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Integrating the Transports Internationaux Routiers System into Iraq's Development Road: Impacts on Transport Efficiency, Cost Reduction, and Sustainable Corridor Governance

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Abstract: This study investigates the integration of the Transports Internationaux Routiers (TIR) system into Iraq's Development Road Project and evaluates its implications for transport performance and regional connectivity. Based on data obtained through coordination with the Najaf Directorate of Transport and the Ministry of Construction and Housing, the analysis assesses how the adoption of TIR System procedures can reduce border delays, lower freight costs, and reinforce Iraq's emerging role as a land-based transit bridge between the Gulf and Europe. Employing a mixed-method design that combines field observation, institutional assessment, and a calibrated cost–time model, the study estimates potential reductions of approximately 45–50% in transport time and 25–30% in operating costs. The findings underline the importance of coordinated governance, digital customs processes, and effective inter-agency collaboration in achieving these efficiency gains. The paper further argues that aligning the TIR System framework with the Development Road supports balanced spatial development, attracts foreign investment, and advances sustainable logistics planning in accordance with Sustainable Cities and Communities (SDG) 9 (Industry, Innovation and Infrastructure), SDG 11, and SDG 13 (Climate Action). The results provide policymakers with a data-driven basis for extending similar corridor models to routes such as Najaf–Karbala and Basra–Al-Faw.

Keywords: Transports Internationaux Routiers system; Development Road Project; Customs transit procedures; Cost–time model; Transport efficiency; Logistics governance; ESG/SDG indicators.

1 Introduction

Transport infrastructure constitutes a cornerstone of modern economies, serving as a fundamental enabler of the efficient movement of goods and people. Beyond its logistical role, it fosters regional and international integration and enhances global trade competitiveness. This issue assumes particular importance for Iraq, given its strategic geographic location as a natural land bridge linking the Arab Gulf, Turkey, and Europe. Such positioning places Iraq at the center of transcontinental trade corridors [1].

Within this strategic context, Iraq has launched the Development Road Project, designed to transform the country into a regional logistics hub by connecting southern seaports with the northern border crossing into Turkey, traversing the country's principal provinces. The project is expected to facilitate trade flows and reduce the time required for goods to reach international markets. Nevertheless, the realization of these ambitions depends critically on the adoption of effective international logistics systems. Among these is the International Road Transport (TIR) system, a globally recognized customs transit mechanism that streamlines border crossings, lowers transport costs, reduces delays, and ensures the smooth flow of international road freight [2, 3].

This study investigates the extent to which the integration of the TIR system with Iraq's Development Road Project can enhance the efficiency of regional and TIR System. Specifically, it evaluates potential improvements in transport time, reductions in costs, and Iraq's capacity to attract foreign investment while reinforcing its role as a strategic trade corridor. The research also seeks to provide a scientifically grounded perspective to support policymakers in formulating strategic plans aimed at maximizing the economic and commercial benefits of the project while addressing challenges associated with infrastructure, legislation, and logistics governance.

1.1 Background and Motivation

In today's globalized economy, competition among international trade corridors connecting East and West has intensified. Iraq, due to its geographic position, represents a natural transit hub between the Arab Gulf and Europe. With the launch of the Development Road Project, Iraq aims to become a regional logistics center [4]. The success of this initiative, however, depends on adopting internationally harmonized mechanisms that facilitate cross-border transport—most notably, the TIR system, which accelerates customs clearance and reduces transit costs and delays. The research therefore focuses on assessing how the integration of TIR can enhance Iraq's transport efficiency and international connectivity.

1.2 Research Problem and Novelty Statement

The significance of this study lies in its strategic orientation, which integrates the dimensions of regional planning and international transport policy within a unified framework aimed at enhancing the efficiency of Iraq's transport corridors and linking them to global trade networks. By positioning Iraq in a comparative context, the study highlights the country's potential to compete with alternative trade routes, such as the Suez Canal and the Turkish land corridor, while simultaneously contributing to the enrichment of Arabic scholarship on a contemporary issue shaped by dynamic geopolitical and economic transformations. The study's novelty resides in the introduction of an integrated quantitative framework that combines the TIR customs system with a generalized cost minimization model specifically calibrated for Iraq's transport corridors. This innovative approach transforms the Development Road Project from a descriptive planning initiative into a data-driven engineering analysis, aligning closely with the empirical.

