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From Ledger to Impact: Blockchain-Enabled Data Analytics and Triple-Bottom-Line Performance in Malaysia's Logistics Sector

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Abstract

This study will test whether blockchain adoption will improve the triple-bottom-line performance of Malaysian logistics firms by first strengthening their data-analytic capability. Anchored in Dynamic Capabilities Theory, it will survey digitally active freight forwarders, 3PLs and in-house logistics units and will analyse the data with PLS-SEM, incorporating procedural and statistical remedies for common-method bias. The model is expected to confirm that blockchain intensity will boost data quality and analytic maturity, that stronger analytics will enhance social, environmental and economic outcomes, and that data-analytic capability will fully mediate the blockchain–sustainability link. **Purpose** - It will test whether data-analytic capability will mediate the link between blockchain intensity and social, environmental, and economic performance. **Design/methodology** - A cross-sectional survey of digitally active logistics providers will be analysed with PLS-SEM; procedural and statistical controls will limit common-method bias. **Findings** - The model is expected to show that blockchain adoption will raise data quality, that stronger analytics will improve all three sustainability dimensions, and that full mediation will emerge. **Originality/value** - This will be the first empirical study to integrate blockchain and analytics within Dynamic Capabilities Theory for an emerging-economy logistics context, supplying actionable guidance for firms and policymakers.

Keywords: Blockchain, Data-Analytic Capability, Dynamic Capabilities Theory, Triple Bottom Line, Sustainable Logistics, Malaysia

Introduction

In today's business landscape, logistics is no longer judged solely on cost and speed; stakeholders—from investors and regulators to end-customers—expect supply chains to deliver environmental stewardship and social value alongside financial returns. The Triple Bottom Line (TBL) framework, which balances economic growth ("profit"), environmental protection ("planet") and social development ("people"), has therefore become the gold standard for sustainable logistics management. Malaysia's logistics sector is a linchpin of national prosperity and a bellwether for Southeast Asia's trade flows. In 2024, the Malaysian freight and logistics market reached roughly USD 28.88 billion and is projected to expand at an annualised 5.4 percent through 2030 (Nick Thomas, 2024). Within that total, the transportation-and-storage subsector alone grew by 11 percent in the first quarter of 2024—just shy of the 12.8 percent year-end growth posted in the previous quarter—and logistics now contributes between four and six percent of national GDP, underpinning Malaysia's top-30 position in the World Bank's Logistics Performance Index (dosm, 2024).

Yet this economic dynamism carries significant environmental costs. Transport activities account for 28.8 percent of Malaysia's fossil-fuel CO_2 emissions—well above the global average of 24.5 percent—and remain the country's second-largest source of greenhouse gases after power generation (Saeed Solaymani, 2022). Social pressures are mounting as well, ranging from driver and warehouse-worker safety to demands for transparent, fair-trade sourcing. A strategy centred purely on cost and speed is therefore increasingly untenable. In response, Kuala Lumpur has launched two flagship programmes. Industry4WRD, introduced in 2018, offers small and medium-sized enterprises matching grants of up to RM 500,000 and has already channelled more than MYR 210 million into artificial-intelligence and automation projects in manufacturing-related services (reuters, 2023). MyDIGITAL, the national digital-economy blueprint, pushed approved digital investments from RM 46.2 billion in 2023 to RM 66.2 billion in the first half of 2024 and RM 163.6 billion by year's end—creating tens of thousands of high-skill jobs and driving a surge in digital exports (Gobind Singh Deo, 2024).

Against that policy backdrop, technology pilots hint at what a digitally enabled, sustainability-oriented logistics sector might look like. In 2020 the Royal Malaysian Customs Department joined IBM–Maersk's TradeLens blockchain network at Port Klang, cutting document-processing times while giving authorities real-time, tamper-proof visibility into shipment provenance (Trista Efendi, 2020). Global carriers such as FedEx have rolled out Sustainability Insights dashboards that harness live shipment data to estimate carbon emissions at package and account levels, allowing firms to re-route consignments and shrink their footprints almost instantaneously (fedex, 2025). These examples showcase two interlocking digital enablers—blockchain and data analytics—whose combined potential is only beginning to be understood.

