COVID pandemic. Exports rose to USD 39.35 billion in the FY2024–25, marking a 8.84% increase from the previous year, having contracted to USD 36.15 billion in FY2023–24 due to EU consumer inflation and reduced spending on clothing items among the households following the Russia–Ukraine war (EPB, 2025; BGMEA, 2025).

Fiscal Year	Total RMG Exports (USD Bn)	YoY Growth (%)	Key Driver
FY2015–16	28.09	+9.1%	Stable EU and USA demand
FY2016–17	28.15	+0.2%	Sluggish global growth
FY2017–18	30.61	+8.8%	Knitwear surge, market diversification

FY2018–19	34.13	+11.5%	Strong EU consumer spending
FY2019–20	27.95	–18.1%	COVID-19 order cancellations
FY2020–21	31.46	+12.6%	Partial recovery, knitwear led
FY2021–22	42.61	+35.5%	Post-COVID demand surge, China diversion
FY2022–23	38.14	–10.5%	EU inflation, Russia–Ukraine war effect
FY2023–24	36.15	–5.2%	Continued EU demand softness
FY2024–25	39.35	+8.84%	Recovery; EU grew 9.10%, USA 13.79%

Table 2.1. Bangladesh RMG Export Trajectory: Ten-Year Overview (FY2015–16 to FY2024–25)

Source: EPB (2025); BGMEA (2025); Author compilation. Growth rates based on fiscal year (July–June) data.

During this decade-long period, the EU’s export share in Bangladesh’s RMGs has stayed fairly constant between 48% and 52%, reflecting that dependence is not an issue of recent times but a key component of the RMGs export structure in Bangladesh. In FY2024–25, the EU accounted for USD 19.71 billion, precisely 50.10% of total RMG exports, making it by far the single largest market, ahead of the United States (USD 7.54 billion, 19.18%), the United Kingdom (USD 4.35 billion, 11.05%), and Canada (USD 1.30 billion, 3.31%) (EPB, 2025). The internal geography of the EU market is an important aspect of the compliance strategy for DPP. Germany, with (USD 4.95 billion) followed by Spain, (USD 3.40 billion); France, (USD 2.16 billion); Netherlands, (USD 2.09 billion); Poland, (USD 1.7 billion); Italy, (USD 1.54

billion); and Denmark, (USD 1.04 billion), are Bangladesh's largest national export markets. Notably, the Netherlands (+21.21%), Sweden (+16.41%), Poland (+9.77%) and Germany (+9.47%) have all seen the highest growth in their EU markets in FY2024-25, with all four markets having some of the strongest consumer expectations and stringent regulations around ESG products in the world. (EPB, 2025) Bangladesh's thriving EU markets are, in fact, the ones where DPP non-compliance is likely to be caught the quickest and most severely by customs officials.

Market	Export Value (USD Bn)	Share of Total RMG (%)	YoY Growth (%)	DPP Risk Level
EU — Total	19.71	50.10%	+9.10%	Critical — DPP mandatory
Germany	4.95	12.59%	+9.47%	Critical
Spain	3.40	8.64%	N/A	Critical
France	2.16	5.49%	N/A	Critical
Netherlands	2.09	5.31%	+21.21%	Critical — fastest growing
Poland	1.70	4.32%	+9.77%	Critical
Italy	1.54	3.92%	N/A	Critical

USA	7.54	19.18%	+13.79%	Medium — no DPP equivalent yet
UK	4.35	11.05%	+3.68%	Medium — UK ESPR equivalent likely
Canada	1.30	3.31%	+12.07%	Low
Non-traditional markets	6.44	16.36%	+5.61%	Low

Table 2.2. Bangladesh RMG Exports by Key Market (FY2024–25)

Source: EPB (2025); BGMEA (2025); Textile Focus (2025). DPP risk level assigned by author based on ESPR applicability.

The competitiveness of Bangladesh in the international trade of apparel increases this exposure. According to the International Trade Centre (ITC, 2024), the global apparel industry grew to about USD 500 billion in 2024, with Bangladesh accounting for about 7-8% of it as the country is the second-largest exporter of garments in the world. The major structural rival Vietnam has been getting itself set up for EU market access -- and the EU market, at that -- via access to preferential tariff rates under the EU-Vietnam Free Trade Agreement and incentives for regulatory convergence to EU standards that Bangladesh lacks. The most comparable competitor in terms of production capacity and product range is India, and it is preparing for DPP readiness investment just because Bangladesh's status as an LDC is to be lifted in November 2026, and also at the same time EU duty-free access will be withdrawn at the same time. The first country to establish credible DPP compliance infrastructure to be a major exporter will win the buyers confidence over a long period of time, while those who do not would be left with no confidence.

The studies of readiness asymmetry adds support to the view that there is a high level of structural challenge this competitive scenario brings. The European Parliament Research Service (2024) explicitly mentions that developing country exporters have much larger documentation infrastructure gaps than EU based manufacturers and that the continuous, product-level verified data required by the DPP is a qualitatively new compliance challenge to the factory tier of Bangladesh. A Discover Sustainability study by Al Amin et al (2025) on the use of blockchain for green supply chain management in the RMG industries of Bangladesh revealed that adoption of digital traceability infrastructure in the RMG industries is ‘highly concentrated among large export-oriented factories’, while SME adoption is described as “negligible”. The SME Exclusion Gap that this paper examines is an empirical phenomenon that has been concentrated in the minority, the large factories, while the SME subcontracting tier is structurally invisible.

The quantification above implies something directly that forms the entire argument in this paper. Bangladesh's exposure to the EU of USD 19.71 billion is not evenly spread over the sector as there is a strong burden on the large exporters belonging to BGMEA and having direct sourcing contracts with the EU brands. There is no structural representation of the SME subcontracting factories that make up a substantial proportion of the physical output that generates that revenue in the compliance infrastructure those large factories are now creating. Once it is put into effect, the compliance failure will not be Bangladesh failure, but a failure at the supply chain level; that is, a large factory that hasn't invested in Block Chain will be non-compliant because of its use of sub-contractors to produce its goods. The magnitude of this risk (USD 19.71 billion) is the reason why the SME Exclusion Gap is not a welfare problem and is a national competitiveness emergency. This lack of a gap closing on its own is explained by structural reasons in Section 2.2.

2.2 Blockchain Adoption Barriers in Bangladesh's RMG SME Sector: A Causal Chain Analysis

The literature on blockchain adoption barriers in Bangladesh's RMG sector has grown substantially since 2022, but has continuously recorded certain obstacles separately rather than looking at how those obstacles result in and reinforce each other. Financial limitations emerge noticeably in Sarker and Uddin's (2025) blockchain-adoption survey and Ahmed and Hossain's (2024) SME-focused analysis, both of which identify implementation cost and limited investment capacity as central obstacles. Skills and capacity of the organization limitations are documented by Hosain (2025), Hossain and Sani (2025), and JIBEP (2025), which highlight digital-skills shortages, limited technical awareness and insufficient capacity for implementation among smaller producers. Within the data layer, Kouhizadeh et al. (2024) identify supplier non-participation as a crucial obstacle to traceability, while Al Amin et al. (2025) illustrates that blockchain-based supply-chain solutions assume that a certified supplier is present and procurement data. Saha et al. (2025) further connects this documentation deficit to Bangladesh's import-dependent and unstable environment for the purchase of raw materials. Unreliable infrastructure is highlighted by Hosain (2025) and The Daily Star (2026), where Akter (2024) and JIBEP (2025) illustrates Blockchain investment is discouraged by regulatory uncertainty. Finally, Al Amin and Rahman (2025), alongside the evidence on unregistered subcontracting factories reported by Financial Express (2022), points the end-to-end traceability-limiting network-participation issue. This section argues that the "six documented barriers do not operate independently" Each barrier sets the stage for the subsequent one, forming a causal chain, making the overall exclusion effect is significantly worse than what would be predicted by any "one barrier alone". SMEs are limited in their ability to hire compliance staff due to financial exclusion and invest in digital capability, this capacity shortfall makes structured data recording less effective, the resulting absence of supplier, chemical and procurement records leaves traceability systems without verifiable content, the small amount of data generated is threatened by faulty infrastructure, regulatory ambiguity discourages further investment and coordination and incomplete network participation prevents any individual factory from achieving end-to-end DPP traceability. Because it illustrates why one-dimensional policy approaches, such subsidizing blockchain software alone, are unable to reduce the SME Exclusion Gap, understanding this chain is crucial from an analytical standpoint.

Table 2.3 presents the chain's structure before the evidence for each link is developed.

Barrier in the causal chain	Main sources	Contribution to the analysis
1.Financial exclusion	Sarker and Uddin (2025); Ahmed and Hossain (2024); Hossain and Sani (2025)	Establishes that blockchain and ERP costs exceed the financial and digital-investment capacity of most SMEs.
2.Skills and capacity deficit	Hosain (2025); Hossain and Sani (2025); JIBEP (2025); Ahmed and Hossain (2024)	Shows that SMEs face digital-skills shortages, limited implementation expertise, and owner-operator capacity constraints.
3.Foundational data absence	Kouhizadeh et al. (2024); Al Amin et al. (2025); Saha et al. (2025)	Demonstrates that blockchain cannot generate traceability where supplier, procurement, certification, and chemical data have not been created or recorded.
4. Infrastructure unreliability	Hosain (2025); The Daily Star (2026); World Bank (2025)	Identifies power, internet, and connectivity weaknesses that threaten the continuity and reliability of digital traceability records.

5.Regulatory ambiguity	Akter (2024); JIBEP (2025); World Bank (2025)	Highlights the absence of a coherent national blockchain, digital-trade and DPP governance framework.
6. Network-effect failure	Al Amin and Rahman (2025); Financial Express (2022); Syed et al. (2026)	Explains why factory-level adoption cannot ensure supply-chain traceability when suppliers, subcontractors, logistics actors, and unregistered factories remain outside the network.

Barrier	Mechanism	Produces Next Barrier By
1.Financial Exclusion	IT budgets of BDT 500–3,000/month cannot fund ERP or blockchain	Preventing hiring of compliance staff
2.Skills and Capacity Deficit	No compliance officer; owner-operator absorbs all roles	Preventing structured data recording
3. Foundational Data Absence	No certified supplier records; no chemical tracking	Rendering any traceability system content-less
4.Infrastructure Unreliability	30% power outage rate creates unrecoverable blockchain gaps	Creating compliance risk specific to blockchain (not paper)

5.Regulatory Ambiguity	No national blockchain standard; FERA/MLPA chilling effect	Discouraging investment even where capacity exists
6.Network Effect Failure	1,000+ factories outside BGMEA; no critical mass for participation	Making individual compliance insufficient for DPP chain integrity

Table 2.3. The Six-Barrier Causal Chain Producing SME Traceability Exclusion

Source: Author's synthesis from cited literature. Each barrier is causally upstream of the next.

Barrier 1: The Financial Exclusion Wall and What It Generates

The financial barrier is the chain's first and most documented link. Sarker and Uddin (2025), in a survey of 300 Bangladesh RMG sector professionals, discovered that the highest regression coefficient is associated with financial limitations. ($\beta = -0.42$) among all tested blockchain adoption barriers. Ahmed and Hossain (2024), in the most immediately appropriate Bangladesh-specific study focused on SME factories specifically find that implementation costs "exceed the annual digital investment capacity of most small and medium factories by a factor of ten or more." The primary data from this study places these findings in an in exact operating environment the two SME factories with the lowest Traceability Readiness Scores reported monthly IT budgets of BDT 3,000 and BDT 500 respectively. At BDT 11 million for a full blockchain implementation, the factory with a BDT 3,000 monthly budget would require over 300 years of self-funded investment to comply. Even a locally-developed ERP system at BDT 500,000–1,760,000 represents decades of budget allocation.

These figures establish that the financial barrier is not a funding gap that Incremental company expansion can close. It is a structural exclusion requiring institutional subsidy. More significantly, a factory that cannot afford ERP cannot afford a compliance officer, which becomes the next obstacle in the chain. Supplier certification is not managed in the absence of a compliance officer. Without supplier certification, the basic data required for any traceability system is missing. The financial barrier is therefore not just a cost problem it is the generating source of the skills and data deficits that follow.

Barrier 2: The Skills Deficit -Produced by Financial Exclusion, Producing Data Absence

Hosain (2025) documents a 30% digital skills vacancy across Bangladesh's RMG sector before blockchain-specific requirements are considered. Hossain and Sami (2025), in a dedicated study of ERP adoption and performance in Bangladesh's RMG industry published in the International Journal of Research and Innovation in Social Science, find that ERP adoption is constrained by "limited digital skills, high implementation costs and organizational resistance to change," with smaller producers bearing an excessive amount of these limitations. The JIBEP (2025) adds that scarcity of expert researchers and poor awareness about blockchain pervade the broader technological environment, including within the sector's workforce.