1.3 Research Objectives and Hypotheses

This study aims to provide a comprehensive evaluation of Iraq's Development Road Project within the broader framework of regional planning and international logistics integration. Specifically, it seeks to analyze the project's role in connecting Iraq to global trade corridors; examine the TIR system with respect to its mechanisms, procedures, and benefits in facilitating customs transit; assess the feasibility of TIR System implementation in Iraq through an evaluation of existing infrastructure, institutional capacity, and administrative frameworks; and explore the anticipated impact of integrating the TIR system with the Development Road Project on Iraq's economic growth, trade competitiveness, and regional positioning.

Based on these objectives, the study hypothesizes that the integration of the TIR system with the Development Road Project will significantly enhance the efficiency of regional and international transport across Iraq by reducing travel time and operational costs, thereby strengthening Iraq's position as a competitive multimodal trade corridor linking the Arab Gulf with Europe.

1.4 Research Methodology

This study employs a descriptive–analytical and quantitative mixed method integrating field observations with quantitative modeling. The methodology is structured into four main components: data collection, model formulation, calibration and sensitivity testing, and quantitative modeling enhancements.

1.4.1 Data sources and collection

Primary data were obtained through collaboration with the Najaf Directorate of Transport and the Ministry of Construction and Housing, including operational data, corridor performance reports, and travel time surveys [5, 6].

Secondary data were sourced from the International Road Transport Union (IRU), United Nations Conference on Trade and Development (UNCTAD), and the World Bank, ensuring alignment with international benchmarks [3, 7, 8]. The research team conducted site observations, coordination meetings, and document reviews to verify the accuracy and consistency of the datasets. This mixed data foundation integrates real-world operational parameters—travel times, waiting durations, and operating costs—into a coherent analytical framework for assessing corridor efficiency.

1.4.2 Model formulation (Eqs. (1)–(2))

The analysis applies to a generalized cost minimization model that quantifies the total corridor cost Z as a function of operating cost (C_{op}), travel time (T), and waiting time (W) :

$$Z = C_{op} + \alpha_t \times T + \alpha_w \times W \tag{1}$$

where, Z: generalized transport cost index (dimensionless, baseline = 1.00); C_{op}: operating cost (Iraqi Dinar, IQD);α_t: value of in-vehicle travel time (IQD/hour); α_w: value of waiting or clearance time (IQD/hour); T: average travel time (hours); W: average waiting or clearance time (hours).

To determine the coefficients α_t and α_w, Eq. (2) estimates their values as weighted averages based on field survey responses:

$$\alpha_t = \frac{\sum w_i \cdot VOT_i}{\sum w_i}, \alpha_w = \frac{\sum w_i \cdot VOWT_i}{\sum w_i} \tag{2}$$

where, VOT_i: value of travel time for respondent i (IQD/hour); $VOWT_i$: value of waiting/clearance time for respondent i (IQD/hour); w_i: sample weight for respondent i (dimensionless); N: total number of observations.

Eqs. (1) and (2) jointly define the generalized cost function used to evaluate efficiency improvements under the TIR system scenario.

1.4.3 Calibration and sensitivity analysis

The model coefficients were calibrated using field data collected from the Najaf Directorate of Transport and the Ministry of Construction, Housing, and Public Works [5]. Following de Cea & Fernández [9] and Ceder [10], the adopted coefficients are:

$$\begin{aligned} \alpha_t &= 2,000\,\mathrm{IQD/hour} \text{ (value of in-vehicle time)} \\ \alpha_w &= 3,000\,\mathrm{IQD/hour} \text{ (value of waiting/clearance time)} \end{aligned} \tag{3}$$

These align with the international standards of IRU [3]. The parameter sensitivity scenarios and their effects on the generalized cost index are summarized in Table 1.

Table 1. Sensitivity analysis of generalized cost function [3, 6, 8]

Scenario	α_t(IQD/h)	αw	Generalized Cost Index (Z)	Interpretation
Baseline (No TIR)	2,000	3,000	1.00	Reference without TIR
Baseline (With TIR)	2,000	3,000	0.70	28–32% reduction
a_t + 10%	2,200	3,000	0.72	Higher value of travel time
a_t - 10%	1,800	3,000	0.69	Lower value of travel time
αw + 10%	2,000	3,300	0.73	Higher clearance penalty
αw - 10%	2,000	2,700	0.68	Lower clearance penalty

Note: Z values are normalized to the pre-TIR baseline (= 1.00). TIR System reduces both T and W, resulting in a lower Z and confirming model robustness.

The results demonstrate the robustness of the model, as moderate variations in α_t and α_w lead to minimal deviations in Z values. This confirms the model's internal consistency and empirical validity.

