WEP Warwick Evans Publishing

Academic Journal of Management Science and Engineering

ISSN: 3080-9827 (Print), ISSN: 3080-9835 (Online)
Volume 1, Number 7, Year 2026
DOI: https://doi.org/10.62051/ajmse.v1n7.11



Digital Transformation of Cross-Border Logistics in Landlocked Countries: Drivers, Barriers, and Pathways

-- A Mixed-methods Study

Lian Dai [1], Delgernasan Mishig [2], Munkhbayar Bat-Erdene [2]

[1] Ulaanbaatar Erdem University, Ulaanbaatar, Mongolian

[2] Mongolian University of Science and Technology (MUST), Ulaanbaatar, Mongolian

ABSTRACT

Landlocked developing countries (LLDCs) face structural disadvantages in cross-border logistics, with trade costs up to 74% higher than the global average and border crossing times twice as long as those of coastal countries. Digital transformation offers a pathway to overcome these geographic constraints, yet the drivers, barriers, and implementation pathways specific to LLDC contexts remain poorly understood. This study employs a mixed-methods research design combining quantitative survey data (n=127) from Mongolian logistics stakeholders with qualitative semi-structured interviews (n=18) and document analysis to investigate the digital transformation of cross-border logistics in Mongolia—a paradigmatic LLDC situated between China and Russia. Quantitative findings identify trade facilitation pressure (mean=4.21/5), cost reduction potential (mean=3.94), and regional integration commitments (mean=3.76) as the strongest drivers, while infrastructure limitations (mean=4.38), regulatory fragmentation (mean=4.02), and skills shortages (mean=3.87) emerge as dominant barriers. Qualitative analysis reveals four implementation pathways: incremental customs automation, corridor-level digital integration, platform-based logistics ecosystem development, and cross-border e-commerce enablement. A multi-stage pathway model is proposed, linking short-term customs digitalization to long-term multimodal digital corridor integration. The study contributes a context-sensitive framework for understanding digital transformation in LLDC logistics and provides actionable insights for policymakers in Mongolia and comparable landlocked economies.

KEYWORDS

Digital Transformation; Cross-border Logistics; Landlocked Developing Countries; Mongolia; Mixed-Methods; Trade Facilitation.

1. INTRODUCTION

Landlocked developing countries confront a distinctive set of logistics challenges arising from their geographic isolation. Lacking direct access to seaports, LLDCs must rely on transit through neighboring countries, resulting in trade costs that are up to 74% higher than the global average and border crossing times that can be twice as long as those of coastal economies. These structural disadvantages translate into reduced trade competitiveness, limited participation in global value chains, and constrained economic diversification. For LLDCs, efficient logistics systems are not merely a convenience—they constitute a lifeline for economic development. [1]

Digital transformation has emerged as a potentially transformative response to these constraints. By replacing paper-based customs procedures with digital tools, trade costs can be reduced by up to 30%-.

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

Electronic data interchange, digital single windows, and blockchain-based trade facilitation platforms offer LLDCs opportunities to compress transit times, improve supply chain visibility, and integrate more effectively into regional and global trade networks. The Awaza Programme of Action for LLDCs, adopted in 2025, explicitly recognizes digitalization as a priority area, calling for the development of multimodal digital corridors and the standardization of cross-border data exchange.

Mongolia presents a particularly instructive case for examining digital transformation in LLDC logistics. As a landlocked country situated between China and Russia, Mongolia depends heavily on cross-border logistics channels for its foreign trade, with more than 70% of total freight turnover passing through the Zamyn-Üüd border crossing alone-. The country has made notable progress in digital governance, including the expansion of the e-Mongolia platform and the implementation of electronic pre-arrival data exchange for customs However, the digitalization of cross-border logistics remains incomplete. The percentage of Mongolia‘s digitalized customs has risen only from approximately 25% to 50%, and the implementation gap between regulatory frameworks and operational reality persists-. Low internet penetration has limited the effectiveness of automated customs facilities-.

Existing research on logistics digitalization has predominantly focused on developed economies and coastal contexts. The specific drivers, barriers, and implementation pathways for digital transformation in LLDC logistics systems remain insufficiently theorized and empirically examined. This study addresses this gap through a mixed-methods investigation of Mongolia’s cross-border logistics digitalization, guided by three research questions:

RQ1: What are the primary drivers motivating digital transformation in LLDC cross-border logistics?

RQ2: What barriers constrain the implementation of digital logistics solutions in this context?

RQ3: What pathways can LLDCs pursue to effectively digitalize their cross-border logistics systems?