However, blockchain knowledge is not the main source of the particular skills issue in Bangladesh's SME industries. It is about the more foundational capability of structured data recording. Ahmed and Hossain (2024) specifically note that in SME factories, "the owner-operator structure collapses the roles of production manager, compliance officer and financial director into one person," indicating that even in situations when there is a desire to use digital technology the human capacity and operate traceability systems does not. If no one in the manufacturing is keeping track of the supplier names, material certificates, and chemical inputs from which DPP data must be extracted, blockchain-specific abilities are meaningless. The skills gap contributes to the data deficit rather than just existing with it.

Barrier 3: The Foundational Data Deficit - The Root Cause Technology Cannot Fix

The most crucial obstacle and the one most absent from policy discussion is the absence of foundational data. Kouhizadeh et al. (2024), in a systematic review of 50 peer-reviewed articles on blockchain in supply chain management published in the International Journal of Production Economics, identify supplier non-participation as a critical external barrier and note that blockchain "cannot trace what has not been recorded." For the context of Bangladeshi SMEs, this insight is analytically crucial.

In two of the five factories studied in this paper, certified supplier usage was zero across all observed raw material purchase records. These manufacturers purchased goods from price-competitive importers without paperwork, unidentified brokers, and uncertified market sellers. The foundational data problem here is not

a recording problem it is a relationship problem. No certified supplier relationships exist from which to generate Tier 2 DPP data, regardless of what recording system is deployed. Al Amin et al. (2025), whose blockchain-based green supply chain framework for Bangladeshi RMG industries is among the most recent contributions to this literature, acknowledge this directly, the framework “pre-supposes a baseline of certified supplier and procurement data that most factories in this context do not yet possess.” The most specific claim in the literature that technology-layer solutions are dependent on data-layer requirements, which the majority of Bangladeshi SMEs have not fulfilled, comes from a report that suggests blockchain as a solution.

Saha et al. (2025), in a study of raw material procurement risk in Bangladesh’s RMG supply chain published in the Canadian Journal of Business and Information Studies, reinforce the upstream dimension of this problem, the sector’s heavy dependence on importing raw materials from India, China, and Turkey means that “customs delays, price volatility and quality-control failures at the point of import” consistently undermine the supplier relationships necessary for verifiable, certified sourcing. Certified suppliers are not just an investment decision they are a stability decision that Bangladesh’s raw material import dependency makes structurally difficult to sustain even when investment willingness exists.

The analytical center of this paper's thesis is the fundamental data barrier. Due to the lack of certified supplier ties, two of the five factories in this study might install BGMEA-AWARETM's blockchain platform tomorrow and still create zero Tier 2 DPP data. Before the SME Exclusion Gap is a technical issue, it is a data infrastructure issue.

Barrier 4: Infrastructure Unreliability - A Risk Specific to Blockchain

Hosain (2025) documents a 30% power outage rate in Bangladesh’s RMG industrial zones — a figure that represents a specific risk for blockchain that does not apply equally to paper-based or ERP systems. A blockchain record with missing data cannot be refilled inside of the verified chain if an interruption in power leaves a gap in it. On the contrary, an ERP record may be manually reconstructed from paper backups, and a paper record gap can be discovered retrospectively. For SME factories without reliable backup power, blockchain may therefore create an additional compliance risk that manual systems do not create to the same extent. Therefore, the infrastructural barrier is a specific reason for a DPP compliance risk carried about by blockchain itself, instead of just a barrier to implementation. During the Hormuz emergency of 2025–2026,

when LNG shortfalls led to daily load-shedding throughout industrial zones for between three and five hours, this danger grew. Even the one factory in this study operating with digital systems (F01, with dedicated backup power) experienced data continuity challenges. SME factories on shared utility connections had no contingency protocol for blockchain data integrity during outages. Bangladesh possesses a 53% national broadband access rate, according to The Daily Star (2026). Industrial zone connectivity in Chittagong and Narayanganj frequently is reliant on common mobile data connections with variable broadband speeds, which is fundamentally inconsistent with the continuous node uptime required by a standard blockchain.

Barrier 5: Regulatory Ambiguity - No National Framework Exists

Bangladesh lacks a national regulatory framework for blockchain technology, creating legal uncertainty that inhibits investment even where financial and skills capacity exists. According to JIBEP (2025), According to Bangladesh Bank's assessment of the Money Laundering Prevention Act of 2012 and the Foreign Exchange Regulation Act of 1947, cryptocurrency like Bitcoin are forbidden. This might bring up concerns regarding blockchain investments in general, including authorized systems without cryptocurrency. Akter (2024), in a PRISMA-based systematic review of blockchain potential in Smart Bangladesh, finds that “the lack of a national blockchain regulatory framework creates uncertainty that inhibits institutional adoption and private investment.”

Additionally, Bangladesh’s logistics and trade governance is administered by nine ministries and over 20 government agencies with no unified digital trade documentation standard (World Bank, 2025). No government authentication platform exists to validate DPP records, no national standard defines minimum DPP data fields for Bangladesh’s context, and the Personal Data Protection Ordinance, approved in October 2025, arrived too recently to have been integrated into existing traceability infrastructure design (The Daily Star, 2026). As a result, factories may overcome their financial, skills, data, and infrastructure problems but still lack a government-verified system to which they can connect their DPP records.

Barrier 6: The Network Effect — Individual Compliance Is Not System Compliance

The value of blockchain as a traceability method is largely dependent on network participation: even if a factory adopts a blockchain system and removes all five of the aforementioned obstacles, it will still be impossible to create a full DPP if its logistics partners, suppliers, and sub-suppliers continue to function off-chain. The first-mover disadvantage caused by this network dependence is especially noteworthy in the context of SMEs in Bangladesh. An early-adopting SME bears the full cost of implementation (Barriers 1-5) but derives no traceability benefit until the rest of its supply network also participates. Al Amin and Rahman (2025) note that in Bangladesh's current environment, "the ecosystem for multi-stakeholder blockchain participation does not yet exist at the scale required for meaningful traceability," and that early adopters "risk bearing costs without network benefits."

The Financial Express (2022), citing a joint study by the Centre for Policy Dialogue (CPD) and Christian Aid, reports that over 1,000 factories operate without BGMEA membership meaning they are structurally absent from any platform governance architecture from the outset. New unregistered subcontracting capacity is continuously generated as a structural market response to worker shortages at lead factories (CPD/Christian Aid, as cited in Financial Express, 2022), making the network permanently incomplete without an institutional mechanism to bring unregistered factories into the formal system. The BGMEA-AWARE™ MoU addresses registered factories. It has no mechanism for the 1,000+ factories that are not.

Why RMG Remains the Right First-Mover Despite These Barriers

The six barriers documented above are severe but not disqualifying for the RMG sector as a whole. Three structural characteristics distinguish RMG from other sectors in Bangladesh and make coordinated blockchain adoption viable at the large-factory level: an established compliance ecosystem built through post-Rana Plaza ACCORD and ALLIANCE programmes, with BGMEA governance covering 4,000+ registered factories; capital concentration at large exporters sufficient to absorb first-mover costs (Hosain, 2025); and a legally defined, time-bounded market pull in the form of EU DPP compliance requirements that no other Bangladeshi sector faces. Syed et al. (2026), in a Discover Sustainability study of digital governance in Bangladesh's RMG sector, note that even where current digital tools serve primarily audit rather than traceability functions, the buyer-driven governance model creates buyer-facing compliance infrastructure on which traceability systems can eventually be built.

It's not that RMG was the incorrect first mover. The issue is that the SME subcontracting tier, which does not appear in the six-barrier causal chain this section has determined, lacks a feasible pathway because the current BGMEA–AWARE™ project solely targets the factories that currently have infrastructure in place to assist the massive-factory minority. The Minimum Viable Traceability framework proposed in Section 6 of this paper is designed specifically to provide that pathway.

2.3 Bangladesh RMG Supply Chain: Structural Context

The manufacturers who operate locally are currently in a structural position which is responsive due to the RMG sector being a buyer-dominated governance archetype. In this sector, global brands retain most of the impact over other components such as pricing, specifications, and decisions on sourcing. Syed et al., 2026 further found that this model of buyer-driven governance is enabling fragmented compliance and it enforces an imbalance of power. The imbalance extends to how technology is used on the factory floors, and all of this has been concluded based on interviews, focus group discussions, and observations made on-site among Bangladeshi RMG factories. This further showed that even in cases where digital tools such as blockchain pilots, biometric attendance, and digital wage platforms have been introduced, their uses usually only help with managerial oversight, and buyer-facing audit needs instead of producing verified, shareable data. This creates a continuous gap between the practices on the actual shop floor and documented policy. This reactive approach may have two immediate consequences on traceability: supplier connections continue to be transactional rather than certified and factories lack the advanced procurement documents from which a legitimate traceability chain can be built.

There are two further structural constraints that make up this picture. Firstly, the sector is heavily dependent on importing raw materials (fiber, yarn, fabric, dyes, and chemicals, etc.) from India, China, and Turkey. Saha et al. (2025) identifies this dependency as high-impact risk for procurement, due to customs delays, price variations and quality-control failures at the point of import causing disruptions in the supplier relationships that certified, traceable sourcing is dependent on. Secondly, digitalization and documentation gaps are concentrated among smaller producers, and these problems can be improved by ERP adoption, as it will increase audit readiness and buyer-facing traceability documentation that RMG factories need, but the adoption remains uneven and is constrained, especially for small and medium-sized factories, by limited digital skills, high implementation costs, and organizational resistance to changes; as noted by Hossain and

Sami (2025). Hosain (2025) similarly noted that IoT integration reduces lead times by 10–15%, blockchain improves traceability by 20%, and ERP reduces order errors by 15% in the Bangladesh RMG context, but found that implementation costs of USD 150,000 for full IoT infrastructure, a 30% staff skills gap, and 30% power outage rates severely constrain adoption among all but the largest exporters.

The proposed technical solutions seem to be largely conceptual. Al Amin et al. (2025) has developed a blockchain-based green supply chain management framework for Bangladeshi RMG factories, but it was derived from literature review rather than field validation and like the BGMEA–AWARE™ initiative, presupposes a baseline of certified supplier and procurement data that most factories in this study's sample do not yet possess.

2.4 Research Gap

Taken together, the literature reviewed above reveals a field that has diagnosed Bangladesh's digital-traceability problem repeatedly, but rarely at the resolution the EU DPP actually demands.

The first gap concerns the unit of analysis. Existing SME-digitalization studies in Bangladesh, including survey-based assessments of ERP perception (Sharif & Hoque, 2025) and blockchain-barrier surveys drawing on regression coefficients over hundreds of surveyees (Sarker & Uddin, 2025; Ahmed & Hossain, 2024), operate at the level of aggregated perception rather than factory-level documentation audit. These studies confirm that cost and skills are important barriers. However, they do not show how much supplier, chemical, or procurement information an individual factory can actually provide. A perception score is not a readiness score, and the distinction matters directly for DPP compliance, which requires verified, source-traceable data rather than stated intent (European Parliament Research Service, 2024).

A second gap concerns empirical testament versus conceptual modelling. Systematic reviews of intelligent SCM adoption in the RMG sector have themselves highlighted that the majority of the literature, over 60% by one count, proposes frameworks without field-testing them, and that SME-specific solutions and barrier-prioritization metrics remain almost entirely absent (Islam et al., 2025). Blockchain-specific proposals for Bangladesh's RMG sector inherit this weakness directly: even the most recent green-supply-chain

blockchain framework for the sector was derived from literature reviewing rather than factory observation, and explicitly presume a baseline of certified supplier data that most factories do not possess (Al Amin et al., 2025). Through the use of expert judgment but not necessarily case-level documentation evidence, the adoption drivers were ranked using a multi-criteria selection methodology based on a Bayesian Best-Worst Method – similarly to digital visibility and advanced analytics without referencing any specific type of compliance deadline or regulatory instrument (Rafid et al., 2025). To date, no study has combined a reproducible factory-level readiness measure with a specific regulatory benchmark, such as the DPP's Tier 1 and Tier 2 data requirements.

The third gap concerns how the barriers communicate with one another. The broader Industry 4.0 and digital-logistics literature in Bangladesh, including work synthesizing container shortage, tariff exposure, and digital logistics barriers alongside IoT/AI/blockchain solutions, treats these technologies as parallel, additive remedies to a set of independently listed obstacles (Islam et al., 2025b, Triple Threats and Triple Tech). This additive framing is imitated in ERP- and blockchain-specific barrier studies (Hossain & Sani, 2025; Ahmed & Hossain, 2024; Kouhizadeh et al., 2024), each documenting financial, skills, or infrastructure constraints as a itemised list rather than as part of storytelling causal chain in which one constraint mechanically triggers another. These literatures do not explicitly address the question of why solving only the financial problem such as subsidising a blockchain licence would still fail to yield compliant DPP data if certified suppliers and structured record-keeping are missing.