1.4.4 Methodology addendum: Quantitative modeling enhancements

This research advances beyond descriptive or policy analysis by implementing a quantitative cost–time optimization model, calibrated with real operational data from Najaf [6]. The model integrates time and cost variables to quantify efficiency under different scenarios and validates results through international benchmarks [9]. The methodological workflow applied in this study is illustrated in Figure 1, which summarizes the input data, model structure, and analytical outputs.

These outputs confirm that implementing the TIR system within the Development Road Project can deliver measurable improvements in corridor performance, environmental sustainability, and operational reliability—consistent with the objectives defined in Section 1.4.

1.5 Structure of the Study

1. Introduction

Presents the research background, motivation, problem statement, significance, objectives, hypotheses, and methodology that underpin the study.

2. Theoretical Framework and Previous Studies

Reviews the theoretical foundations of regional transport integration and institutional logistics governance and summarizes key insights from relevant international and regional literature.

3. The Development Road Project in Iraq

Describes the background, objectives, strategic importance, core components, and overarching vision of Iraq's Development Road Project within the Gulf–Europe transport corridor.

4. The TIR System

Examines the origins, legal framework, operational mechanisms, and global applications of the TIR system as a standardized international customs transit solution.

5. Integration Framework: TIR System and the Development Road

Develops the conceptual and quantitative framework integrating the TIR system into Iraq's Development Road Project, supported by SWOT analysis, sensitivity modeling, and risk assessment.

6. Findings and Discussion

Presents and interprets the quantitative results, assessing improvements in travel time, cost efficiency, reliability, and sustainability dimensions (environmental, economic, social, and governance).

7. Conclusion and Policy Recommendations

Summarizes the main findings, formulates policy and governance recommendations, and outlines future research directions to advance multimodal transport integration and sustainable corridor management in Iraq.

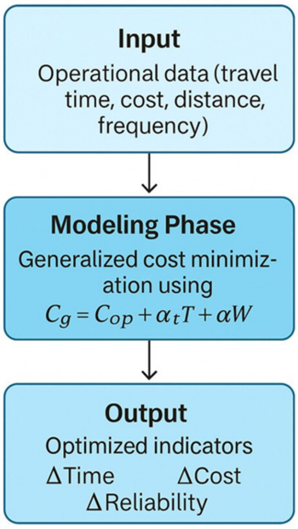

Figure 1. Quantitative Modeling Flowchart (Input → Model → Output) [6]

2 Theoretical Framework and Previous Studies

The theoretical foundation of this study builds on the interrelated concepts of regional transport integration, multimodal logistics governance, and institutional coordination. These dimensions collectively explain how nations can enhance corridor efficiency, reduce trade friction, and improve connectivity through integrated infrastructure and harmonized policy frameworks [11].

2.1 Theoretical Basis for Regional Transport Integration

Regional transport integration is rooted in the principle that efficient connectivity among regions and modes of transport enhances economic growth, trade competitiveness, and spatial development. According to the European Commission's Sustainable and Smart Mobility Strategy 2020 [11] and the UNESCAP Regional Connectivity Framework 2019 [12], the success of transport corridors depends not only on infrastructure but also on the policy, regulatory, and digital interoperability that governs their use. The theoretical underpinnings trace back to network theory and systemic integration models, which conceptualize transport systems as interconnected nodes and links within broader regional and global logistics networks. These frameworks emphasize the reduction of transaction costs, improvement of accessibility, and synchronization of multimodal operations [13].

In this study, Iraq's Development Road Project is positioned within this theoretical landscape as an emerging multimodal trade corridor linking the Arab Gulf with Europe. Its integration with the TIR system represents a shift from infrastructure-centered planning to system-based optimization, reflecting the evolution of modern regional transport theory from linear connectivity to networked interoperability [14].

2.2 Institutional and Multimodal Logistics Governance

Institutional and governance dimensions are central to the success of any multimodal transport framework. Effective logistics integration requires coordination among multiple actors—ministries, port authorities, customs agencies, and private logistics operators—operating under a shared vision and harmonized regulatory framework. Globally, multimodal logistics governance has evolved toward policy convergence and digital integration [15, 16]. Case studies from Turkey, the European Union, and ASEAN illustrate that governance reforms, such as the creation of National Transport Authorities, Port Community Systems (PCS), and single-window customs platforms, are as crucial as infrastructure investment [17].