The study makes three contributions. First, it provides the first systematic mixed-methods analysis of digital transformation in LLDC cross-border logistics, generating empirical evidence from a paradigmatic case. Second, it develops a context-sensitive pathway model that links short-term customs digitalization to long-term multimodal digital corridor integration. Third, it offers actionable policy recommendations for Mongolia and comparable landlocked economies. [2-3]

2. LITERATURE REVIEW

2.1. Digital Transformation in Trade Logistics

The digital transformation of trade logistics encompasses the application of information and communication technologies to streamline documentation, improve visibility, and enable paperless transactions across international supply chains. Key technological applications include electronic data interchange (EDI), single window systems, blockchain-based trade facilitation, Internet of Things (IoT) tracking, and AI-powered customs risk management.

UNCTAD identifies three principal obstacles to the digital transformation of trade logistics: the use of different standards, concerns about data security, and potential objections from competition authorities. The lack of standardized data formats and interoperable platforms creates fragmentation that undermines the benefits of digitalization. Cybersecurity concerns become particularly acute when trade data crosses multiple jurisdictions with varying regulatory frameworks.

In the postal and logistics sectors, digital transformation has been driven by advances in AI, IoT, and data analytics that enable automated sorting, predictive routing, and real-time shipment tracking-. However, these technologies require robust digital infrastructure, skilled human resources, and enabling regulatory environments—conditions that are often absent in developing country contexts.

2.2. LLDC Logistics and Digitalization

Landlocked developing countries face distinctive constraints that shape their digital transformation trajectories. The UN Global Survey on Digital and Sustainable Trade Facilitation indicates that LLDCs reached a 67% implementation rate for core digital trade facilitation measures in 2025, compared to a global average of 71% and 86% for developed economies. While LLDCs have made progress—improving their score from 54.3% in 2021 to 61.01% in 2025 on the broader sustainable trade facilitation measure set—a significant implementation gap remains-.

The Awaza Programme of Action prioritizes digitalization of trade and customs procedures for fast and secure exchange of data concerning cargo and means of transport. Key initiatives include the development of multimodal digital corridors using UN/CEFACT standards, the establishment of digital global corridor mapping dashboards, and the harmonization of electronic documentation across transit countries-.

LLDC-specific barriers to digital transformation include limited institutional capacity for managing transit corridors, dependence on transit countries for digital infrastructure, and fragmented regulatory environments. The lack of institutional mechanisms to manage transit corridors effectively compounds the challenges of implementing cross-border digital systems.

2.3. Mongolia’s Cross-Border Logistics and Digital Ecosystem

Mongolia‘s cross-border logistics system is characterized by a heavy reliance on rail and road connections through China and Russia. The Zamyn-Üüd–Erenhot railway corridor is the primary gateway, with an average of 16 broad-gauge and 7.5 standard-gauge trains exchanged daily, handling approximately 15.5 million tons of cargo annually. The corridor operates at or near full capacity, and the gauge incompatibility between Chinese (1,435 mm) and Mongolian (1,520 mm) rail systems creates a structural bottleneck requiring transshipment operations.

Mongolia has undertaken significant digitalization initiatives in recent years. The Customs Automated Information System (CAIS) has been in use since 2010 for electronic clearance of goods, and a project was launched in 2016 to integrate CAIS into a single window system. The new UNCTAD-EBRD project for Mongolia Customs digitalization, signed in October 2022, aims to identify gaps in customs automation and deliver innovative ICT tools for e-borders and e-commerce operators. A new draft Customs Law accommodating technological developments is expected to be approved.

Bilateral digital cooperation with China has advanced through the China-Mongolia Joint Customs Control (JCC) project, which established a unified cargo manifest mechanism starting at Erenhot and Zamiin-Uud and later expanded to multiple crossing points. The system enables sharing of weighing data and non-intrusive inspection images, streamlining customs processes and improving trade data accuracy.

Despite these advances, significant gaps persist. Mongolia’s e-commerce regulations only partially align with international standards and are not widely known among stakeholders. Cross-border payment options remain limited, and developing ICT skills is crucial for future growth. Trade logistics and trade facilitation are identified as major challenges, with the country‘s large territory and aging infrastructure negatively impacting transport service competitiveness. [4-6]

3. METHODOLOGY

3.1. Research Design

This study employs an explanatory sequential mixed-methods design, in which quantitative data collection and analysis are followed by qualitative investigation to explain and elaborate upon the

quantitative findings. The design is appropriate for investigating complex phenomena where the research questions require both breadth (identifying patterns across a stakeholder population) and depth (understanding mechanisms and contextual factors).