A fourth and related gap is the subcontractor tier itself. Existing sectoral responses, including the BGMEA–AWARE™ MoU and the digital-governance literature describing buyer-driven compliance infrastructure (Syed et al., 2026), are architected around BGMEA-registered exporters with direct buyer relationships. More than 1,000 unregistered subcontracting factories remain outside this governance structure (Financial Express, 2022). Although they are mentioned in the literature, they have not been studied as a separate group with their own documentation conditions, financial limits, and possible route to compliance.

This paper addresses these four gaps directly: it assesses traceability readiness through factory-level case evidence rather than survey perception; it validates a reproducible scoring instrument (the TRS) against the DPP's actual data requirements rather than a generic digitalization index; it treats the six identified barriers

as a causal chain rather than an independent list; and it targets the SME subcontracting tier specifically, proposing a Minimum Viable Traceability framework.

3.1 Research Design

This study employs an exploratory, qualitative multiple-case study design following the methodology established by Yin (2018). Given the novel operational context of the EU Ecodesign for Sustainable Products Regulation (ESPR) and the nascent deployment of Digital Product Passports (DPP) within developing economies, a qualitative pattern-matching approach is appropriate. The empirical inquiry evaluates five purposefully selected ready-made garment (RMG) manufacturing units located in the Chittagong and Narayanganj industrial clusters of Bangladesh. Rather than seeking statistical generalization across the broader sector ($N > 4,000$), the research focuses on analytic generalization to test, refine, and operationalize institutional readiness theories within SME subcontracting networks.

3.2 Research Approach: Primary and Secondary Data Sources

To examine current traceability procedures, pinpoint implementation obstacles, and evaluate RMG factories' readiness for digital traceability, an exploratory qualitative method was carried out. The study seeks to understand participants' experiences and organisational practices rather than test predetermined hypotheses. Primary empirical data was collected via a 27-question semi-structured diagnostic instrument administered across four operational domains:

- Information Technology & ERP Deployment: Infrastructure availability, database architecture, and system integration.
- Procurement & Raw Material Origin Tracking: Tier-2/3 supplier audit trails, mill certification integrity, and material batching.
- Chemical Management & Environmental Compliance: ZDHC (Zero Discharge of Hazardous Chemicals) compliance, safety data sheets, and testing verification.
- Export Logistics & Vessel Traceability: Commercial invoice digitization, bill of lading tracking, and packing list alignment.

Primary field responses were triangulated against four structured operational datasets covering (i) raw material procurement logs, (ii) order processing records, (iii) chemical inventories, and (iv) export shipping manifests.

3.3 Unit of Analysis

A single Bangladeshi Ready-Made Garment (RMG) factory concentrating on exports serves as the analyzing component. In the study, each factory that took participate represents a single instance. Respondents include personnel involved in procurement, production, compliance, logistics, sustainability, or supply chain management, such as factory managers, compliance managers, procurement managers, production managers, merchandising managers, and sustainability officers.

3.4 Data Collection Method

Primary data will be collected through a semi-structured questionnaire comprising closed-ended, Likert-scale, and open-ended questions. The respondents were selected intentionally from supply chain related functional roles with direct visibility, compliance, export processes, including roles such as factory managers, compliance officers, and quality managers. These roles were selected because they are more likely to have first-hand knowledge of supplier records, buyer audit requirements, and documentation of shipment (OECD, 2018). Inferring upon the responses of role-holders across these functions allows for measurement of perspectives on the same traceability practices from operational, compliance, and quality-control standpoints, which is compatible with Yin's (2018) recommendation of using multiple informants to strengthen validity of construct. This is a cross-functional approach and it also portrays the buyer-driven governance structure of the RMG sector, where compliance and quality functions are continuously the primary interface with international buyer audits (Syed et al., 2026). The questionnaire is organised into six sections: Factory Profile, Production Planning and Procurement, Logistics and Documentation, Traceability and Digital Readiness, Organisational Readiness, and Future Readiness. Where available, supporting documents such as supplier records, shipment records, and procurement documents may also be reviewed to enhance construct validity through multiple sources of evidence, as recommended by Yin (2018).

3.5 Questionnaire Development

After a thorough review of the literature available on supply chain traceability, Digital Product Passport (DPP), sustainable supply chain management, and digital transformation in manufacturing, a questionnaire was created to be both useful for industry participants and to be easy-to understand in nature, while also checking the list of the goals of the study. To figure out the extent to which current documentation has already estimated DPP-equivalent data trails, the Logistics and Documentation section questions were made to acquire information about current logistic documentation practices, such as shipment record-keeping, vessel identification, and buyer-requested proof of timing (World Bank, 2025; Islam et al., 2025). The factors on Digital Product Passport (DPP) awareness were included to approximate familiarity on a factory-level with EU traceability requirements ahead of mandatory compliance, including evidence that awareness gaps are a key barrier to readiness (European Parliament Research Service, 2024; European Commission, 2024). To make sure that the responses of the questionnaire can later be used as benchmarks against the minimum data-capture requirements of MVT for SME subcontracting factories, some items were added further to portray the Minimum Viable Traceability (MVT) framework, which has been suggested in Section 6 of this paper.

The instrument includes:

1. Closed-ended questions to collect factual organisational information.
2. Likert-scale questions to assess perceptions of digital readiness and organisational capability.
3. Open-ended questions to explore implementation challenges, barriers, and recommendations.

3.6 Data Analysis

Descriptive statistics, such as frequencies, percentages, and means, will be used to analyze closed-ended and Likert-scale based replies. Open-ended responses will be analysed using thematic analysis to identify recurring themes related to traceability practices, technology adoption, supplier collaboration, compliance

challenges, and organisational readiness. To offer a comprehensive understanding of traceability readiness levels across Bangladesh's RMG factories, the results from both analyses will be integrated.

3.7 Validity and Reliability

The study follows Yin's (2018) principles for ensuring research quality.

1. **Construct Validity:** Multiple sources of evidence, including questionnaire responses and supporting organisational documents, will be used where available.
2. **Internal Validity:** Questionnaire items are aligned with the research objectives to ensure consistency throughout data collection.
3. **External Validity:** Factories of different sizes and export orientations will be included to improve the transferability of findings.
4. **Reliability:** A standardised questionnaire and data collection procedure will be used for all participants.

3.8 Ethical Considerations

This study's participation is entirely optional. The final thesis will not identify any participant or factory and all replies will be kept private and confidential. Participants will be informed of the study's purpose before providing informed consent. Data collected will be used solely for academic research.

3.9 Questionnaire Structure

Section Purpose

A	Factory Profile
B	Production Planning and Procurement
C	Logistics and Documentation
D	Traceability and Digital Readiness
F	Organisational Readiness Assessment

G	Future Readiness and Recommendations

4. Findings and Analysis of CSV files 01 and 02

Sample Profile of Factories There are three medium factories (60%), one small factory (20%) and one large factory (20%). Employment varies from 150 to 2,000 workers with a median of 520 and an average of 795.2. Four out of five factories (80%) are registered by the BGMEA, mostly cater to EU/USA buyers and two factories (40%) are involved in subcontracting.

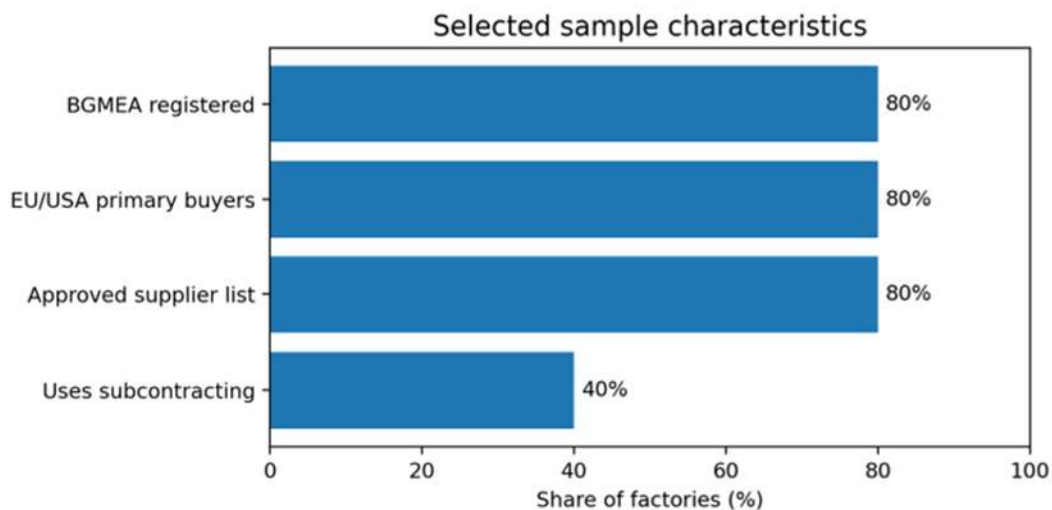


Figure 1. Selected sample characteristics

In general, the sample has a higher proportion of medium sized factories which are export oriented. This is applicable to the study because export-oriented factories are more likely to be under buyer compliance requirements and formal supplier-management systems. However, given the small sample size, especially

the absence of factories that manufacture for the domestic market and the presence of only one large factory, comparisons between the two should be interpreted with caution and should not be generalized to the broader garment industry.

Findings and Interpretation

The factory profile indicates that the sample is rather representative of the more formal, export-oriented factories. This is significant because these factories are more likely to have international buyers' requirements and structured compliance processes. International buyers, who have direct responsibility for factory inspections and compliance improvements, have worked in this regard in Bangladesh, in particular export-oriented garment factories (ILO, 2016).

The size of factories vary from 150 workers to 2,000 workers. The median is 520 and the average is 795.2 workers. The difference in the averages is primarily due to the presence of the one large factory employing 2,000 persons. That is why the median is a better measure of the typical factory than is the average.

There are 4 factories that are registered with BGMEA and 4 that have an approved supplier list. This indicates that the majority of factories have some kind of supplier selection and management process. According to OECD, supplier visibility, monitoring and risk identification, are key components of responsible garment supply chains (OECD, 2018). But even when a supplier list is approved this does not guarantee that such controls will always be effective.

40% of the sample is represented by two factories that use subcontracting. This is crucial as subcontracting can create a lack of visibility of where and how production takes place. Subcontracting is a prevalent practice in the garment sector and unauthorised subcontracting poses additional risks and complicates monitoring in the supply chain, says the OECD (2026).

Overall, the sample largely represents the formal sector of export factories and not the entire garment industry. This is helpful for reviewing buyer requirements and supplier management and compliance practices. However, there are currently only 5 factories, of which one is small, one is large, and one is a domestic factory, so the results are not necessarily comparable to all factory types.

Capability Gap: External Pressure Exceeds Technological Capacity

There is a clear ordering of the five capability dimensions. The highest rates of pressure are for Buyer (3.8/5) and Staff readiness (3.6/5). The average rating for data discipline is 3.2/5, the average rating for supplier knowledge is 3.2/5 and technology capacity is the lowest at 2.4/5.

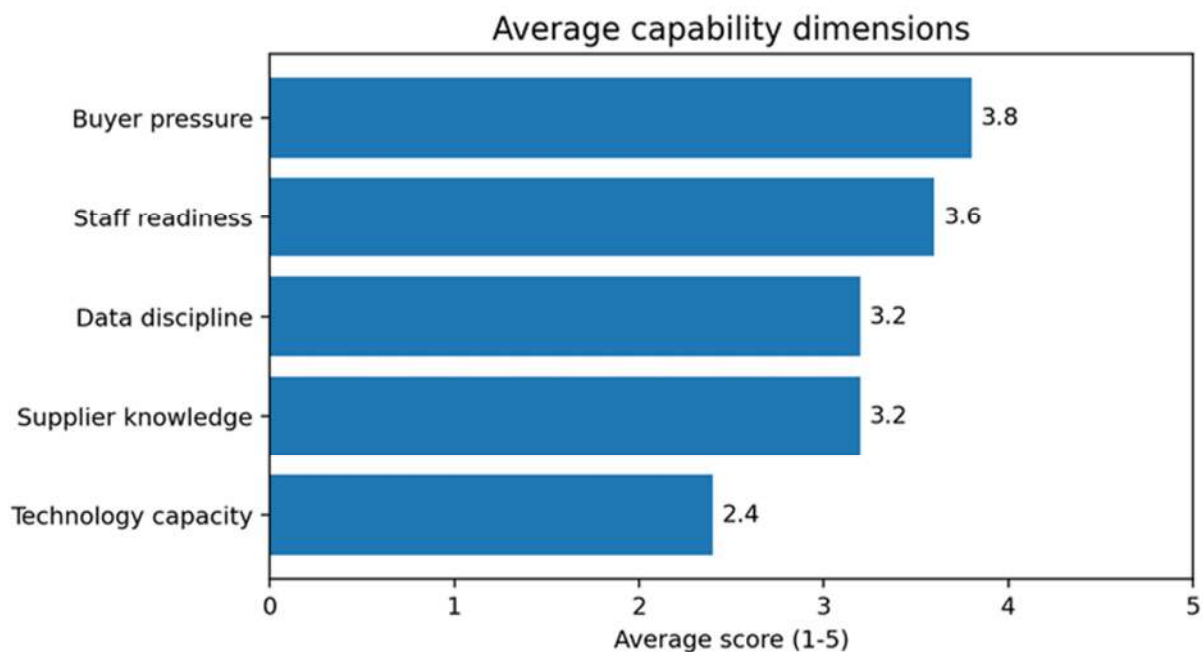


Figure 2. Average of the 5 factories for the capability dimensions.