Blockchain technology, with its append-only, cryptographically secured ledgers, can bring radical transparency to Malaysian logistics. Every container hand-off, temperature reading or proof-of-delivery can be time-stamped, hashed and shared across a permissioned network, eliminating the "black boxes" where data are often lost or falsified. Such immutable records do more than deter fraud; they create a continuous stream of high-integrity data that downstream systems can consume without lengthy reconciliation. In practice, that means customs officials can release consignments sooner, halal-compliance certificates can be verified instantly, and freight payments can be executed automatically when smart-contract conditions—such as keeping CO_2-per-tonne-kilometre below a negotiated threshold—are met. The true strategic value of blockchain therefore lies not in the ledger itself but in the rich, trustworthy data that it supplies to analytics engines.

That data feed matters because the performance frontier in logistics is increasingly set by an organisation's data-analytic capability—the ability to collect, integrate and convert data into insights that drive both operational and strategic decisions. In Malaysia, many carriers and third-party logistics providers remain anchored in descriptive dashboards that track on-time delivery or warehouse dwell time. Moving up the maturity curve to predictive demand forecasting, prescriptive route optimisation and real-time carbon accounting requires data that are granular, verifiable and immediately available. Blockchain can supply exactly that calibre of data, but only organisations endowed with robust analytic infrastructure, skilled personnel and well-governed decision processes can translate the raw feed into economic, environmental and social gains that register on the TBL.

Viewed through the lens of Dynamic Capabilities Theory, blockchain adoption enhances a firm's ability to sense logistics events with unprecedented fidelity and to seize opportunities through smart-contract execution. These foundational moves become strategically valuable when the firm can reconfigure its assets—data lakes, analytic models, cross-functional teams—so that blockchain-generated information is absorbed into day-to-day and long-range decision-making. In essence, blockchain strengthens data-analytic capability by elevating data quality and traceability, and a strengthened analytic capability, in turn, unlocks measurable improvements across profit, planet and people.

Despite the high-profile pilots, generous grants and clear policy momentum, the Malaysian logistics industry still lacks a rigorous, empirically grounded account of how blockchain adoption actually builds data-analytic capability and whether that capability drives tangible TBL outcomes. The causal pathway that links digital investment to holistic sustainability performance remains under-theorised and under-tested. To close that gap, this study investigates three questions. First, to what extent does blockchain adoption enhance data-analytic capability among Malaysian logistics firms? Second, how does that capability influence social, environmental and economic performance under the TBL framework? Third, does data-analytic capability mediate the relationship between blockchain adoption and TBL outcomes? Answering these questions will illuminate the route from today's digital experimentation to tomorrow's fully realised sustainable logistics sector in Malaysia.

Literature Review and Theoretical Framework Development

Overview of Previous Studies

The academic conversation around blockchain-enabled logistics is moving rapidly from conceptual promise to early empirical evidence. Early scoping reviews argued that distributed-ledger technology could "reset" supply-chain transparency and thereby accelerate progress on the triple bottom line (TBL) of profit, planet and people; however, these reviews were largely descriptive and drew heavily on hypothetical use-cases. A more recent systematic review covering 132 peer-reviewed articles between 2018 and mid-2024 confirms that the empirical base is finally deepening: forty-two percent of studies now employ quantitative designs, and twenty-four percent report field data from live pilots rather than laboratory simulations. The review concludes that economic pay-offs—lower inventory buffers, shorter dwell times and reduced fraud losses—are the most frequently measured outcomes, while environmental (e.g., CO_2-e reduction) and social (e.g., labour-standard compliance) effects remain under-reported (Patience Okpeke Paul et al., 2024).