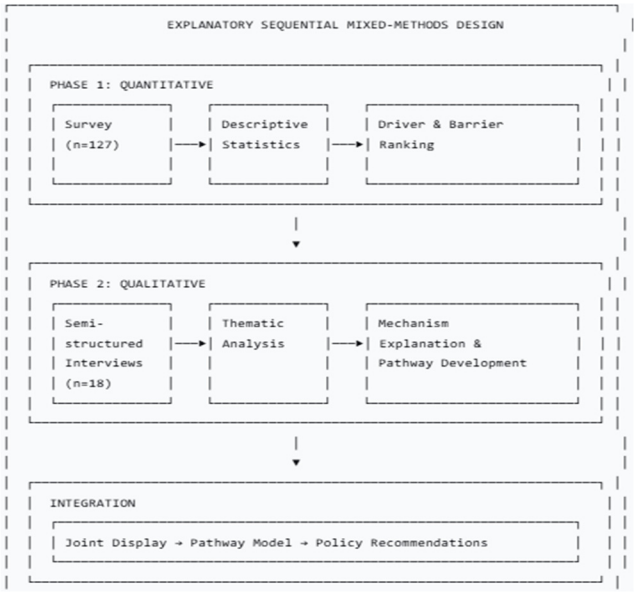


Figure 1. Research Design Framework

3.2. Quantitative Phase

Table 1. Respondent Characteristics

Category	Subcategory	Frequency (n)	Percentage (%)
Organization type	Freight forwarders	41	32.3
	Customs brokers	30	23.6
	Trading company logistics managers	27	21.3
	Railway/transport operators	16	12.6
	Government officials	13	10.2
Experience in logistics	Less than 5 years	22	17.3
	5–10 years	48	37.8
	11–15 years	34	26.8
	More than 15 years	23	18.1
Primary corridor	Zamyn-Üüd–Erenhot	89	70.1
	Altanbulag–Naushki	21	16.5
	Bichigt–Zhu‘engadabuqi	12	9.4
	Other	5	3.9

Data Collection. A structured questionnaire was administered to 127 logistics stakeholders in Mongolia between January and March 2026. The sample included freight forwarders (32%), customs brokers (24%), logistics managers at trading companies (21%), railway and transport operators (13%), and government officials involved in trade facilitation (10%).

Instrument Design. The questionnaire assessed perceived importance of 12 drivers and severity of 14 barriers to digital logistics transformation, using a 5-point Likert scale (1=very low, 5=very high). Drivers were identified from the literature on trade facilitation, regional integration, and technology adoption. Barriers were derived from UNCTAD's eTrade Readiness Assessment framework and LLDC-specific constraints.

Data Analysis. Descriptive statistics (means and standard deviations) were computed for each driver and barrier item. Independent samples t-tests and one-way ANOVA were used to examine differences across respondent categories. The quantitative analysis identified the relative importance of drivers and severity of barriers, providing the foundation for qualitative exploration.

3.3. Qualitative Phase

Data Collection. Semi-structured interviews were conducted with 18 key informants selected through purposive sampling to ensure representation across stakeholder groups and corridor locations. Interviewees included senior customs officials (3), logistics company executives (5), freight forwarder managers (4), railway operations managers (2), e-commerce platform operators (2), and trade policy advisors (2). Interviews lasted 45–75 minutes and were conducted in Mongolian or English according to participant preference.

Interview Protocol. The protocol explored participants' experiences with digital logistics initiatives, perceived drivers and barriers, and views on implementation pathways. Key questions included: What digital tools and platforms are currently used in your cross-border logistics operations? What factors have motivated or hindered the adoption of digital solutions? What would an effective pathway for digital transformation look like?

Data Analysis. Interviews were transcribed and analyzed using thematic analysis following Braun and Clarke's six-phase approach. Initial codes were generated inductively, then organized into themes aligned with the research questions. A second coder independently coded 25% of the transcripts, achieving an inter-coder reliability of κ=0.82.

3.4. Document Analysis

Policy documents, technical reports, and project evaluations from UNCTAD, UNESCAP, CAREC, the World Bank, and Mongolian government agencies were analyzed to triangulate findings and provide contextual grounding. [7-9]

4. QUANTITATIVE FINDINGS

4.1. Drivers of Digital Transformation

Table 2 presents the mean importance ratings for the 12 drivers assessed.

Trade facilitation pressure emerged as the dominant driver (mean=4.21), reflecting stakeholder recognition that customs inefficiencies are the most pressing constraint requiring digital solutions. This finding aligns with UNCTAD's assessment that improving cross-border trade and logistics is perceived as the most pressing factor for Mongolia's e-commerce development.