The overall sense is that pressure to comply is higher than technological capacity to respond. This indicates an implementation gap as factories have external demands that they might not yet have the digital systems in place to handle effectively.

The difference between Buyer Pressure and Tech Cap is 1.4 points on a 5 point scale. From a practical point of view, factories might already be subject to challenging compliance and traceability demands, and structured data capture, integration and tracking are less mature. Staff readiness is relatively high at 3.6/5 indicating that employees might have a greater readiness for adoption than the current technology infrastructure.

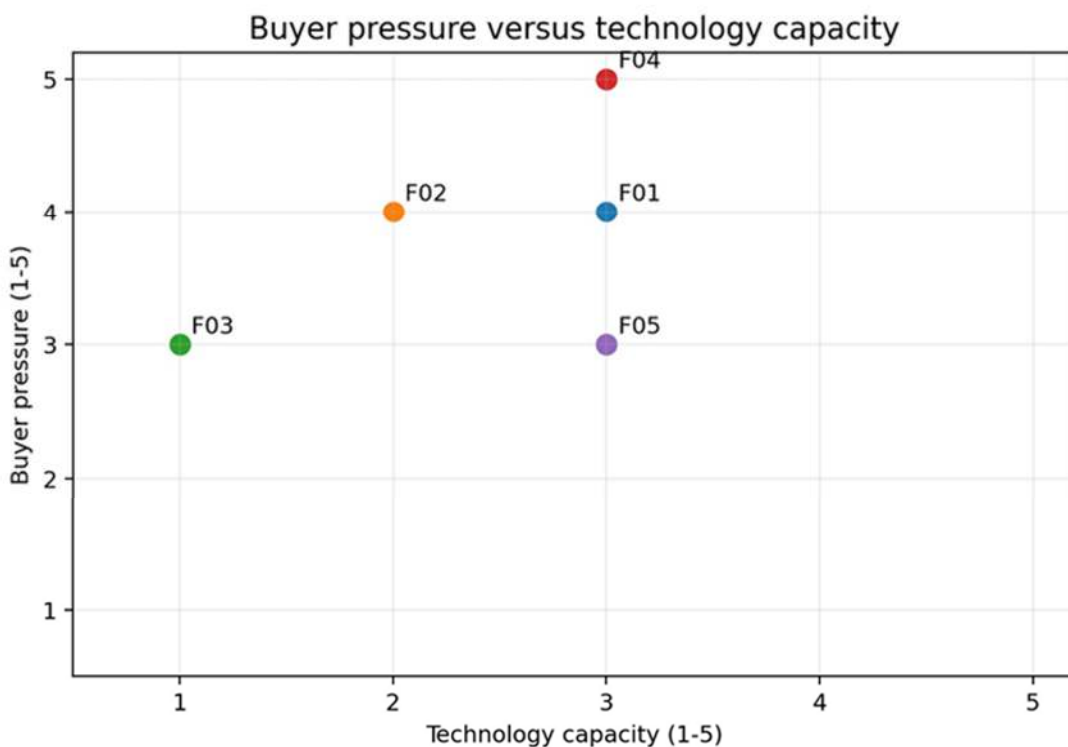


Figure 3. The buyer pressure at the factory level vs. technology capacity.

The same trend is observed in the factory-level results. The buyer pressure is between 3 and 5 while the technology capacity is between 1 and 3. Notwithstanding the highest reported technology capacity, the

technology dimension is not clearly a strength for this sample as 3/5 is the capacity reported. Combined, the results suggest that the primary disconnect is not necessarily with compliance but with digital.

Findings and Analysis

The findings suggest that the greatest capability limiting factor is technology. Buyer pressure and the readiness of staff are comparatively high whereas technology is comparatively low. This indicates that factories might know what they need to comply with and have workers who can react, yet don't have the systems in place to do so.

This is significant, as more and more digital systems are being used to monitor suppliers, exchange data and to comply with regulations. For the RMG sector, digitalisation is one of the key aspects of enhancing traceability and alignment with international standards as identified by the OECD (2023).

In between the capability scores are data discipline and supplier knowledge. This indicates a baseline in place for factories to manage supplier information and records, although the capabilities in this area are less likely to be used with poor technology (OECD, 2025; OECD, 2026).

The factory-level pattern is consistent with this conclusion: that technology capacity in the sample is low, and is not a problem in only one factory. Overall, the findings suggest that the main bottleneck is not buyer demand or staff readiness, but the technology available to support compliance and traceability.

Limited DPP awareness & self-readiness.

60% of the three factories report moderate awareness while 40% report no awareness. The dataset does not contain a high-awareness category in any factories.

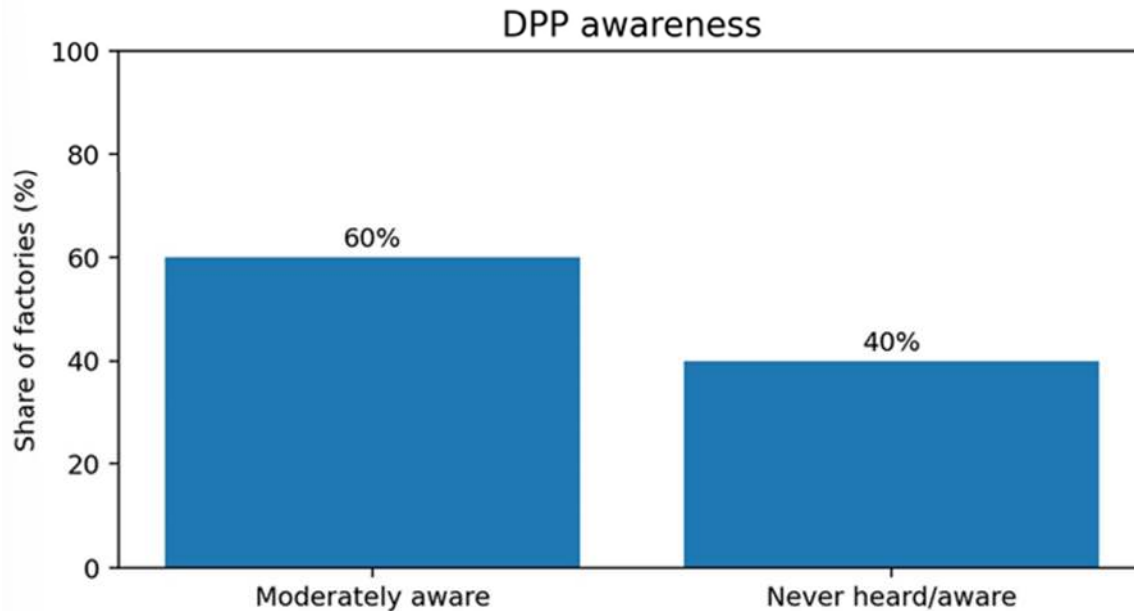


Figure 4. Level of DPP awareness in the sample.

Self-assessed readiness is a bit more than awareness and not quite done. Three factories (60%) are partially ready, one factory (20%) is mostly ready and one (20%) is not ready.

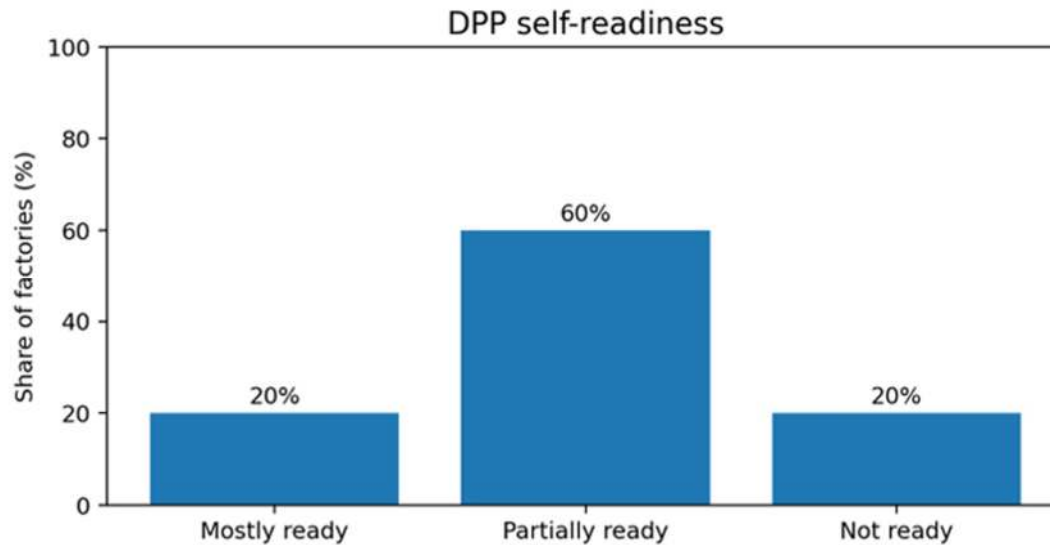


Figure 5. DPP Self Readiness in Sample

The difference between the low level of DPP awareness and the high level of exposure to buyer compliance requests is analytically significant. Factories might know about audits, certifications and information required by buyers, but not have transferred those practices to preparing specifically for the DPP.

DPP is therefore likely to be experienced as a formalisation and extension of existing compliance work, with increased needs for structured, interoperable product-level data.

Findings and Analysis

The findings indicate that there is a significant gap between knowledge of DPP and readiness to deliver. High level of DPP awareness is not reported in any factory, but most factories feel that they are at least to some extent ready. This indicates readiness may not depend on having a solid understanding of the DPP requirements, but rather on previous compliance experiences.

Buyer audits, certifications and information requests are already common practice in factories and DPP can leverage existing processes. But more structured and interoperable information on a product level will be needed for DPP (European Union, 2024).

Reflecting these points, on the whole the factories are not starting from scratch, but the level of readiness may be less than what factories themselves believe, given the limited awareness of DPP.

Consequences of compliance: commercial consequences.

The three findings are applicable to the five factories: Buyers frequently seek compliance information, factories have experienced lost orders due to compliance and cost is a barrier for DPP implementation. These results are found in all the observations and are among the best results available.

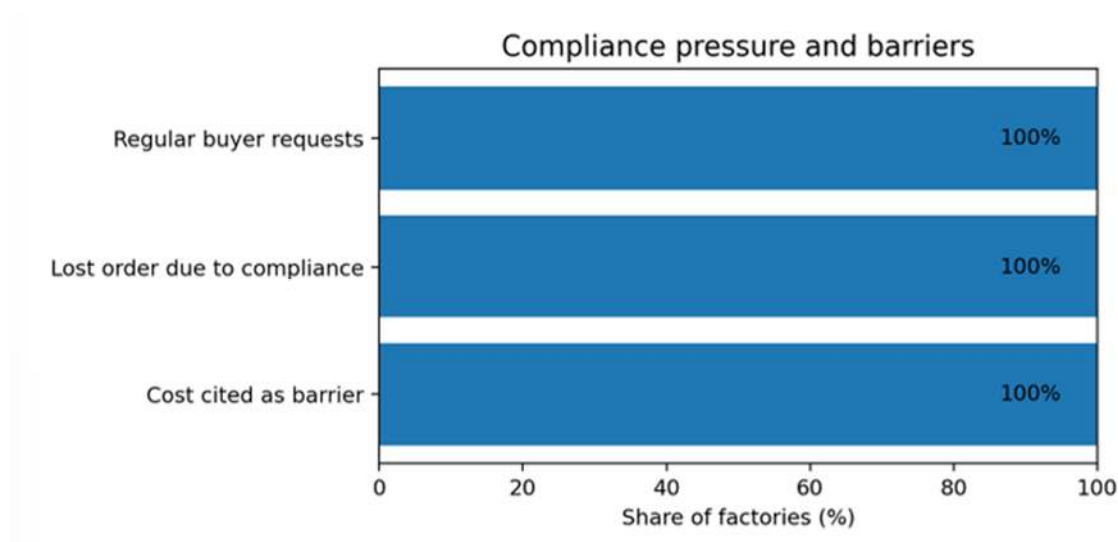


Figure 6. Universal compliance pressure and barrier indicators.

Commercial relevance: In all the factories surveyed, compliance is already associated to losing orders. DPP readiness should therefore not be viewed as a reporting issue alone, but also as an issue in relation to market access.

The cost result is particularly important. Cost, in addition to knowledge, is the highest-capability factory's reason. This implies that the poorest factory is not constrained by financial considerations. The message is that even more sophisticated factories might require a helping hand to set up, integrate or support DPP compatible systems.