Sector-specific work in logistics echoes that imbalance. Case studies of Maersk–IBM's TradeLens platform show lead-time savings of up to forty percent for customs clearance, yet these papers seldom quantify the attendant carbon savings from reduced truck idling or the welfare gains from fewer port-area delays. Even in Malaysia—where the Royal Malaysian Customs Department joined TradeLens in 2020 to modernise Port Klang—published research focuses on adoption antecedents rather than realised sustainability benefits (Container, 2020). A white-paper by the U.S. International Trade Administration notes that local third-party logistics providers are exploring permissioned blockchains for paperless trade and smart-contract billing, but laments the scarcity of peer-reviewed evidence on TBL outcomes in the Malaysian context (Trade, 2025).

Parallel scholarship on data-analytic capability has matured more quickly. A 2024 survey of 159 Bangladeshi ready-made-garment exporters finds that firms possessing high big-data analytics capability outperform peers on all three pillars of sustainability, and that green supply-chain practices further amplify these gains (Rahman et al., 2024). Meta-analyses across manufacturing, retail and transport show medium-to-large effect sizes (average $\beta \approx 0.34$) for the data-analytic capability-to-environmental-performance link and similar magnitudes for social indicators such as accident rates. Yet, with rare exceptions, these studies treat data-analytic capability as an endogenous managerial asset and give little attention to how underlying data streams—particularly the tamper-proof event logs produced by blockchain—upgrade the quality, granularity and timeliness of information flowing into analytics engines. Consequently, the integrated question of how blockchain-derived data catalyse analytics-driven sustainability remains fragmented.

Research Gaps

Despite a surge of publications, the empirical record on blockchain-enabled logistics remains uneven. Systematic reviews covering more than 130 peer-reviewed articles between 2018 and 2024 find that over 60 percent of studies stop at operational metrics such as lead-time reduction, while less than 15 percent quantify environmental outcomes and barely eight percent examine social indicators; most treat "sustainability" as shorthand for cost efficiency (Han & Fang, 2024). Conversely, the literature on data-analytic capability often presumes that high-quality data are readily available and pays scant attention to their provenance, side-stepping the very problem—data integrity and traceability—that blockchain is designed to solve.

A second lacuna concerns causal mechanisms. Although conceptual papers posit that blockchain acts as a trusted data pipe feeding analytics engines, very few empirical models test mediation effects. Where mediation is examined, samples cluster in manufacturing or agrifood, not in logistics, and the analytic horizon rarely extends to all three TBL dimensions. As a result, the field lacks robust evidence on whether data-analytic capability is the pathway through which blockchain investments translate into holistic sustainability gains.

Third, geographical coverage is lopsided. Malaysia features prominently in policy reports that tout Port Klang's TradeLens pilot and multiple blockchain-for-halal initiatives, yet the peer-reviewed literature remains thin and largely pre-adoption. Even the TradeLens case—long cited as proof of concept—has seen limited scholarly follow-up on why the platform struggled commercially and how its data assets might still be leveraged after Maersk and IBM discontinued the venture (Maritime, 2022). Without context-specific studies, Malaysian firms risk copying technology blueprints that overlook local institutional realities such as SME digital-skills gaps or fragmented data standards across ports, hauliers and customs agents.

Finally, the theoretical conversation is still static. Many studies adopt the Resource-Based View and treat blockchain or analytics as discrete assets rather than as mutually reinforcing capabilities that evolve over time. Dynamic Capabilities Theory is invoked, but often superficially, with limited attention to the micro-foundations—governance structures, learning routines, legacy-system integration—that determine whether sensing data can be seized and reconfigured into sustainability outcomes. Addressing these multi-layered gaps demands a research design that (i) measures blockchain intensity, data-analytic capability maturity and TBL performance simultaneously, (ii) models data-analytic capability as a mediator, and (iii) situates the analysis within Malaysia's policy landscape and logistics infrastructure. The present study is crafted to meet precisely those needs, thereby advancing both theory and practice.