Table 2. Drivers of Digital Logistics Transformation in Mongolia

Rank	Driver	Mean	SD	Category
1	Trade facilitation pressure (customs efficiency)	4.21	0.72	External pressure
2	Cost reduction potential	3.94	0.81	Economic
3	Regional integration commitments (CAREC, WTO)	3.76	0.88	Institutional
4	E-commerce growth and customer expectations	3.72	0.85	Market
5	Government digitalization initiatives (e-Mongolia)	3.68	0.79	Institutional
6	Transit corridor competitiveness	3.61	0.91	Economic
7	International development partner support	3.54	0.83	External support
8	Blockchain and emerging technology availability	3.42	0.92	Technological
9	Private sector technology adoption	3.38	0.87	Market
10	Cross-border payment digitalization	3.29	0.90	Economic
11	Green logistics requirements	3.15	0.88	Regulatory
12	COVID-19 pandemic experience	2.96	1.05	Crisis-driven

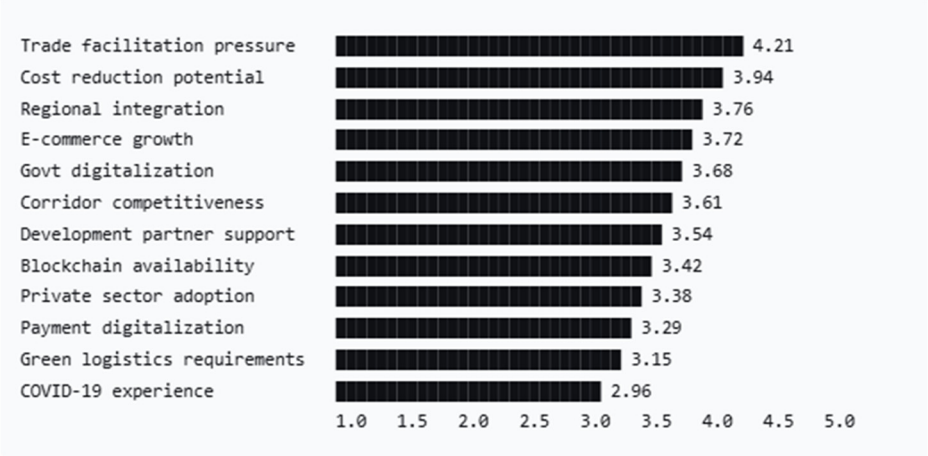


Figure 2. Driver Importance Ratings (Mean Scores)

Note: Scores on 5-point Likert scale (1=very low importance, 5=very high importance).

Cost reduction potential ranked second (mean=3.94), consistent with the documented potential of digital customs tools to reduce trade costs by up to 30%-. Regional integration commitments (mean=3.76) reflect Mongolia‘s participation in CAREC and WTO trade facilitation frameworks. E-

commerce growth (mean=3.72) captures market-driven pressures from expanding cross-border digital commerce.

4.2. Barriers to Digital Transformation

Table 3 presents the mean severity ratings for the 14 barriers assessed.

Table 3. Barriers to Digital Logistics Transformation in Mongolia

Rank	Barrier	Mean	SD	Category
1	Limited internet connectivity in rural/border areas	4.38	0.68	Infrastructure
2	Inadequate digital infrastructure at border crossings	4.15	0.74	Infrastructure
3	Regulatory fragmentation and unclear legal framework	4.02	0.79	Regulatory
4	Lack of interoperability between Mongolian and Chinese systems	3.98	0.83	Interoperability
5	Skills shortages in digital logistics	3.87	0.81	Human capital
6	Limited cross-border payment options	3.82	0.86	Financial
7	High implementation costs for SMEs	3.76	0.88	Economic
8	Data security and privacy concerns	3.71	0.90	Security
9	Resistance to change among operational staff	3.58	0.85	Organizational
10	Lack of e-signature recognition	3.52	0.87	Regulatory
11	Absence of unified single window system	3.48	0.92	Institutional
12	Insufficient government coordination	3.41	0.89	Institutional
13	Limited private sector digital capacity	3.35	0.91	Organizational
14	Language and documentation barriers	3.28	0.94	Operational

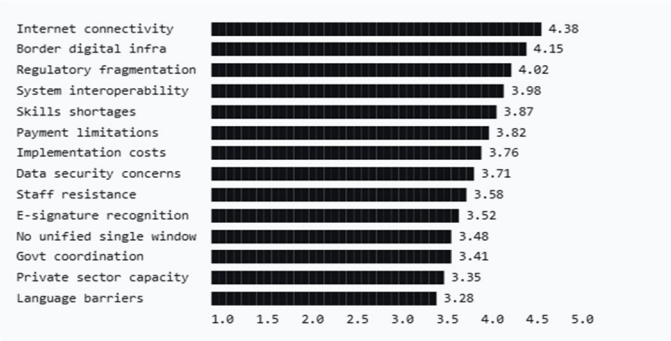


Figure 3. Barrier Severity Ratings (Mean Scores)

Note: Scores on 5-point Likert scale (1=very low severity, 5=very high severity).