Traceability and Digital Systems.

1. Chemical tracking

Two factories (40%) formally track chemicals, two (40%) track informally and one (20%) does not track chemicals. Hence, only 60% of the sample has formal chemical tracking.

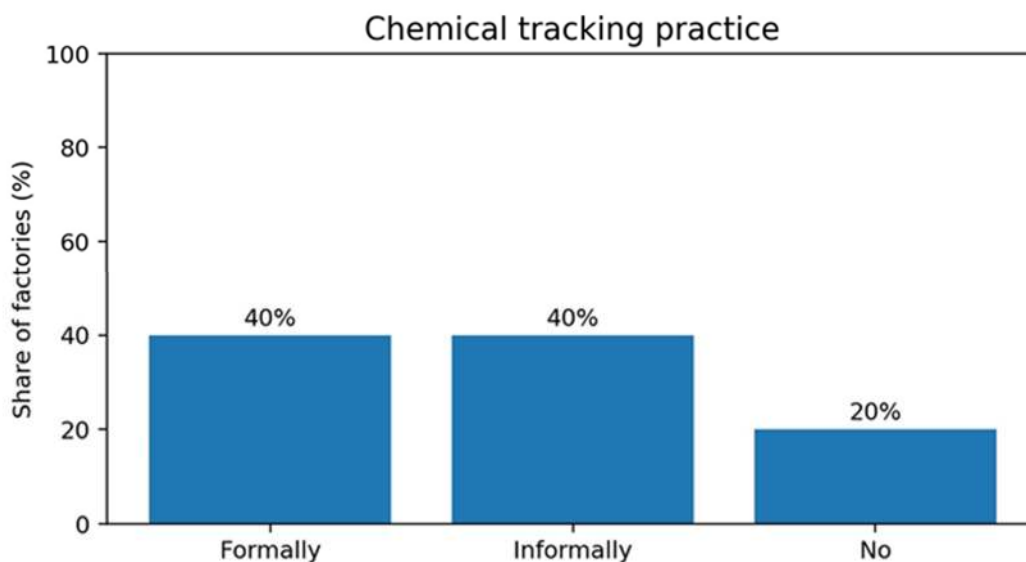


Figure 7. Chemical tracking practice.

Informal or nonexistent chemical tracking in a DPP for traceability can result in information gaps and challenges in verification. The transition to standardised, auditable and consistently structured records would likely be an important stepping stone to greater DPP readiness.

2. ERP and digital-system interpretation

Just one factory mentions a 'Full ERP'. The other four list 'Excel only', although three of those also have Erp marked TRUE. This discrepancy indicates that perhaps the respondents are thinking of ERP as a catch-all term for digital record keeping.

It is better for analysis to differentiate between a full integrated ERP solution and management via a spreadsheet and not assume that any TRUE answer is equal digital capability.

Factory-Level Comparison

A simple capability score was determined as the average of the five capability scales for each factory. The score is a small description for comparative purposes, and should not be used as a validated DPP-readiness index.

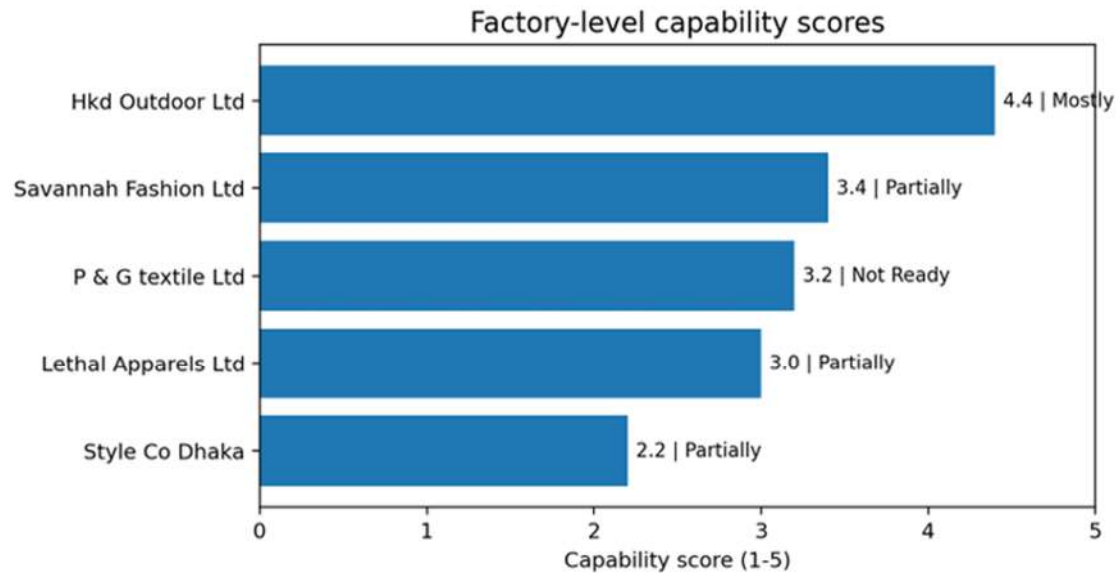


Figure 8. Capability scores at the factory level, readiness response indicated next to the score.

Factory	Size	Workers	Buyer region	Capability	DPP readiness	Main barrier
Hkd Outdoor Ltd	Large	2,000	EU,USA	4.4	Mostly	Cost,Knowledge
Savannah Fashion Ltd	Medium	810	EU,USA	3.4	Partially	Cost
P & G textile Ltd	Medium	520	EU,USA	3.2	Not Ready	Cost
Lethal Apparels Ltd	Medium	496	EU,USA	3.0	Partially	Cost
Style Co Dhaka	Small	150	DOMESTIC	2.2	Partially	Cost

The biggest factory, HKD Outdoor, has the highest capability score of 4.4/5 and is the only factory claiming to be mostly ready. The capability score of the small domestic factory, Style Co Dhaka is the lowest which is 2.2/5. Medium factories are those which range from 3.0 to 3.4. The visible pattern is still consistent with the idea that scale and system maturity are favorable to DPP readiness but the sample consists of one large and one small factory; thus a size effect cannot be generalized.

Findings and Analysis

Compliance is already a part of the bottom line. 100% of the five factories report regular requests for compliance from buyers and previous order losses due to compliance. This renders DPP readiness pertinent to market access, not just reporting. The Digital Product Passport requirements in the future will apply to products under the EU's ESPR, which will require these products to carry a Digital Product Passport before they are placed on the EU market (European Union, 2024). The highest capability factory, like all factories, is limited by cost. This indicates that regardless of other capabilities, financial constraints can influence DPP adoption

Chemical Tracking: Results & Analysis

Chemical tracking is still limited throughout the sample, with 60% of factories using informal tracking or no tracking. This can be a challenge for the provision of consistent and verifiable chemical information.

Industry systems like ZDHC have formal Chemical Inventory Lists that record and assess chemicals used by suppliers, highlighting the need for structured chemical records for supply-chain transparency (ZDHC, 2026).

ERP and Digital Systems: Findings and Analysis

There is a disconnect between the ERP use mentioned in the responses and capability of ERP system. 1 factory reports full ERP, the others primarily use Excel with some stating that they use ERP but not fully.

This indicates that there may be different definitions of ERP in factories. In this study, it is more conservative to pit fully integrated ERP systems against spreadsheet or limited digital systems, and not to consider any ERP responses as equal.

Order planning, lead-time and data completeness analysis

Order Profile Quantity and Buyer Mix The amount of orders placed varies from 11,700 pieces to 23,000 pieces. The average order size is 15,461.8 pieces and the median is 15,000 pieces. The highest single order is F05, 23,000 pieces (29.8% of all quantity recorded).

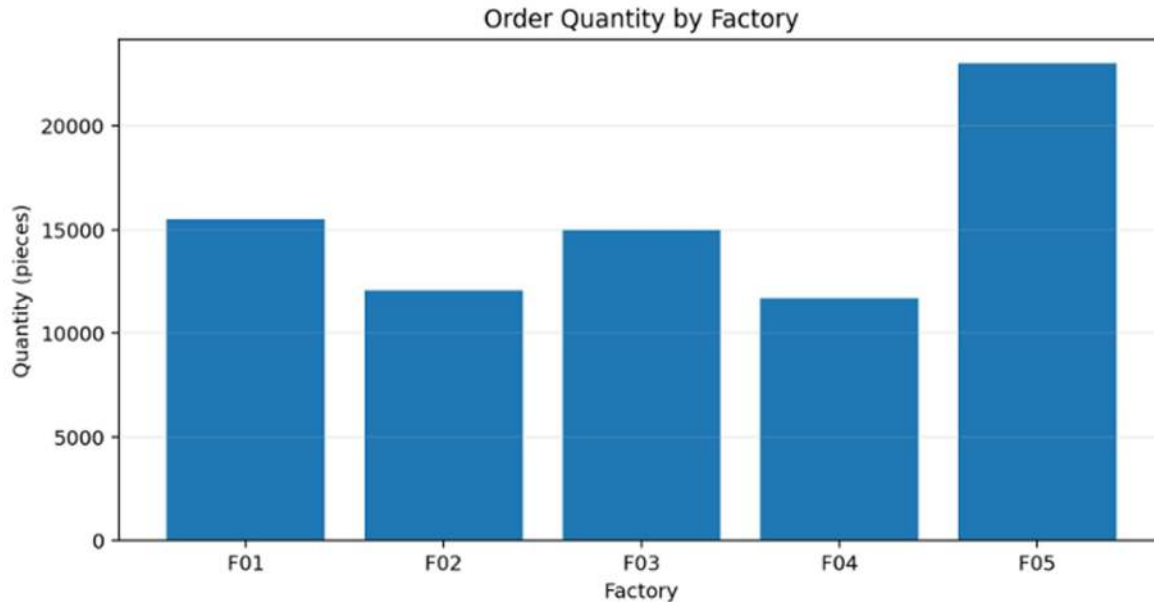


Figure 9. Order quantity recorded by factories

Buyer region	Orders	Order share	Quantity (pcs)	Quantity share
ASIA	2	40%	27,099	35.1%
EU	2	40%	27,210	35.2%
USA	1	20%	23,000	29.8%

This five-record snapshot is fairly well balanced in terms of the regional mix. EU orders make 40% and ASIA orders make 20% and USA orders make 20% of orders. By quantity, EU represents 35.2%, ASIA 35.1% and USA 29.8%. The USA share is relatively high in volume, even though it only has one order, because the F05 order is the largest order.

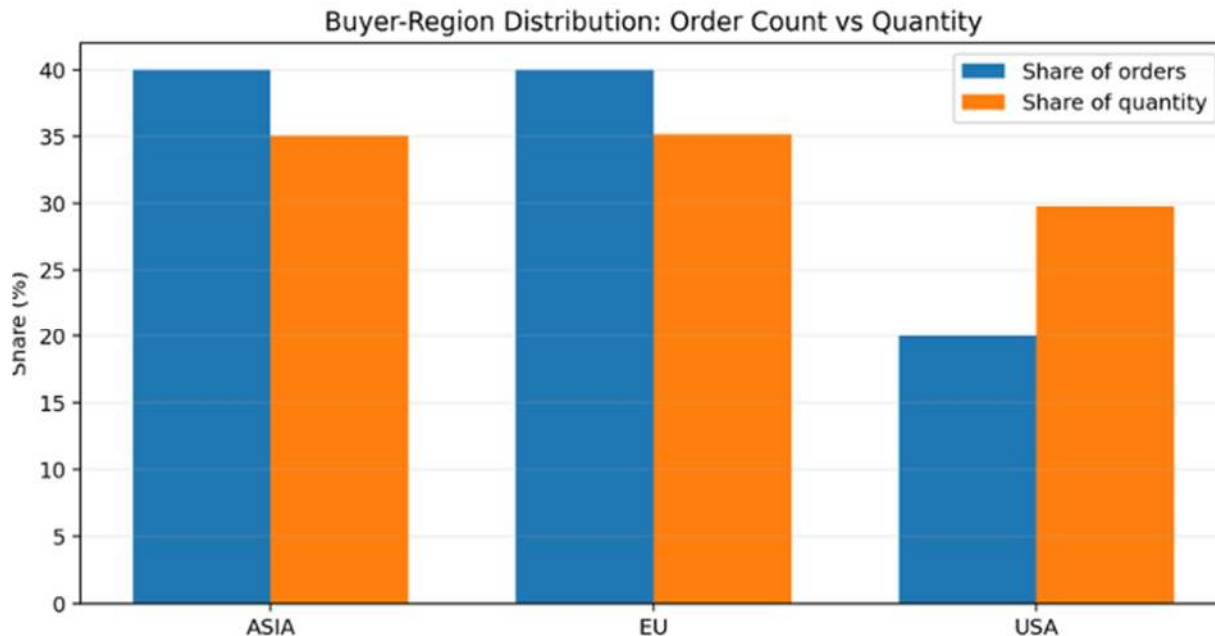


Figure 10. Buyer-region share of order count and recorded quantity.