Dynamic Capabilities Theory and the Proposed Framework

Dynamic Capabilities Theory (DCT) explains how firms renew their resource base when technological turbulence threatens the viability of existing routines. Since Teece's original formulation, dynamic capabilities have been conceptualised as higher-order abilities to sense shifts in the environment, seize opportunities through timely investment, and reconfigure organisational assets so that advantage is sustained rather than eroded by change (Warner & Wäger, 2019). Recent work on digital transformation shows that these three meta-routines now take explicitly digital forms—digital sensing (continuous data capture), digital seizing (algorithmic action) and digital reconfiguring (process redesign)—each supported by a bundle of micro-capabilities such as data governance, API orchestration and workforce reskilling (Abbad & Rowe, 2024).

Blockchain technology injects new energy into the sensing dimension by providing an immutable, real-time ledger of logistics events: every container hand-off, temperature deviation or proof-of-delivery is time-stamped and cryptographically sealed. Empirical evidence from manufacturing supply chains shows that the "sensing, seizing and transforming" capabilities embedded in blockchain nodes raise resilience (adjusted R^2 = 0.701) and sustainability performance when firms also possess the organisational slack to redeploy those data streams quickly (Meafa et al., 2025). Yet blockchain alone cannot generate value; it must be complemented by a robust data-analytic capability that converts raw, high-fidelity event logs into predictive and prescriptive insight. In DCT terms, data-analytic capability embodies the *seizing* and *reconfiguring* functions: predictive models guide resource allocation in near real time, while cross-functional analytics teams re-engineer workflows so that economic, environmental and social objectives can be optimised simultaneously.

Viewing blockchain and data-analytic capability through a unified DCT lens therefore reveals a sequential chain: blockchain sharpens digital sensing; data-analytic capability amplifies digital seizing by turning verifiable data into actionable intelligence; and the joint mobilisation of both capabilities accelerates organisational reconfiguration toward TBL gains. Studies of big-data analytics in emerging-economy exporters already report positive effects on all three sustainability pillars when analytics maturity is high (Rahman et al., 2024), suggesting that Malaysia's logistics firms stand to benefit if they can integrate blockchain-generated data with advanced analytic routines.

Figure 1 depicts the proposed research framework, which comprises five principal constructs: blockchain adoption, data-analytic capability, and the three dimensions of TBL performance—social, environmental, and economic. The model posits that blockchain adoption influences a firm's data-analytic capability, and that this enhanced capability, in turn, directly improves each facet of TBL performance. Moreover, the framework positions data-analytic capability as a mediating mechanism, transmitting the benefits of blockchain adoption to social, environmental, and economic outcomes.