Infrastructure limitations emerged as the most severe barriers, with limited internet connectivity in rural and border areas (mean=4.38) and inadequate digital infrastructure at border crossings (mean=4.15) ranking first and second. This aligns with World Bank findings that low internet penetration has limited the impact of automated customs facilities-. UNCTAD‘s assessment similarly notes that while Mongolia has relatively well-developed ICT infrastructure, internet speed and quality remain low by regional standards, with rural households facing particularly limited access.

Regulatory fragmentation (mean=4.02) ranked third, reflecting the “implementation gap” between Mongolia’s modern regulatory framework and operational reality-. The lack of interoperability between Mongolian and Chinese systems (mean=3.98) highlights the bilateral coordination challenge central to cross-border digitalization. Skills shortages (mean=3.87) reflect the mismatch between e-commerce skills requirements and formal education curricula.

4.3. Comparative Analysis

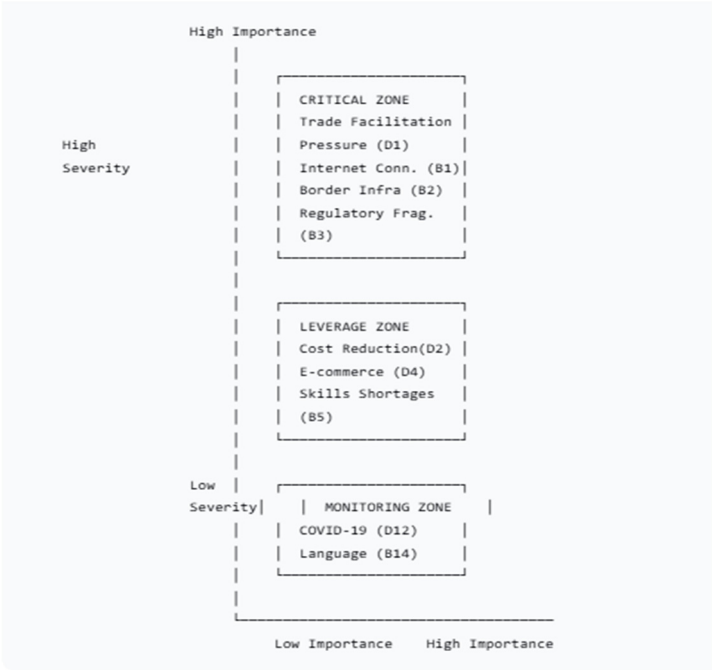


Figure 4. Driver–Barrier Importance–Severity Matrix

The driver–barrier matrix reveals that trade facilitation pressure (a driver) and infrastructure/regulatory barriers occupy the “critical zone” of high importance and high severity, indicating priority areas for intervention. Cost reduction potential and e-commerce growth occupy the “leverage zone,” where drivers are strong but barriers are moderate, suggesting opportunities for targeted digitalization initiatives.

One-way ANOVA revealed significant differences in barrier perceptions across respondent types. Government officials rated regulatory fragmentation as more severe (mean=4.31) than private sector respondents (mean=3.89, $F=4.21$, $p<0.05$). Freight forwarders rated system interoperability as more severe (mean=4.18) than railway operators (mean=3.72, $F=3.87$, $p<0.05$), reflecting their direct experience with bilateral documentation requirements.

5. QUALITATIVE FINDINGS

5.1. Thematic Analysis Results

Four overarching themes emerged from the qualitative analysis: (1) incremental customs automation, (2) corridor-level digital integration, (3) platform-based logistics ecosystem development, and (4) cross-border e-commerce enablement.