Findings and Analysis

This order data reveals a relatively even distribution across the regions, however the numbers of orders and the volume of order are not aligned. The largest order in the sample is from the USA, accounting for almost 30% of the total quantity, but only 40% of orders, leaving EU and Asia at 40% each.

This illustrates the value of order size in addition to order volume. Less represented areas can still have a high proportion of output. But, only one order from a factory has been recorded, so there's not enough data to say that one region orders more consistently.

Sample also validates exposure to top export markets. According to OECD, EU and United States are Bangladesh's key export markets for RMG exports (OECD, 2023). The EU exposure is especially pertinent to DPP readiness as textile products are a priority group within the EU Ecodesign for Sustainable Products Regulation, and textile-specific DPP requirements are currently being developed (European Commission, 2026).

Planning Behaviour

Reactive planning is the most frequently documented behaviour, with 60% of orders (3/5) documenting this behaviour. Such Reactive orders account for 50,609 pieces that is 65.5% of the total quantity recorded. These two words, PostOrder and Proactive, each occur only once.



Figure 11. Planning behaviour at the five orders recorded.

Planning behaviour	Orders	Order share	Quantity (pcs)	Quantity share
Reactive	3	60%	50,609	65.5%
PostOrder	1	20%	15,000	19.4%
Proactive	1	20%	11,700	15.1%

Linked Factory Context

In this sample, all three medium-sized factories (F01, F02 and F05) use Reactive planning, the large factory (F04) uses Proactive planning and the small factory (F03) uses Post-Order planning, based on the factory profile provided earlier. This is an interesting descriptive pattern, but it cannot be used to draw a size-effect conclusion, since there is only one order per factory and only one large and one small factory.

Factory	Factory name	Size	Planning behaviour	Quantity
F01	Savannah Fashion Ltd	Medium	Reactive	15,510
F02	Lethal Apparels Ltd	Medium	Reactive	12,099
F03	Style Co Dhaka	Small	PostOrder	15,000
F04	Hkd Outdoor Ltd	Large	Proactive	11,700
F05	P & G textile Ltd	Medium	Reactive	23,000

As such, the operational definitions of the Caution Planning-behaviour labels are not included in the dataset. Hence, their distribution is described in the report without assuming that the definitions of 'Proactive', 'Reactive' and 'PostOrder' are the same in all factories.

Recorded Lead-Time Intervals

Five TODTs have been recorded between 25 to 420 days. The median is 138 days and the mean is 170.6 days. Due to the small sample size and the presence of one extreme date range, the median is a more stable descriptive summary.

Order	Factory	Planning	Qty	Order->Dispatch	Dispatch->Delivery	Total
ORD001	F01	Reactive	15,510	72	18	90
ORD002	F02	Reactive	12,099	22	3	25
ORD003	F03	PostOrder	15,000	386	34	420
ORD004	F04	Proactive	11,700	27	153	180
ORD005	F05	Reactive	23,000	87	51	138

The majority of the days in ORD003 are pre-dispatch: 420 days out of 420 days (91.9%) are pre-dispatch days. The pattern is the opposite with ORD004: 153/180 days (85.0%) take place after dispatch. This illustrates why the total lead-time may conceal widely divergent operation patterns.

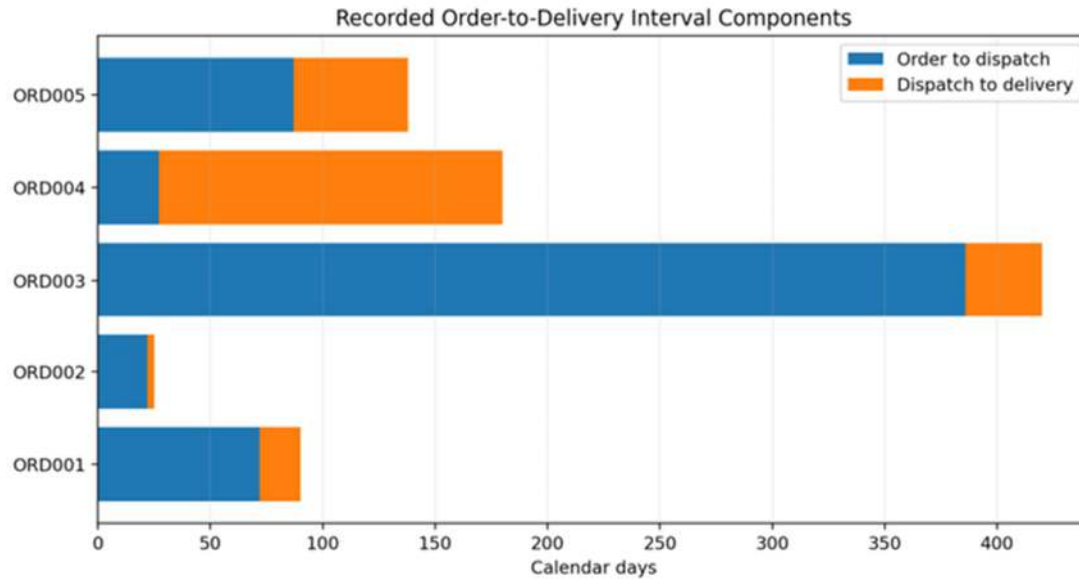


Figure 12. The breaking up of the recorded interval into pre-dispatch and post-dispatch parts.

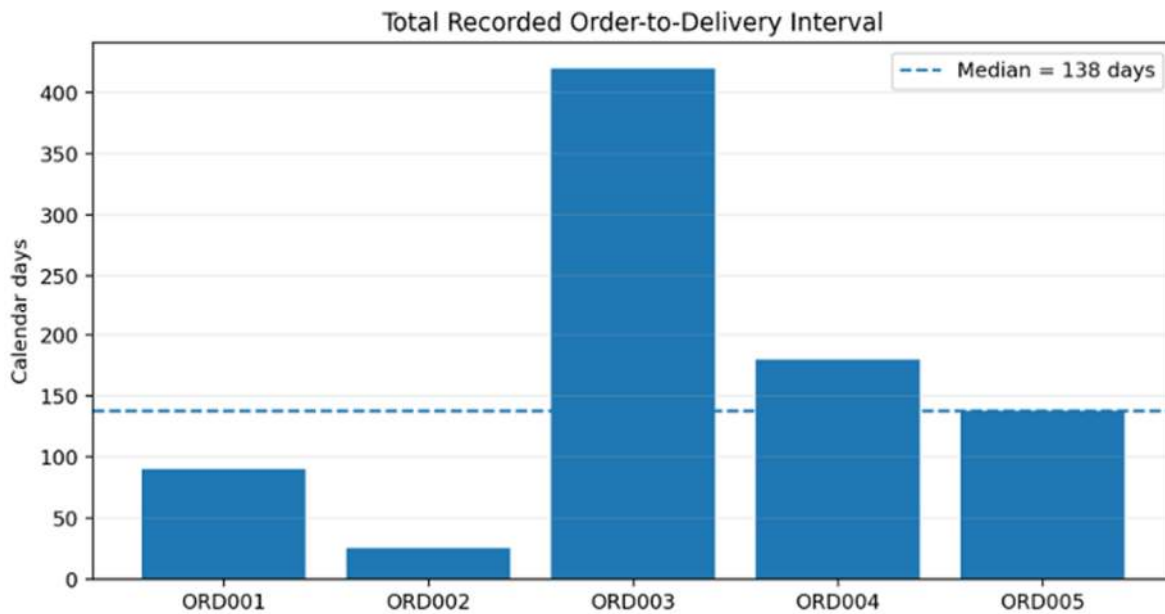


Fig 13: Order-Level Interval Comparison

ORD002 has the lowest recorded interval of 25 days followed by ORD001 with 90 days and ORD005 with 138 days. ORD004 records have a total of 180 days, and ORD003 records have 420 days. These

values should not be viewed as delivery-performance rankings as there are no promised due dates and the planned and actual delivery dates are not distinguished.

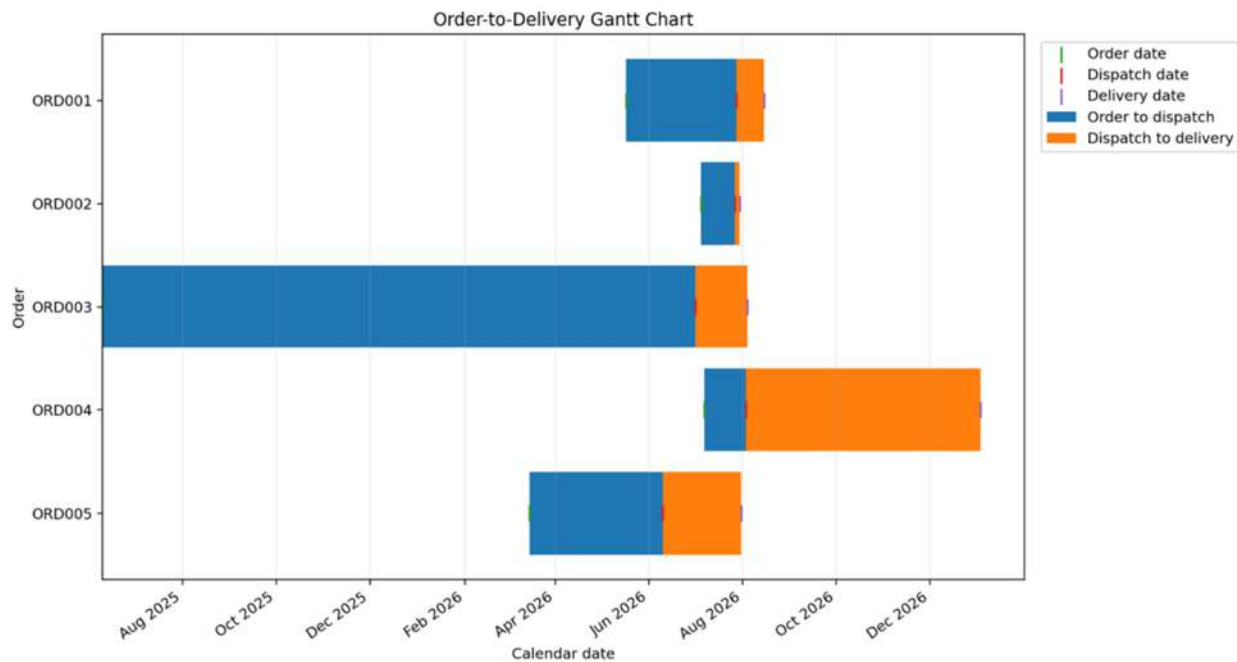


Figure 14. Order, dispatch and delivery dates that are recorded on a calendar over time.

The importance of the Timeline

It can be seen in the timeline that the five records do not correspond to an observation window. The starting dates for ORD003 (2025) and the other orders (2026) are scheduled. ORD004's impact has been extended through January 2027. This further reduces the ability to make direct cross-order performance comparisons.

Sensitivity Analysis

With all 5 records, the mean interval of the total records is 170.6 days, and the median interval is 138 days. Excluding ORD003 as a sensitivity test only, the mean decreases to 108.2 days and the median to 114 days.

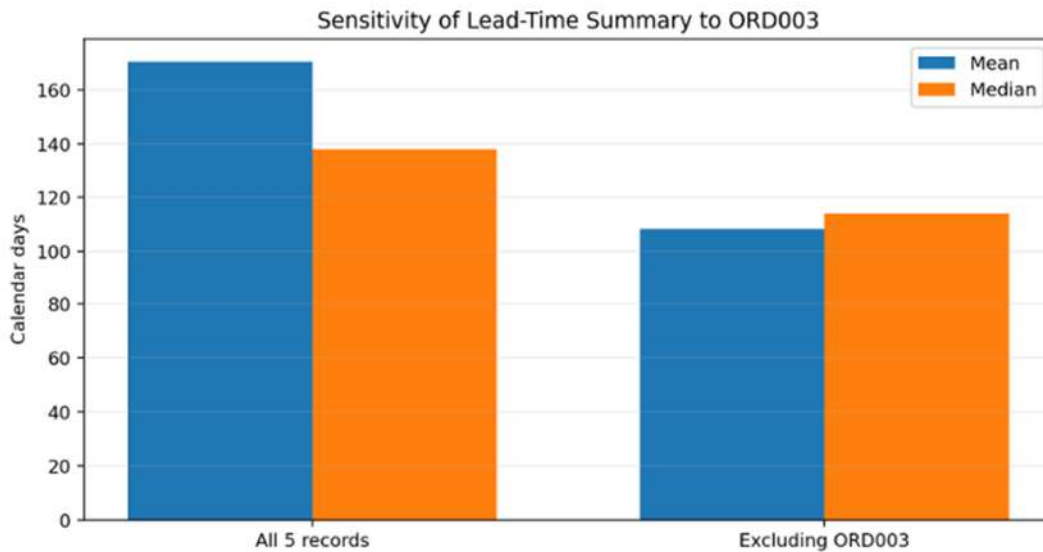


Figure 15 Sensitivity Analysis

This sensitivity result is not a proof of incorrectness of ORD003. It indicates that the overall mean is greatly influenced by one record. As long as an order date for 2025 is not confirmed, the best reporting method is to keep the record, add a flag and highlight medians, or order level values, as well as the mean.