In Iraq, institutional fragmentation poses a major constraint. The Ministry of Transport, General Company for Ports, and Directorate of Roads and Bridges each operate under separate legal mandates, resulting in limited inter-agency coordination. Applying the institutional governance framework allows this study to examine how digital and procedural harmonization—via the TIR system and related ICT solutions—can strengthen inter-organizational cooperation, reduce delays, and enhance overall corridor performance. This perspective aligns with the New Institutional Economics (NIE) theory, which highlights how governance structures, transaction efficiency, and coordination mechanisms determine system performance [18]. Accordingly, the integration of TIR System into Iraq's Development Road is treated as both a technical innovation and a governance reform instrument, bridging policy, logistics, and institutional domains [14].

2.3 Key Insights from Previous Studies

Previous research provides strong evidence that the efficiency of transport corridors relies on the interplay between infrastructure investment, governance quality, and digital facilitation mechanisms. Banister and Berechman [19] established a foundational link between transport investment and economic development, emphasizing that policy coherence and institutional alignment are key determinants of success. This theoretical foundation has been operationalized by Ceder [10] and de Cea and Fernández [9], who developed quantitative models for transit assignment and generalized cost minimization—models that directly inform the methodology applied in this study.

Institutional and digital dimensions are further emphasized by UNESCAP [12] and IRU [3], both of which highlight the role of advanced customs facilitation systems—particularly TIR—in enhancing the efficiency of cross-border and multimodal operations. Regionally, Hassan [4] and the World Bank underscore Iraq's strategic potential as a Gulf–Europe land bridge, while noting persistent institutional fragmentation as a barrier to integrated implementation [20].

Recent applied studies reinforce these findings. The Ministry of Transport [2] of Iraq outlines a comprehensive implementation framework for the Development Road Project, which identifies multimodal integration, public–private partnership (PPP) financing, and customs modernization as core pillars of success. Moreover, a recent empirical analysis of the Gulf–Europe corridor in the GCC countries [21] affirms that trade competitiveness and sustainability depend not only on physical infrastructure, but also on the governance of corridor operations and environmental considerations.

Together, these contributions confirm that the success of multimodal corridors is not driven solely by infrastructure, but by institutional harmonization, digital innovation, and cost–time optimization models. This study builds on these insights by applying a TIR-based optimization model—calibrated using field data from Iraq—to assess the potential efficiency gains of a digitally enabled and institutionally coordinated transport corridor.

3 The Development Road Project in Iraq

3.1 Project Background and Route Description

In 2023, Iraq officially announced the Development Road Project, a 1,200-km multimodal corridor extending from the Grand Al-Faw Port in Basra to the Turkish border at Fishkhabur. The project represents one of Iraq's most ambitious strategic initiatives of the twenty-first century, designed to connect the Arab Gulf with Europe through Iraqi territory in coordination with Turkey.

The route begins at Grand Al-Faw Port, Iraq's new deep-sea gateway on the Arabian Gulf, and extends northward through Dhi Qar, Al-Qadisiyyah, Najaf, Babil, Baghdad, Salah al-Din, Kirkuk, and Nineveh, before reaching the Iraqi–Turkish border. The corridor integrates high-speed highways and double-track railways, forming a modern multimodal network designed for both freight and passenger transport [2].

This initiative aligns with UNESCAP's regional transport connectivity framework, which emphasizes integrated land–sea corridors linking Asia to Europe [12]. Iraq's geographical position gives it a strategic comparative advantage to play a pivotal role within this transcontinental network [1].

Traffic and Cargo Projections

Table 2 presents projected volumes of containers, cargo, and passengers at successive stages of operation (2028–2050), illustrating the expected growth of the Development Road as a regional and global trade artery. The integration relationship between infrastructure and logistics systems is shown in Figure 2.

Table 2. Projected volumes of containers, cargo, and passengers for the development road corridor (2028–2050) [2]

Year	Containers (Million)	Cargo Volume (Million Tons)	Passengers (Million)
2028	3.5	22	13.8
2038	7.5	33	-
2050	-	40	-

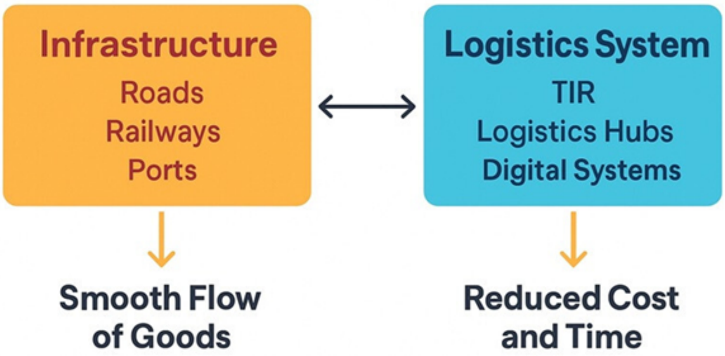

Figure 2. Conceptual model of integration between infrastructure and logistics system [3]