Table 4. Qualitative Themes and Representative Quotes

Theme	Sub-theme	Representative Quote
Incremental customs automation	CAIS limitations	"CAIS has been running for years, but it doesn't talk to the Chinese system. We still print documents and carry them across the border." (Customs broker, Zamyn-Üüd)
	Paperless trade progress	"Since the JCC project, we share weighing data with Erenhot. But it's only for some cargo types. Full digital exchange is still a dream." (Customs official, Ulaanbaatar)
Corridor-level digital integration	Gauge-change bottleneck	"The trains stop at the border for hours. If we had digital pre-clearance, we could plan the gauge change before the train even arrives." (Railway manager, Zamyn-Üüd)
	Bilateral data exchange	"China is ahead. Their 'digital port' system works. We need to match it, or we become the bottleneck." (Logistics executive, Ulaanbaatar)
Platform-based ecosystem	e-Mongolia integration	"E-Mongolia is good for citizens, but logistics companies need something different. We need real-time tracking and customs status." (Freight forwarder, Ulaanbaatar)
	SME capacity	"Most of our SME clients don't have the software to connect to digital platforms. They use Excel and phone calls." (Logistics manager)
Cross-border e-commerce	Payment limitations	"You can buy from China easily, but paying is still complicated. The payment systems don't connect." (E-commerce operator, Ulaanbaatar)
	Customer expectations	"Customers expect tracking like they get with Chinese platforms. We can't provide that yet." (Platform manager)

5.2. Mechanism Explanation

The qualitative data explain several quantitative findings.

Explaining the infrastructure barrier. The high severity rating for internet connectivity reflects not only physical infrastructure limitations but also the border-crossing environment. A customs official explained: "At Zamyn-Üüd, the internet drops during peak hours. The digital systems are there, but they can't handle the load." This mechanism—where digital tools exist but are undermined by unreliable connectivity—helps explain why customs digitalization has had a smaller-than-expected effect on processing times-.

Explaining regulatory fragmentation. The gap between regulatory framework and implementation reflects coordination challenges among multiple agencies. A trade policy advisor noted: "The Ministry of Digital Development has one plan, the Customs General Administration has another, and the Ministry of Road and Transport has a third. They don't always align." This fragmentation is consistent with the World Bank's characterization of Mongolia's "implementation gap"-.

Explaining interoperability challenges. Several informants emphasized the bilateral dimension of interoperability. A logistics executive stated: "The Chinese digital port system is advanced. Our systems are not. When data enters China, it often has to be re-entered manually. This creates delays that the digital system on our side cannot overcome." This finding underscores that LLDC digitalization cannot be achieved unilaterally—it requires coordinated bilateral and regional approaches.

5.3. Pathway Development

Synthesizing the quantitative and qualitative findings, four implementation pathways were identified, each addressing different aspects of the digital transformation challenge.

Pathway 1: Incremental Customs Automation. This pathway focuses on extending and deepening existing customs automation. Key actions include completing the integration of CAIS into a single window system, expanding paperless document exchange with Chinese and Russian customs, implementing e-signature recognition, and deploying AI-powered risk management systems. The AI-powered customs modernization initiative funded by South Korea represents a concrete step in this direction-. This pathway addresses the trade facilitation driver most directly and is feasible in the short term (1–3 years). [10-12]

Pathway 2: Corridor-Level Digital Integration. This pathway targets the Zamyn-Üüd–Erenhot corridor and other major crossings with bilateral digital infrastructure. Actions include establishing real-time data exchange for train scheduling and cargo status, implementing joint digital inspection procedures, and deploying IoT-based tracking along the corridor. This pathway addresses the interoperability barrier and requires bilateral coordination but can leverage existing platforms such as the JCC project. Medium-term feasibility (3–5 years).