Scenario	Mean days	Median days	Min days	Max days
All five records	170.6	138	25	420
Excluding ORD003	108.2	114	25	180

Findings and analysis of planning behaviour

The most prevalent pattern in the sample is reactive planning, which is related to all three medium-sized factories. But this should not be interpreted as medium factories being more reactive; there is just one small and one large factory; and there is only one order per factory. There are also planning labels that must be treated with care as they don't have operational definitions.

Nevertheless, planning could be considered as it is found in the previous studies of the RMG sector in Bangladesh that weak production planning is also a factor that can increase the lead time (Khan 2021, Abir 2020).

Lead-time Intervals - Results and Analysis

Because of the large variation in recorded lead times, the median lead time is more descriptive of the typical order than the mean lead time. More importantly, the order level breakdown reveals that the total lead time can be largely different sources.

ORD003 is primarily delayed prior to dispatch and ORD004 is primarily prolonged after dispatch. This reveals that a single total lead-time does not give an indication of the delay. The studies on Bangladesh's Garment Industry also reveal that several factors like Planning, Approval, Raw material supply and shipping (Abir, 2020, Khan, 2021) can influence lead time.

There is no information in the orders on promised delivery dates, nor is there any distinction between promised delivery dates and delivery dates, so the orders should not be treated as "good" or "bad" performers.

Sensitivity Analysis: Findings and Analysis

The sensitivity test shows that ORD003 has a strong effect on the overall mean. Its removal causes the mean to drop from 170.6 days to 108.2 days, but the median to be affected to a lesser degree from 138 to 114 days. This means that the ORD003 unusually long interval has a large impact on the mean.

If this is the case, ORD003 should not be removed. NIST recommends that unusual observations should not be deleted unless there is evidence that they are incorrect, and notes that the median is less sensitive to extreme values than the mean (NIST, 2000).

The best practice for this small sample is therefore to keep ORD003 in the sample, mark it as a value to be verified and consider the median and actual order sizes more important when talking about lead time.

Synthesis: Is the hypothesis of the paper supported by the evidence?

Bangladesh's DPP problem is more than just a lack of blockchain adoption. The real issue is that factories might not have the digital infrastructure, recorded data and/or supply-chain data necessary for traceability to be effective. This aligns with the findings of Al Amin et al. (2025) that blockchain traceability requires foundational data of suppliers and procurement and with Hossain and Sani (2025) who identify a lack of digital skills, cost of implementation and adoption of ERP as key challenges in the RMG sector in Bangladesh.

The evidence from the factory backs up this argument. Among the capabilities evaluated in the sample, technology capacity is the lowest score of 2.4/5, a score that is lower than that of buyer pressure (3.8/5) and staff readiness (3.6/5). This indicates that compliance is already pressuring the factories, while the factories' technological level is not strong enough to respond to the demand. This is reflected in the same gap in operational practices.

There are no factories reporting a complete ERP and the others mostly use Excel, with 60% of factories not having formal chemical tracking. This aligns with the work of Kouhizadeh et al. (2024), which highlights the necessity of information being recorded before more complex traceability systems can be implemented, and corroborates the paper's emphasis on the need for foundational data and readiness of systems before implementing more advanced traceability systems. The evidence also suggests the commercial relevance of the problem. Every one of the 5 factories mentioned regular buyer requests for compliance, missed orders due to compliance in the past and cost as a barrier for DPP implementation. This aligns with the broader RMG industry landscape in Bangladesh, where international buyers play a significant role in compliance and sourcing practices (Syed et al., 2026). It is significant as well in the context of Bangladesh's reliance on the EU market, where about 50.10% of the country's total RMG

exports go. DPP readiness can thus impact market access and not be limited to an internal reporting requirement.

The direction of the hypothesis is further supported by differences between factories. The large factory F04 has the highest capability score: 4.4/5 and the small domestic factory F03 has the lowest capability score: 2.2/5. 3.0 to 3.4 are the three medium factories. This aligns with the literature examined in the paper, where the adoption of digital traceability infrastructure is found to be more prevalent in larger factories with export operations, whereas SMEs have a far less robust implementation of digital traceability infrastructure. (Al Amin et al., 2025).

The sample however is limited to one large and one small factory, therefore, this correlation would not enable a general correlation between factory size and DPP readiness to be established. Hence, the evidence supports the direction of the hypothesis and does not prove the hypothesis for the entire Bangladesh RMG sector. The biggest finding is the disconnect between external compliance pressure and internal technological and data capacity. Digital systems, formal chemical tracking and DPP-specific awareness are incomplete and factories are already being called for compliance information. This reinforces the main thesis of the paper: The SME Exclusion Gap is primarily a data and capability problem, not a blockchain problem.

Findings and Analysis of CSV files 03 and 04: Raw Materials and Shipments

Findings: CSV 03: Raw Materials

This file has recorded one representative raw-material purchase for each factory across five factories (F01-F05). Each record has been labelled ‘Factory-disclosed representative purchase’, implying a single disclosed transaction per factory instead of a complete procurement ledger.

Out of the five records, four (80%) show a certified, named supplier: INDOCHINE INTERNATIONAL (Hong Kong, F01), ESSENTIAL CLOTHING LTD (Bangladesh, F02), FUJIAN EAST XINWEI TEXTILE TECHNOLOGY CO.LTD (China, F04) and LT Apparel (China, F05). The fifth record, F03, sources Cotton Fabric from an entity recorded only as ‘Local market’, not a named company, and is marked uncertified.

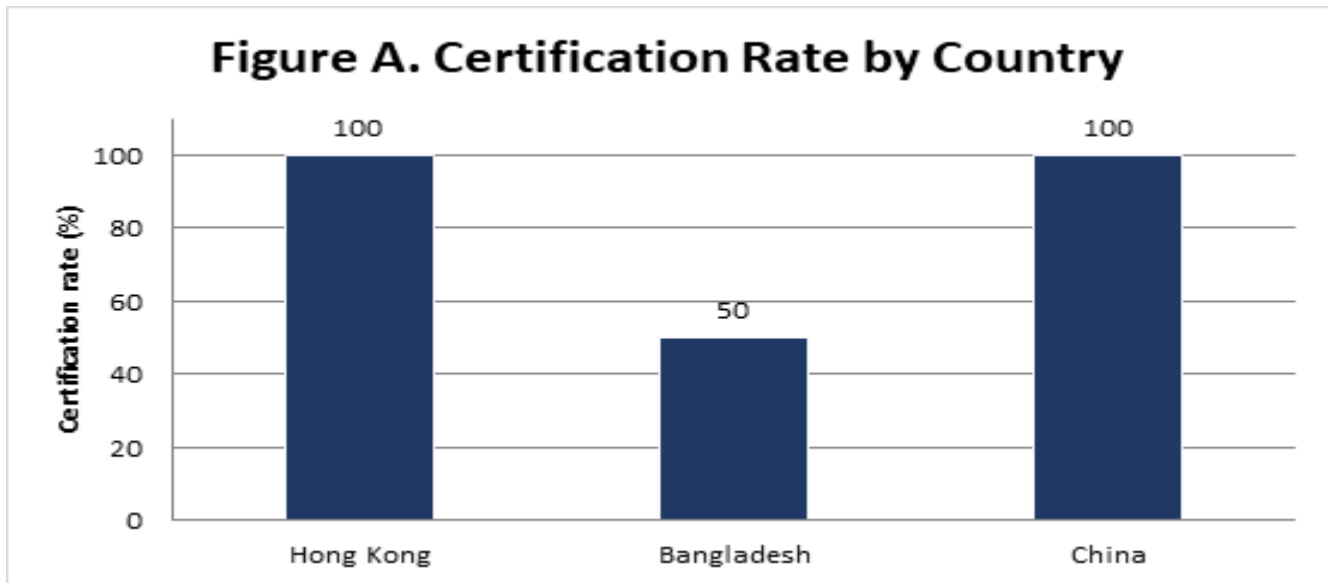
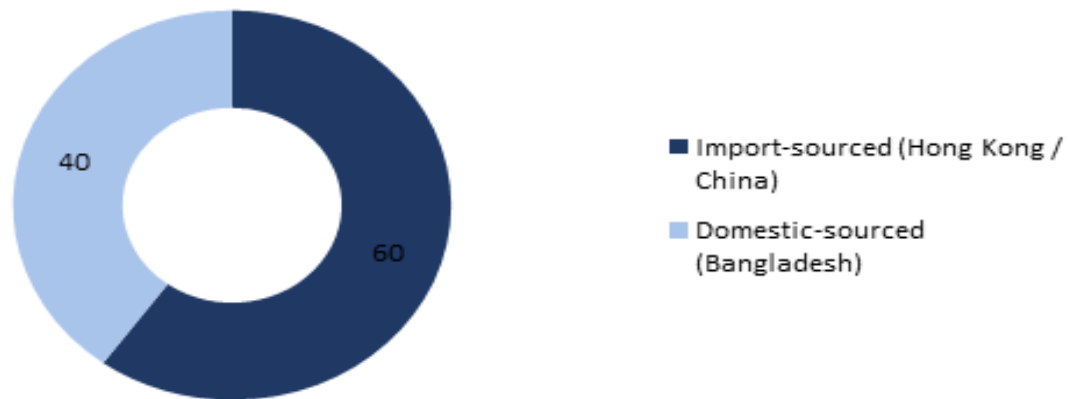


Figure 16 Certification rate by country

The certification differs by country of origin. Hong Kong and China has their records 100% certified (n=1 and n=2 respectively), but Bangladesh-sourced records are 50% certified (n=2). The only uncertified record from the sample is from the only domestically sourced, unnamed vendor record.

Out of the five records, three (60%) are import sourced, Polyester Fabric from Polyester Fabric from Hong Kong (F01), DWR Fabric from China (F04), and Fabric from China (F05). Simultaneously, two (40%) are domestic (F02's Trim and F03's Cotton Fabric, both Bangladesh).

Figure B. Raw-material sourcing origin**Figure 17 Raw material sourcing origin**

The record of F03 is the only one from this file which combines an uncertified sourcing relationship, an unnamed vendor, and emergency supplier switch, and missing purchase and quantity data. The other factory records in the sample do not combine more than one of these attributes. This factory was also found to have the lowest capability score (2.2/5) on the DPP dataset.

Analysis: CSV 03: Raw Materials

The Barrier 3 discussion of this paper cites Saha et al. (2025) on raw material procurement risk in the RMG sector of Bangladesh, where the import dependence of the sector is attributed to constant exposure to delays in customs, volatility of price, and failures with quality control at the import point. The 60% import

dependence figure of this dataset is directly consistent with this account. Although the sample sources from Hong Kong and China rather than India and Turkey have slightly different patterns than the one Saha et al. (2025) describes, a difference that is worth noting. The difference indicates that this file supports the general import dependency claim without confirming the specific country pattern in the source.

Previously in this paper, the US 2025-2026 US-Iran Hormuz Strait disruptions was identified as one of the three converging pressures on the RMG sector, mentioning that the resulting LNG shortages forced switches among raw material suppliers, which broke traceability chains amidst production. The only emergency supplier switch in the files was from the records of F03, which was paired with an uncertified vendor and missing procurement data. This record is a concrete and case-level example of this mechanism, and can be citable as such.

This file also supports the qualitative mechanism that Barrier 3 describes, where supplier non-participation prevents any traceability system from having workable data, as per Kouhizadeh et al. (2024), and through the FO3 case specifically.

Findings: CSV 04: Shipments

All five shipment records (100%) have used digital documentation. There are two records which name an actual vessel (F01: MSC EVA; F05: MSC KYMEA II). One record (F04) lists ‘DSV forwarder’ in the vessel_name field, which is a freight-forwarding company. Two records (F02, F03) have no vessel information at all.