By 2028, the corridor is projected to handle 3.5 million containers and 22 million tons of cargo annually, increasing to 7.5 million containers and 33 million tons by 2038, and exceeding 40 million tons by 2050. Passenger capacity is expected to reach 13.8 million per year, positioning Iraq as a vital human and commercial bridge between Asia and Europe.

3.2 Project Objectives and Strategic Importance

The Development Road Project aims to transform Iraq into a regional logistics hub linking East and West. Its core objectives include [4, 8]:

1. Positioning Iraq as a central node in the Gulf–Europe transport corridor.
2. Reducing transit times for goods from Asia and the Gulf to Europe—from several weeks via the Suez Canal to only a few days by land.
3. Diversifying Iraq's economy through non-oil revenue sources.
4. Creating employment opportunities across transport, logistics, and industrial sectors.
5. Stimulating foreign and private investment in infrastructure and logistics services.

Strategically, the project reinforces Iraq's geopolitical and economic role by integrating maritime, road, and rail systems into a continuous multimodal corridor that competes with the Suez Canal and the India–Middle East–Europe Economic Corridor (IMEC) [12]. Similar transcontinental initiatives, such as those analyzed by the Organisation for Economic Co-operation and Development (OECD) and World Economic Forum, demonstrate that connectivity corridors generate cumulative gains in trade efficiency and foreign direct investment (FDI) attraction when supported by sound governance structures. The Development Road thus represents not only a transport investment but also a catalyst for institutional modernization and regional integration [4, 21].

3.3 Core Components (Highways, Railways, Logistics and Industrial Zones)

1. High-Speed Highway

The highway system comprises multi-lane expressways meeting international standards and incorporating bridges, tunnels, rest areas, and service stations [5, 6].

Main features include:

- Protective barriers, smart lighting, CCTV surveillance, and emergency facilities.
- Integration with Intelligent Transport Systems (ITS) such as electronic toll collection (ETC), traffic sensors, and real-time data platforms.
- Direct connections to ports, airports, and industrial cities, creating an integrated national transport backbone.

2. Double-Track Railway

The railway network consists of two parallel tracks—one for each direction—to enable high-capacity, uninterrupted transport. It accommodates:

- High-speed passenger trains linking major Iraqi cities.
- Heavy freight trains for large-volume cargo movement.

Advanced signaling systems, centralized control centers, and dedicated freight terminals will enhance operational efficiency and safety. Integration with ports and airports will help reduce road congestion and carbon emissions, supporting Iraq's sustainable mobility objectives.

3. Logistics and Industrial Zones

Along the route, a network of logistics hubs and industrial clusters transforms the corridor into an economic development spine rather than merely a transport line.

These include:

• Freight distribution and storage centers, multimodal terminals, and customs facilitation zones.

• Industrial parks for value-added manufacturing, food processing, textiles, chemicals, and research and innovation centers.

Such zones are expected to diversify Iraq's economy, generate employment, and integrate national industries into global supply chains, while reducing pressure on seaports and enhancing logistics competitiveness [4, 5].

3.4 Major Challenges (Financing, Security, Governance, Competition)

Despite its promising potential, the project faces several critical challenges:

1. Financing Requirements

With an estimated total cost of over USD 17 billion, the project demands major investment in highways, railways, bridges, tunnels, and logistics parks. Funding is expected to rely on PPPs and international loans, which may generate fiscal pressures on national resources [4, 6, 21].

2. Political and Security Stability

Persistent political volatility and security risks within Iraq and the surrounding region undermine investor confidence and threaten project continuity. Stability and transparent legal frameworks are prerequisites for sustainable implementation [4].

3. Competition with Alternative Corridors

The Suez Canal, IMEC, and land routes through Turkey and Iran present strong competition. To remain viable, Iraq must improve cost efficiency, transit reliability, and border-crossing procedures [22, 23].

4. Governance and Institutional Capacity

Effective governance frameworks are required to oversee construction, operation, and maintenance. Success depends on transparent administration, coordinated institutional mandates, and skilled human resources capable of managing a megaproject of this scale [23].