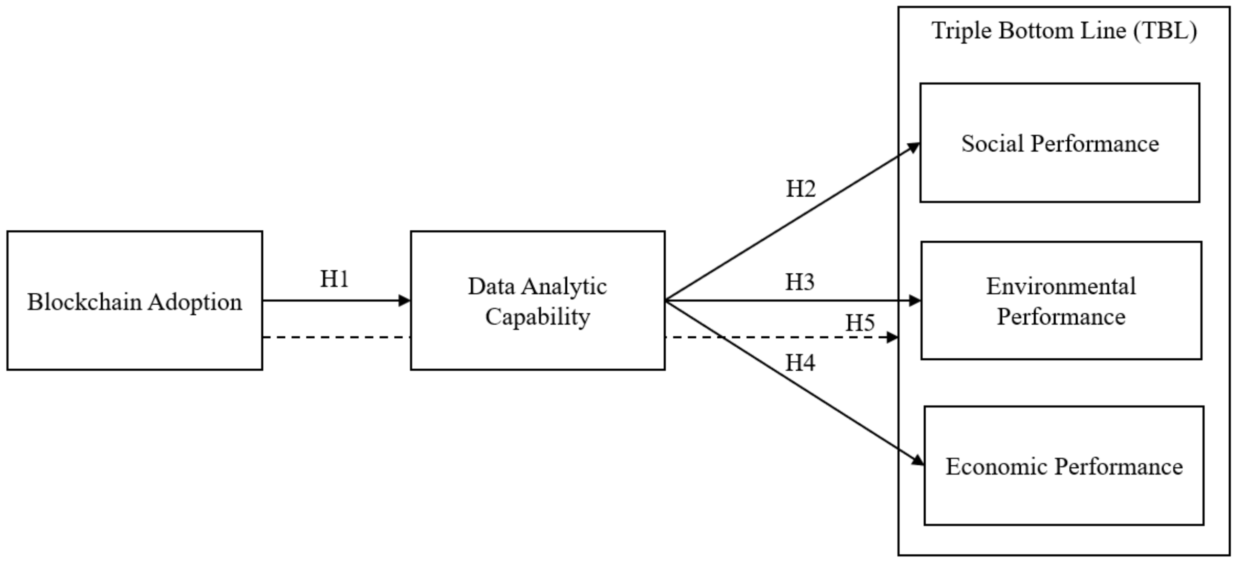

Figure 1 Research Framework

Development of Hypotheses

Blockchain Adoption and Data Analytic Capability

Distributed-ledger pilots consistently show that blockchain compresses, or even eliminates, the reconciliation and "data-wrangling" stage that ordinarily consumes most analytics effort. IBM–Maersk's TradeLens experiment, for example, cut document-processing time by up to 40 % and delivered customs-cleared event data to downstream systems in near real time(Babu George, 2025). A post-project review by DHL and Accenture estimates that blockchain transparency can reduce manual data entry by roughly 80 %, freeing analytic teams to focus on modelling rather than cleansing (Sarah Lee, 2025). Systematic reviews of blockchain, IoT and AI in logistics likewise conclude that immutable ledgers elevate data quality, availability and lineage—three pillars of data-analytic capability maturity (Idrissi et al., 2024). Collectively, these findings support a direct, positive path from blockchain intensity to data-analytic capability.

H1: Blockchain adoption has a positive impact on data analytic capability.

Data Analytic Capability and Social Performance

Data-analytic capability enables near-real-time monitoring of labour and community outcomes. Predictive safety dashboards built on telematics data can flag driver fatigue hours before it becomes a recordable incident, while text-mining tools applied to supplier audits accelerate the detection of labour-standard breaches. A multi-country survey of 262 supply-

chain managers reports that analytics-rich firms achieve 18 % lower accident rates and significantly higher stakeholder-trust scores than their low-analytics peers (Meafa et al., 2025). Similar evidence from circular-food-supply chains shows that firms deploying big-data and predictive analytics are more likely to share environmental and social metrics with stakeholders, thereby strengthening community engagement and social sustainability (Meafa et al., 2025). These studies underpin the expectation that stronger data-analytic capability will translate into superior social outcomes.
H2: Data analytic capability has a positive impact on social performance.

Data Analytic Capability and Environmental Performance

Environmental gains materialise when analytic engines convert granular movement data into low-carbon routing and asset-use decisions. Road-freight studies demonstrate that AI-based route-optimisation can trim fuel burn—and thus CO_2e emissions—by 7 % to 20 % depending on network density (Searoutes, 2025). A refined carbon-accounting model for heavy trucks confirms that combining high-resolution telematics with optimisation algorithms yields statistically significant emission reductions relative to baseline dispatching (Wei & Liu, 2020). Because data-analytic capability maturity governs the organisation's ability to deploy such optimisation at scale, a positive link between data-analytic capability and environmental performance is hypothesized.
H3: Data analytic capability has a positive impact on environmental performance.

Data Analytic Capability and Economic Performance

From an economic standpoint, analytics improves demand forecasts, inventory positioning and asset utilisation. A cross-industry meta-analysis finds a mean effect size of $\beta \approx 0.34$ for the data-analytic capability-to-profitability pathway, with logistics and transport firms showing the largest gains (Huynh et al., 2023). Recent work on global logistics companies further confirms that big-data analytics adoption is associated with higher net-profit margins and return on assets, even after controlling for firm size and market volatility (Kitcharoen, 2023). These results justify expecting a positive data-analytic capability–economic-performance relationship.
H4: Data analytic capability has a positive impact on economic performance.