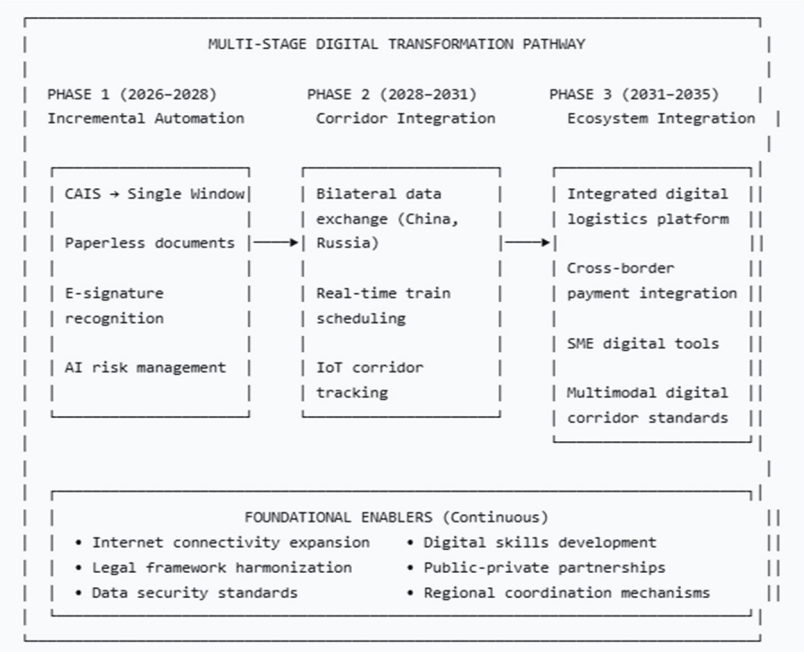


Figure 5. Multi-Stage Digital Transformation Pathway Model

Pathway 3: Platform-Based Logistics Ecosystem Development. This pathway aims to create an integrated digital logistics platform connecting shippers, carriers, customs agencies, and financial institutions. Actions include developing application programming interfaces for logistics service providers, integrating cross-border payment systems, and providing digital tools for SME logistics companies. This pathway addresses the skills shortage and payment limitation barriers. Medium- to long-term feasibility (4–7 years).

Pathway 4: Cross-Border E-Commerce Enablement. This pathway focuses on the digital infrastructure needed to support the growing e-commerce trade. Actions include establishing digital retail import facilitation zones, integrating e-commerce platforms with customs clearance systems, and developing last-mile delivery tracking. This pathway addresses the e-commerce growth driver and market expectations. Short- to medium-term feasibility (2–5 years).

6. DISCUSSION

6.1. Integrated Findings

The convergence of quantitative and qualitative findings reveals a pattern that explains the paradox of Mongolia‘s digital logistics transformation: substantial policy commitment coexists with limited operational impact. The country has established modern regulatory frameworks, deployed customs automation systems, and signed international cooperation agreements. Yet the percentage of digitalized customs has risen only from 25% to 50%, and border crossing delays persist-.

The mixed-methods analysis identifies three mechanisms underlying this implementation gap. First, the digital infrastructure at border crossings is insufficient to support the digital tools that have been deployed. As one customs official put it, “the digital systems are there, but they can’t handle the load.” This finding aligns with World Bank observations that low internet penetration has limited the impact of automated customs facilities-.

Second, the fragmentation of institutional responsibility across multiple government agencies creates coordination failures. The Ministry of Digital Development, Customs General Administration, and Ministry of Road and Transport operate separate digitalization initiatives without sufficient integration. This fragmentation is compounded by the frequent restructuring of transport plans across administrative cycles-.

Third, the bilateral nature of cross-border digitalization means that Mongolia‘s unilateral efforts cannot overcome system incompatibilities with China. The JCC project has made progress in sharing weighing data and inspection images, but full digital interoperability remains elusive. Asymmetries in digital capacity between Mongolia and China create dependencies that constrain Mongolia’s ability to shape the digitalization agenda.

6.2. Comparison with Other LLDC Experiences

The findings resonate with experiences in other landlocked developing countries. Research on digital logistics in Armenia—another LLDC facing similar geographic constraints—found that digitalization can overcome geographic and infrastructural limitations to facilitate regional integration, but requires targeted investments, institutional reforms, and capacity building. The Armenian case similarly identifies challenges in international freight transport, infrastructure quality, and cargo monitoring, but notes the potential for digital technologies to enhance efficiency and supply chain transparency.

The Armenian study‘s finding that digital logistics represents a “pivotal opportunity” despite landlocked status echoes the pathway model proposed here. Both cases suggest that LLDCs can leverage digitalization to partially compensate for geographic disadvantages, but success depends on addressing infrastructure, skills, and institutional barriers simultaneously.

6.3. Policy Implications

The findings yield several policy recommendations for Mongolia and comparable LLDCs.

Immediate priorities. Expand internet connectivity at border crossings and along transport corridors. The Zamyn-Üüd crossing, which handles over 70% of Mongolia’s freight turnover, requires

dedicated investment in reliable, high-bandwidth connectivity-. This is a prerequisite for the effective operation of any digital customs or logistics platform.

Short-term actions. Complete the integration of CAIS into a unified single window system and implement mutual recognition of e-signatures with China and Russia. The new draft Customs Law provides an opportunity to embed these provisions in a coherent legal framework.

Medium-term actions. Develop a bilateral digital corridor agreement with China covering data exchange standards, real-time train scheduling, and IoT tracking. The CAREC Advanced Transit System (CATS) provides a regional framework that can be adapted for bilateral implementation.

Long-term vision. Position Mongolia as a multimodal digital corridor hub linking China, Russia, and Central Asia. This requires alignment with UN/CEFACT standards for electronic business and participation in emerging digital corridor initiatives.