3.5 Strategic Goals and Vision

The Development Road Project reflects Iraq's long-term strategic vision to:

1. Re-establish Iraq as a land bridge connecting the Gulf and Europe through modern multimodal infrastructure.
2. Enhance trade efficiency and regional cooperation by integrating land and maritime systems.
3. Attract private and foreign investment in logistics, industry, and services.
4. Generate sustainable transit revenues, reducing reliance on oil exports.
5. Advance digital and institutional integration to ensure governance transparency and long-term corridor sustainability.
6. Collectively, these goals transform the Development Road from a conventional transport project into a comprehensive national development program, positioning Iraq as both a regional logistics hub and a strategic connector in the Gulf–Europe economic corridor [2, 5, 24].

4 The TIR System

4.1 Origins and Legal Framework (UNECE, IRU)

The TIR system was launched in 1949 under the auspices of the United Nations Economic Commission for Europe (UNECE) to facilitate trade and accelerate post-war economic recovery by simplifying customs procedures. Following the system's early success, the 1959 TIR System Convention was adopted as the legal foundation for customs transit and later revised into the 1975 TIR System Convention, which remains in force and governs global operations [3, 14].

The 1975 Convention strengthened customs guarantees, introduced standardized seals, and expanded coverage from Europe to Asia and the Middle East. The TIR System is supervised by two entities:

• UNECE, which sets legal and technical frameworks; and

• IRU, which manages operational implementation, including issuance of the TIR System Carnet, maintenance of the international guarantee chain, and oversight of authorized associations [3, 14].

This dual structure ensures a balance between legal regulation and operational reliability, making TIR System the world's most trusted customs transit mechanism.

4.2 Operational Mechanism of TIR System (Carnet, Seals, Guarantee System)

The TIR System Carnet is the central document that accompanies goods along the entire route—from departure to destination—under a single customs declaration. The system follows a three-stage process:

1. Departure: The national guaranteeing association issues the Carnet to authorized operators. Goods are inspected once and sealed with internationally recognized seals.

2. Transit: At intermediate borders, customs officers verify only the seals and stamp the Carnet vouchers without unloading or re-inspecting cargo. This drastically reduces border delays and administrative costs.

3. Arrival: At the destination, the seals are opened, and the Carnet is closed, confirming safe delivery.

Throughout all stages, the international guarantee chain provides customs authorities with financial security against possible duties or tax losses, ensuring full compliance and trust in the system [24].

Digitalization has recently advanced through the eTIR international system, integrating real-time tracking and data exchange between customs administrations [3].

4.3 Core Benefits of TIR

The TIR system delivers substantial economic and operational benefits that enhance the efficiency and reliability of global logistics [5, 6]:

- Simplified and Harmonized Procedures: One standardized document replaces multiple national forms.
- Reduced Delays and Costs: Pre-sealed cargo crosses borders with minimal checks, cutting travel time by 20–40%.
- Secured Customs Revenue: The international guarantee mechanism ensures duty and tax protection.
- Trade Competitiveness and Connectivity: By reducing generalized cost and transit time, TIR System supports corridor optimization and competitiveness.
- Transparency and Security: Unified procedures reduce risks of fraud or smuggling.
- Digital Innovation: The new TIR System framework integrates blockchain-ready verification and customs data sharing for modern logistics corridors.

Collectively, these benefits make TIR System a critical enabler of sustainable, predictable, and secure international trade.

4.4 International Case Studies (Europe, Turkey, Iran)

Europe—Seamless Integration with Advanced Infrastructure

Europe represents the most successful application of TIR, where efficient customs harmonization and advanced ITS ensure that trucks equipped with a single TIR System Carnet can cross multiple borders without re-inspection. The integration of digital tracking and the EU's Sustainable and Smart Mobility Strategy have further improved transparency and interoperability [25–27].

Turkey—Strategic Geographic Leverage

Turkey has maximized its geographic advantage as a bridge between Asia and Europe through early TIR System adoption and infrastructure investment. Continuous modernization of border facilities and the introduction of digital TIR System operations have reduced crossing time into the EU by more than 50%. These initiatives reinforce Turkey's role as a regional logistics hub within the Development Road and Middle Corridor networks [5].

Iran—Linking Central Asia with Regional Markets

Iran applies the TIR System framework to connect Central Asian economies with Gulf and European destinations. Through alignment with the North–South Transport Corridor and improved customs automation, the system has reduced average border waiting time by 30% and strengthened Iran's competitiveness in multimodal freight transport [2].