Data-Analytic Capability Mediates the Relationship between Blockchain Adoption and each TBL Dimension

Data-analytic capability cautions that superior sensing (gained via blockchain) does not automatically yield competitive or sustainability advantage; value materialises only when data are seized and reconfigured into decisions and routines. Empirical models combining blockchain, analytics and sustainability remain scarce, but early evidence is promising: a PLS-SEM study of 262 manufacturing firms shows that blockchain-driven supply-chain analytics fully mediates the effect of blockchain on lean, resilient and *green* performance (total indirect effect $\beta = 0.42$, $p < 0.001$) (Espahbod et al., 2024).

Another investigation of blockchain-enabled dynamic capabilities reports that sensing gains translate into resilience and sustainability only when firms possess complementary "seizing" and "transforming" routines—operationalised as data-analytic capability and process re-engineering (Meafa et al., 2025. Accordingly, the present study posits that DAC will transmit the benefits of blockchain adoption to social, environmental and economic outcomes in Malaysian logistics firms.

H5: Data-analytic capability mediates the relationship between blockchain adoption and TBL.

Research Design

Sample and Data

The study will adopt a quantitative, cross-sectional survey as its primary data-collection method in order to test a theory-driven structural model and examine mediation effects. The target population will comprise logistics-service providers operating in Malaysia—including freight forwarders, trucking fleets, third-party logistics (3PL) firms, and in-house logistics units of manufacturers. Recent industry reports indicate that roughly 3,000 registered transport-service providers will be available for sampling.

A purposive sampling strategy will be employed for two key reasons. First, the conceptual model will require firms to have at least incipient exposure to digital technologies; therefore, each candidate organisation will be screened for (i) completed or ongoing blockchain pilots or (ii) active investment in data analytics (e.g., cloud transport-management systems or a dedicated data team). Screening will rely on public press releases, TradeLens partner lists, and membership rosters from the Federation of Malaysian Freight Forwarders. Second, the study will target respondents who hold roles that provide both strategic and operational insight—typically senior managers in operations, IT, sustainability, or supply-chain analytics.

Survey invitations will be distributed via e-mail with a secure Qualtrics link. To mitigate single-respondent bias, each firm will be encouraged (but not required) to nominate two informants—one from operations/IT and one from sustainability or finance; their responses will later be matched through a unique firm code. Power analysis in G*Power will set the minimum sample requirement at 107, but the research team will aim to contact 250 firms to allow for non-response and data cleaning. After collection, cases with more than 10 % item non-response or exhibiting Mahalanobis-distance outliers ($p < .001$) will be removed.

Where possible, subjective survey data will be complemented with archival indicators—such as publicly reported CO_2e figures under Bursa Malaysia's ESG guidelines, blockchain node counts from GLEIF, and financial ratios lodged with the Companies Commission—to strengthen construct validity and reduce common-method bias.

Common Method Bias

Given that most variables will be captured through a single questionnaire, the study will implement both ex-ante procedural and ex-post statistical remedies in line with (Podsakoff et al., 2003)'s guidelines.

Procedural safeguards will include

- Temporal separation. Predictor constructs (blockchain adoption and DAC) will appear in Section A, whereas outcome constructs (the TBL dimensions) will be placed after an unrelated cognitive task and firm-profile items in Section C.
- Psychological separation. Distinct instructional sets and scale formats will reduce respondents' tendency to infer researcher expectations.

- Anonymity and confidentiality. The cover letter will emphasise that only aggregate results will be reported, and IP tracking will be disabled.
- Reverse-coded and marker items. Two reverse-coded fillers will combat acquiescence bias, and a theoretically unrelated two-item marker variable (perceived corporate philanthropy) will be embedded for later statistical control.