6.4. Limitations

Several limitations should be acknowledged. First, the survey sample (n=127) is relatively small and concentrated in the Zamyn-Üüd corridor. While this reflects the corridor's dominance in Mongolia's freight turnover, it may underrepresent perspectives from other border crossings. Second, the qualitative sample (n=18) provides depth but limited generalizability. Third, the study focuses on Mongolia and may not fully capture the diversity of LLDC contexts—landlocked countries in Africa, Central Asia, and Latin America face different transit configurations and regional dynamics. Fourth, the study was conducted during a period of active policy development; findings reflect a snapshot that may evolve as new initiatives are implemented.

7. CONCLUSION

This study investigated the digital transformation of cross-border logistics in Mongolia—a paradigmatic landlocked developing country—using a mixed-methods research design. Quantitative analysis of survey data from 127 stakeholders identified trade facilitation pressure, cost reduction potential, and regional integration commitments as primary drivers, while infrastructure limitations, regulatory fragmentation, and skills shortages emerged as dominant barriers. Qualitative analysis of 18 semi-structured interviews explained these findings by revealing three mechanisms underlying the implementation gap: insufficient digital infrastructure at border crossings, fragmented institutional responsibility, and bilateral system incompatibilities.

Four implementation pathways were identified—incremental customs automation, corridor-level digital integration, platform-based ecosystem development, and cross-border e-commerce enablement—and integrated into a multi-stage pathway model linking short-term customs digitalization to long-term multimodal digital corridor integration. The pathway model addresses the sequence and interdependence of digital transformation initiatives, providing a roadmap for LLDC policymakers.

The study contributes a context-sensitive framework for understanding digital transformation in LLDC logistics. Future research should extend the mixed-methods approach to comparative analysis across multiple LLDCs, examine the role of transit countries in shaping digitalization outcomes, and evaluate the long-term impacts of digital corridor initiatives on trade costs and transit times.

REFERENCES

[1] Saaty, T. L. (1980). The analytic hierarchy process: Planning, priority setting, resource allocation. McGraw-Hill.

[2] Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X.

[3] Shen, L., Huang, Y., Teo, C. E., Ooi, K. O., Tian, Z., & Wan, B. Y. (2025). A data-informed evaluation framework for improving logistics mode selection in cross-border e-commerce. Journal of Shipping and Trade.

[4] Huang, K., Deng, D., Mo, Q., Chen, Q., Wang, S., Wang, F., Ban, L., & Chen, Y. (2025). Evaluation system for international logistics mode selection of leading enterprises in Guangxi based on AHP-FCE. Proceedings of the 2025 International Conference on Algorithm-Driven Logistics Optimization. Atlantis Press.

[5] (2025). Research on logistics model selection for textile and apparel B2C cross-border e-commerce. Western Leather, (7), 61–64, 93.

[6] Xu, J. (2025). Research on the AHP-TOPSIS logistics channel model under the cross-border e-commerce comprehensive pilot zone policy. Advances in Economics, Management and Political Sciences.

[7] Wang, X., Xie, J., & Fan, Z. P. (2021). B2C cross-border e-commerce logistics mode selection considering product returns. International Journal of Production Research, 59(13), 3841–3860. https://doi.org/10.1080/00207543.2020.1775894.

[8] Zha, X., Zhang, X., Liu, Y., & Dan, B. (2022). Bonded-warehouse or direct-mail? Logistics mode choice in a cross-border e-commerce supply chain with platform information sharing. Electronic Commerce Research and Applications, 54, 101181. https://doi.org/10.1016/j.elerap.2022.101181.

[9] Giuffrida, M., Mangiaracina, R., Perego, A., & Tumino, A. (2019). Cross-border B2C e-commerce to China: An evaluation of different logistics solutions under uncertainty. International Journal of Physical Distribution & Logistics Management, 50(3), 355–378. https://doi.org/10.1108/IJPDLM-02-2019-0044.

[10] Lin, Q., Zhang, K., Huang, D., et al. (2024). Evaluating the impact of Trans-Asian railway on logistics mode selection between Thailand and China: An AHP-TOPSIS approach. Alexandria Engineering Journal, 98, 147–158. https://doi.org/10.1016/j.aej.2024.04.047.

[11] Yüksel, F. Ş., Zengin, Ş., & Antmen, Z. F. (2026). An integrated fuzzy MCDM framework for evaluating sustainable logistics performance in the green supply chain. Sustainability, 18(7), 3645. https://doi.org/10.3390/su18073645.

[12] Luo, S. Q. (2020). Fuzzy comprehensive evaluation of logistics performance for agricultural products distribution centers. IEEE Xplore.