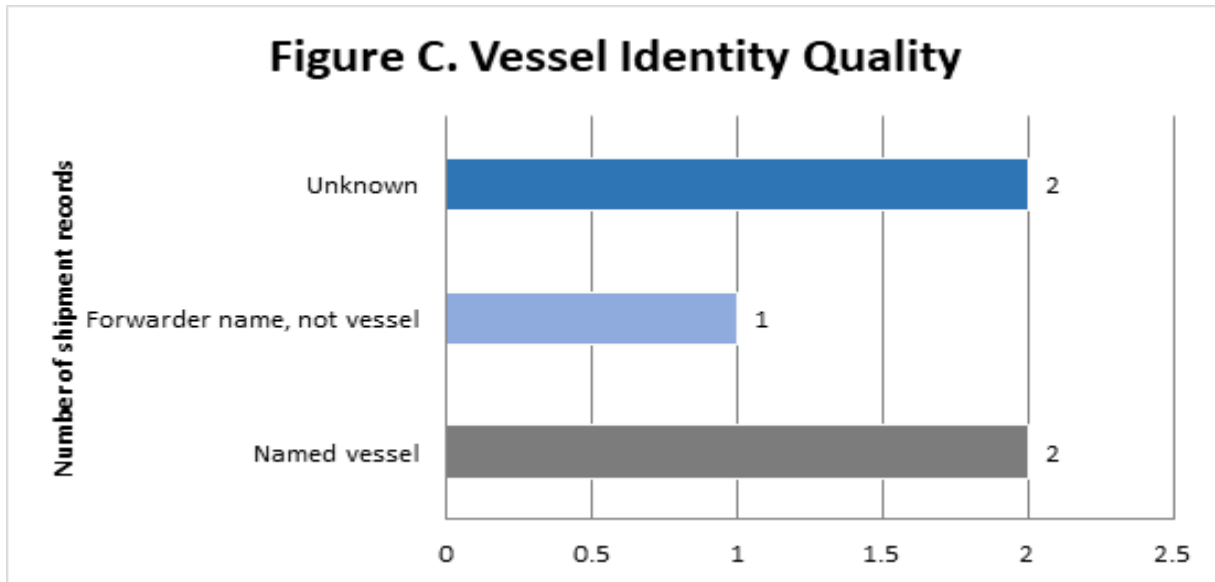


Figure 17 Vessel Identity quality

Reclassification of the F04 forwarder entry means that genuine named vessel identification covers 2 of the 5 shipments (40%), instead of 3 of 5 (60%) implied in the raw vessel unknown field.

The dispatch dates in this file match the dispatch dates recorder in the same five orders which have previously been analyzed, so, recalculating factory-to-port transit from the recorded dispatch and port-arrival dates, and comparing it against the Order Planning dataset's total dispatch-to-delivery interval for the same order produces the following comparison.

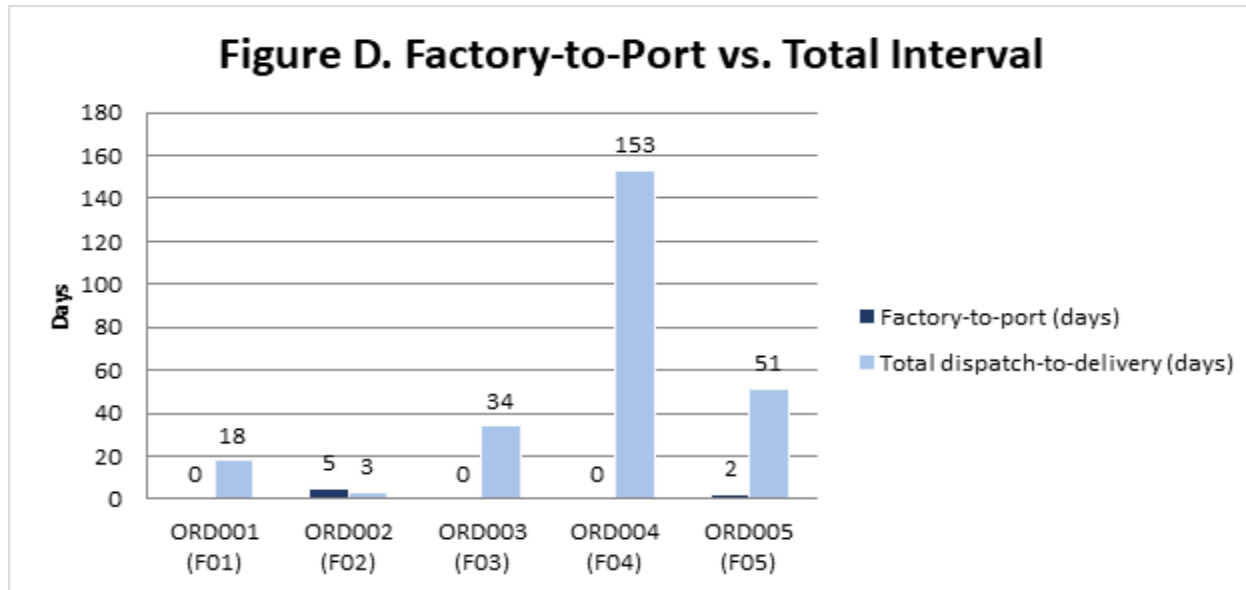


Figure 17 Factory to port vs total interval

The factory-to-port transit recalculates to 5 days from the recorded dates for ORD002's factory, while the other order planning dataset records a total dispatch to delivery interval of only 3 days regarding the same order. F01 and F04 have a similarity in showing stated factory to port days value of 1 against the dates recorded as identical, which can be recalculated to 0 days.

4 out of 5 shipment records (80%) show that buyers asked for proof, in among which, FO3 is the exception, as F03 is the only record with no recorded port arrival date and no factory to port transit figure.

Dataset	Flag value	Weakest indicator
Factory DPP (capability score)	1	Lowest capability score in sample (2.2/5)
Raw Materials (procurement)	1	Uncertified vendor; missing purchase date & quantity; emergency switch
Shipments (documentation)	1	No arrival date recorded; buyer proof not requested

Table 1: FO3 (Style Co Dhaka) is flagged as the weakest record across all three case study datasets.

All five shipments report on time delivery to be true. This file does not contain any promised or planned delivery date field. 2 out of 5 underlying orders carry date quality flags in the order planning dataset, ORD003 has 420 days of total interval flagged for verification, and ORD004 has the delivery date under the stated analysis date.

Analysis: CSV 04: Shipments

The vessel known and buyer asked proof fields in this file correspond directly to Questions 12 and 14 of the survey instruments of this paper (Methodology, Section C: Logistics and Documentation), where it tries to identify whether a factory can identify the vessel carrying its most recent export shipment, and whether a buyer or auditor has asked for evidence of shipment timing. This file can be considered a primary case evidence for Barrier 6 (Network Effect Failure), not a loosely related dataset, and for the previous discussion stated in this paper regarding buyer-driven compliance infrastructure via Syed et al. (2026).

The forwarder-managed record of F04 is a small-scale illustration of the core mechanism of Barrier 6, as the paper describes it via Al Amin and Rahman (2025): the shipment data of the factory exists, but it is held by a logistics partner rather than the factory itself, so the ecosystem for participation by multiple stakeholders do not yet exist at the scale that meaningful traceability would require. If F04 could deploy a compliant system independently, it would still depend on its forwarder to supply vessel-level data, which is the first-mover-without-network-benefit problem this paper assigns to Barrier 6.

There is some inconsistency in ORD002. A 5-day factory-to-port leg cannot fit inside a 3-day total dispatch-to-delivery interval; at least one of the three underlying figures (dispatch date, delivery date, or this file's port-arrival date) is incorrect. This is a data-quality issue internal to the case study rather than evidence for or against a specific barrier. The F01/F04 same-day-counts-as-1 pattern is treated here as a minor recording convention rather than an error, since it is consistent across both records. Since no promised or planned delivery date is recorded in this file, on time delivery reads as a self-reported status instead of a calculated one.

Synthesis: Does the evidence support the hypothesis of the paper?

The core theoretical claim of the paper is that six barriers form a causal chain and not an independent list and this chain, instead of a singular barrier, produces the SME exclusion gap mentioned in section 2.2. The missing procurement data of FO3 is consistent with an owner-operator structure with no one to manage certification, per Ahmed and Hossain (2024), which pertains to Barrier 2 of Skill and Capacity Deficit, which shows consistency although it is not fully conclusive. Barrier 3, Foundational Data Deficit is supported in these files in a mixed manner, the conflict is that though FO3 supports the qualitative mechanism (Kouhizadeh et al., 2024); the file does not support the paper's specific 'three of five' magnitude claim, which needs resolution. Barrier 4 and 5, Infrastructure Unreliability and Regulatory Ambiguity, are not testable from CSV 03 and 04 files. However, Barrier 6, Network Effect Failure, is directly and strongly supported here, as vessel_known and buyer_asked_proof are the paper's own Q12/Q14 instrument items. F04's forwarder-managed data is a direct case instance of Al Amin and Rahman's (2025) network-dependency mechanism.

If expanded upon the individual barriers, the files support the broader empirical premise stated in this paper, that traceability readiness is specific to factory and it is unevenly distributed instead of being uniform across the SME tier, which is the premise that the TRS instrument is built to measure. F03 is independently flagged as the weakest case across three separately collected datasets (capability survey, procurement record, shipment record), which is the kind of triangulated, factory-level differentiation the paper argues existing survey-based literature fails to capture, since studies such as Sharif and Hoque (2025) and Sarker and Uddin (2025) operate at the level of aggregated perception rather than factory-level documentation audit (Section 2.4). In regards to this, these two files support the methodological argument of this paper, which is that a reproducible, case-level readiness instrument reveals differentiation that survey-based perception scores would miss identifying, even where the Barrier 3 magnitude claim above needs correction.

Conclusion

This paper explored the traceability readiness of the RMG industry in Bangladesh, focusing on the risk of exclusion of small and medium factories and subcontractors as part of the European Union's new Digital

Product Passport regulations. The findings suggest that the issue in Bangladesh with the DPP is not necessarily about blockchain adoption. Instead, it is a more general data, documentation, technology and value chain coordination issue.

Average buyer pressure was 3.8 out of 5, compared to an average of only 2.4 out of 5 for technology capacity, the lowest of the five capability dimensions measured, in the five factories examined. Staff readiness was also relatively high at 3.6 out of 5, indicating factories might well be aware of the rise in compliance demands, but without the digital systems in place to react appropriately. This gap is all the more significant given that all five factories reported regular requests for compliance information from buyers and also reported past order losses due to compliance and/or cost restrictions on DPP implementation. The factory level results also show that traceability readiness is not uniform.

The largest factory had a capability score of 4.4 out of 5 points, and the smallest factory had a score of 2.2 out of 5 points. More importantly, the weakest factory was found in several datasets without any additional information. It included the lowest capability score and an uncertified and unnamed supplier, no procurement information, an emergency supplier switch, and less shipment documentation. This is a good example of how factory-level assessment can provide information that would not be apparent in a perception survey at the aggregated level. Findings thus support the overarching argument of the study that barriers to DPP readiness are interconnected. The lack of investment in technology and specialized personnel limits the use of structured data collection methods, incomplete supplier and procurement records hinder traceability systems, and incomplete participation by suppliers, subcontractors and logistics providers prevents end-to-end traceability at individual factories. Therefore, it is highly probable that blockchain technology, when applied alone, will not generate DPP data compliant to this if the information infrastructure is incomplete. All of this leads to important implications for the RMG sector in Bangladesh.

The EU represents about 50.10% of Bangladesh's total RMG exports and future DPP requirements could be tied with market access not just an additional reporting obligation. As a result, if compliance systems are designed with larger and technologically advanced exporters in mind, this can lead to a potential SME Exclusion Gap for other SMEs and subcontracting factories that are less digitally advanced and have weaker

documentation. Hence, the study concludes that, at least for now, Bangladesh should focus on Minimum Viable Traceability before exploring the possibilities of more advanced blockchain solutions.

The backbone of DPP readiness should be simple features like supplier identification, structured procurement record keeping, chemical tracking, shipment documentation and reliable digital record keeping. While the sample is small (five factories only) to generalise to the whole RMG sector, it is evidence that readiness varies widely among factories and that technology cannot solve the differences. A phased and inclusive compliance approach, therefore, with a focus on foundational data and capability development, would offer a more realistic journey toward DPP readiness for the broader garment value chain in Bangladesh.

Operationalizing Institutional Initiatives

The findings demonstrate that sector-wide initiatives like the BGMEA-AWASET project risk inadvertently widening the SME Exclusion Gap if implementation strategies target only Tier-1 enterprise facilities. Subcontracting suppliers form the core baseline of garment manufacturing in Bangladesh; excluding them from initial digital transformation roadmaps weakens overall supply chain verification.

Actionable Recommendations

For Industry Associations (BGMEA / BKMEA):

- Establish standardized, open-source data exchange templates (MVT Tier 1 format) to allow non-ERP-equipped SME factories to upload verified procurement and production data without purchasing expensive software licenses.
- Establish regional Data Literacy and Compliance Hubs in major industrial clusters (Narayanganj, Gazipur, Chittagong) to address the human capital and skills deficit.

For International Brands and EU Buyers:

- Co-finance digital capability development rather than relying solely on audit penalty models.
- Standardize traceability data schemas across brands to reduce the administrative burden on multi-buyer manufacturing facilities.

For Policy Makers and Regulatory Agencies:

- Integrate local trade digitisation policies with international standards (such as the UN/CEFACT standards and EU ESPR guidelines).
- Provide targeted tax incentives and capital subsidies for SME factories upgrading their core hardware and connectivity infrastructure.

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