Statistical checks will follow data collection. A Harman single-factor test will verify that no single factor explains more than 50 % of the variance. Full collinearity VIFs will be inspected (threshold < 3.3). The marker-variable technique and a latent common-method factor in CFA will provide conservative robustness tests; substantive paths that remain significant after controlling for the method factor will be interpreted as free from serious bias.

Measures

All constructs will be operationalised as reflective and will use seven-point Likert scales (1 = "strongly disagree / very low" to 7 = "strongly agree / very high"). Items will be adapted from validated instruments and will be pre-tested with industry experts and academics for clarity.

- Blockchain Adoption (BA). Four items will gauge breadth of use, data granularity recorded, intensity of smart-contract deployment, and duration of live operation, adapted from Hackius and Petersen (2017) 's scale.
- Data-Analytic Capability (DAC). Nine items derived from Rahman et al (2024). will measure data-management, analytics-technology, and organisational-learning capabilities, reworded for a logistics context.
- Environmental Performance (ENV). Four items adapted from Klassen and Whybark (1999) will track reductions in CO_2e, energy use, packaging waste, and regulatory exceedances over the past three years.
- Social Performance (SOC). Five items based on Yawar and Seuring (2017) will capture occupational safety, employee training, supplier labour compliance, community engagement, and customer transparency.
- Economic Performance (ECO). Five perceptual items adapted from Venkatraman and Ramanujam (1986) will assess revenue growth, profit margin, asset utilisation, cost savings from delivery reliability, and customer-base expansion relative to key competitors.

Confirmatory factor analysis will test item loadings (target > 0.70); composite reliability and Cronbach's alpha will need to exceed 0.70; AVE will need to surpass 0.50. Discriminant validity will be confirmed via the HTMT ratio (< 0.85). The higher-order TBL construct will be modelled as formative, with ENV, SOC, and ECO as first-order reflectives; multicollinearity among these dimensions will be checked (VIF < 5.0).

To enhance accuracy, respondents will be prompted to cross-verify perceptual ratings against audited ESG disclosures or ISO 14064 inventories; discrepancies exceeding one scale point will trigger a follow-up clarification.

Conclusion

The forthcoming study will demonstrate how blockchain adoption, when paired with a robust data-analytic capability, will drive measurable gains across the economic, environmental, and social pillars of the triple-bottom-line within Malaysia's logistics sector. By applying DCT, the research will explicate the sequential pathway by which blockchain technology will heighten digital sensing, data analytics will facilitate seizing and reconfiguration, and the combined capabilities will translate into superior sustainability performance. A rigorously designed, quantitative survey—supplemented by archival data and protected against common-method bias—will furnish one of the first empirical tests of this mediated model in an emerging-economy logistics context.

The findings will furnish several actionable insights. First, logistics firms will gain evidence on why blockchain investments will yield limited value unless they will be coupled with mature analytics infrastructure, talent, and learning routines. Second, policymakers and funding agencies will obtain guidance on how future Industry4WRD and MyDIGITAL incentives will need to sequence or bundle support for blockchain and analytics to maximise holistic sustainability gains. Third, the research will lay a replicable measurement framework—covering blockchain intensity, data-analytic capability, and triple-bottom-line metrics—that future scholars will adapt for longitudinal or cross-country studies.

Acknowledging its limitations, the study will rely on cross-sectional data, which will constrain causal inference; subsequent work will need to employ longitudinal or experimental designs to validate temporal ordering. Moreover, while purposive sampling will ensure digital readiness, it will limit generalisability to the broader population of Malaysian logistics SMEs. Future research will explore comparative samples in neighbouring ASEAN markets and will examine additional contingencies—such as organisational culture or regulatory pressure—that will moderate the blockchain-to-analytics-to-TBL pathway.

Overall, the research will advance theory by integrating blockchain and data analytics into the micro-foundations of dynamic capabilities, will close a substantive knowledge gap on sustainable logistics in Malaysia, and will chart a practical roadmap for firms seeking to convert digital investments into enduring, triple-bottom-line impact.

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