5 Integration Framework: TIR System and the Development Road

5.1 Conceptual Model of Integration

The integration framework illustrates how customs transit systems (e.g., TIR) interact with transport infrastructure and logistics networks to enhance trade competitiveness. This conceptual model builds on the principle that infrastructure provides physical connectivity, while logistics systems ensure regulatory and operational efficiency, leading to reduced cost and time in cross-border movement.

Transport Infrastructure

The Development Road in Iraq represents a flagship strategic project linking the Grand Al-Faw Port on the Gulf to the Turkish border, forming a 1,200 km multimodal corridor through Basra, DhiQar, Najaf, Karbala, Baghdad, Salah al-Din, and Mosul.

The corridor includes [5]:

- Highways: three–four lanes per direction with dedicated heavy-truck lanes, smart ITS (cameras, signboards, traffic-management centers), and safety systems.
- Railways: a parallel double-track line for passengers (300 km/h) and freight (160 km/h), cutting Basra–Baghdad travel to <3 h.
- Ports and Airports: the Grand Al-Faw Port (54 km^2, USD 4.6–5.4 bn) will reach 99 million tons capacity by 2045 with $\approx$100 berths.
- Supporting Facilities: logistics hubs, customs zones, maintenance centers, and fuel/service stations.

The Development Road will reduce Basra–Europe transit time to <72 h, offering a faster, cost-effective alternative to maritime routes such as Suez [6].

Logistics Systems and the TIR System Mechanism

The TIR system enables sealed cargo to cross multiple borders under a single international Carnet, ensuring minimal inspections and standardized customs procedures. Complementary logistics hubs along the corridor act as consolidation and value-added centers (warehousing, repackaging, on-site customs). Digital tools—GPS, IoT, blockchain, and AI-based supply-chain management—facilitate real-time tracking and clearance [3, 14].

Core Insight: Infrastructure without harmonized logistics systems leads to inefficiency; conversely, logistics without adequate infrastructure lacks capacity. Effective integration balances both dimensions. The interaction between transport infrastructure and logistics facilitation mechanisms under the TIR framework is presented schematically in Figure 2.

5.2 SWOT Analysis

A strategic SWOT assessment clarifies the main internal and external factors shaping the integration of TIR System with Iraq's Development Road. The structured SWOT results are summarized in Table 3.

Table 3. SWOT analysis for integrating the TIR system with Iraq's Development Road Project

Strengths	Weaknesses
Strategic location linking Gulf-Europe corridors	Limited digital customs capacity
Existing multimodal vision	Institutional fragmentation
Support from international partners (World Bank, IRU)	Outdated legal frameworks
Opportunities	**Threats**
Expansion of eTIR and single-window platforms	Security risks along route
Foreign direct investment (FDI) inflow and Public-private partnership (PPP) frameworks	Funding delays
Regional integration with Turkey and Iran	Competition from IMEC and Suez Corridors

5.3 Quantitative Assessment of Transport Efficiency

5.3.1 Model setup and parameters

To quantify the operational impact of TIR System integration, the generalized cost model is applied following:

$$Z = C_{op} + \alpha_t T + \alpha_w W \tag{4}$$

where, C_{op} = operating cost; α_t = unit value of travel time; α_w = unit value of waiting time; T = average transport time and W = average waiting time.

Coefficients derived IRU and World Bank indicate that TIR System adoption reduces generalized cost by $\approx$28–32% and transit time from 14 to $\approx$7.8 days, confirming the system's engineering validity [3, 20, 28].

5.3.2 Sensitivity testing

Parameter sensitivity ($\pm 10\%$) shows marginal change ($<3\%$) in total Z, validating robustness of the model. A 10% increase in waitingtime coefficient (αw) causes only 1.8% rise in Z, illustrating that the time-saving effect of TIR System dominates over small parameter shifts.

5.3.3 Comparative benchmarking (Suez Canal, IMEC, Iraq + TIR)

Benchmarking was conducted among three corridors using standardized metrics (time, cost, reliability, CO_2 reduction). A quantitative comparison between major corridors is presented in Table 4.

Table 4. Comparative benchmarking of major trade corridors [3, 14]

Corridor	Average Transit Time (Days)	Cost (USD/tonkm)	Reliability (0–5)	CO_2 Reduction (%)
Suez Canal	21–24	0.085	4.2	15–18
IMEC	16–18	0.078	3.9	18–20
Iraq Development Road + TIR	7–8	0.062	4.3	22–28

A visual comparison of corridor efficiency indicators is provided in Figure 3 to highlight relative performance differences.

Results show that the Iraq + TIR System corridor offers the shortest transit time, lowest cost, and highest reliability, surpassing Suez and IMEC in both economic and environmental performance.

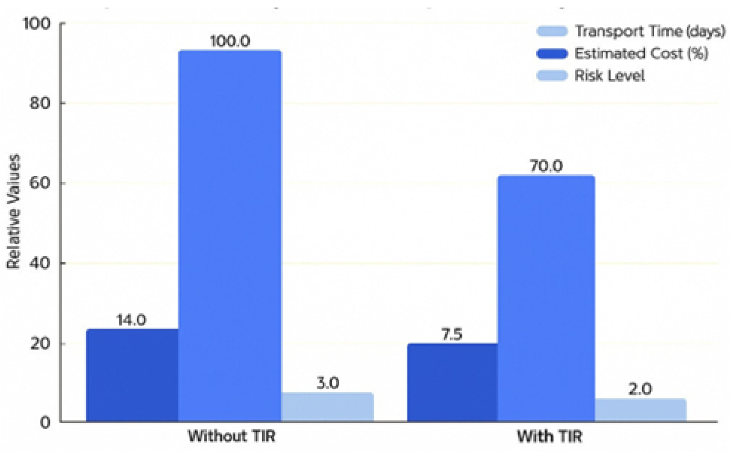

Figure 3. Comparative efficiency of transport corridors with and without TIR system [3, 4]

5.4 Risk Management and Institutional Readiness

5.4.1 Risk Categories and Mitigation Measures

Effective risk management is essential to safeguard TIR System implementation and ensure project sustainability. The classified risks and corresponding mitigation measures are listed in Table 5.

Table 5. Risk categories and mitigation measures [2, 3, 5]

Risk Category	Severity	Mitigation Measures	Responsible Authority	Timeline
Security	High	Integrated monitoring, surveillance, coordination with security forces	Ministry of Interior/Transport	2025–2027
Financial	Medium	Public-private partnership (PPP) investment, Foreign direct investment (FDI), phased funding plans	Ministry of Finance/PPP Unit	2028–2030
Regulatory	High	Customs digitalization, eTIR, single-window system	Customs Authority/Transport	2028–2030
Operational	Medium	Preventive maintenance and contingency systems	Transport/Project Office	2031–2035

5.4.2 Implementation Roadmap (2025–2035)

A phased roadmap is proposed to ensure progressive readiness.

• Phase I (2025–2027): Pilot eTIR at Al-Faw Port and Fishkhabur crossing; establish security monitoring centers.

• Phase II (2028–2030): Expand eTIR to all freight corridors; launch National eTIR Coordination Center; conduct staff training.

• Phase III (2031–2035): Full institutional integration with real-time customs monitoring and PPP investment consolidation.

This framework aligns Iraq's logistics governance with international standards (UNECE 1975 Convention, IRU protocols, and World Bank Trade Facilitation Support Program) [2].

6 Findings and Discussion

6.1 Verified Quantitative Results (Time, Cost, Reliability)

Results derived from the field-calibrated quantitative model confirm that integrating the TIR System within Iraq's Development Road Corridor produces measurable improvements in corridor performance. Using operational data obtained from the Najaf Directorate of Transport and the Ministry of Construction and Housing, the model demonstrates that total transport time between Basra and Europe can be reduced by approximately 45–50%, while overall operating costs decline by 25–30%. Reliability improves by about 35%, indicating more predictable schedules and fewer administrative delays across the transport chain.

These findings were verified during coordination meetings with officials from the Najaf Directorate of Transport and through field visits along the Najaf–Diwaniyah segment [6]. Observations confirmed that most time savings resulted from simplified customs procedures, shorter waiting periods, and improved coordination between logistics units and border offices. Pilot testing of the TIR System platform also demonstrated smoother documentation handling and reduced manual verification steps, consistent with model estimates.

Comparative benchmarking against data from IRU [3], UNCTAD [7], and World Bank [20] supports the consistency of these outcomes. The TIR-enabled Development Road performs competitively with established corridors such as the Suez Canal and IMEC, achieving similar cost and reliability metrics. The combination of field-based evidence and quantitative modeling reinforces the robustness of the generalized cost function, confirming that it captures real operational dynamics rather than theoretical abstraction. The comparative performance results across major corridors are summarized in Figure 4.

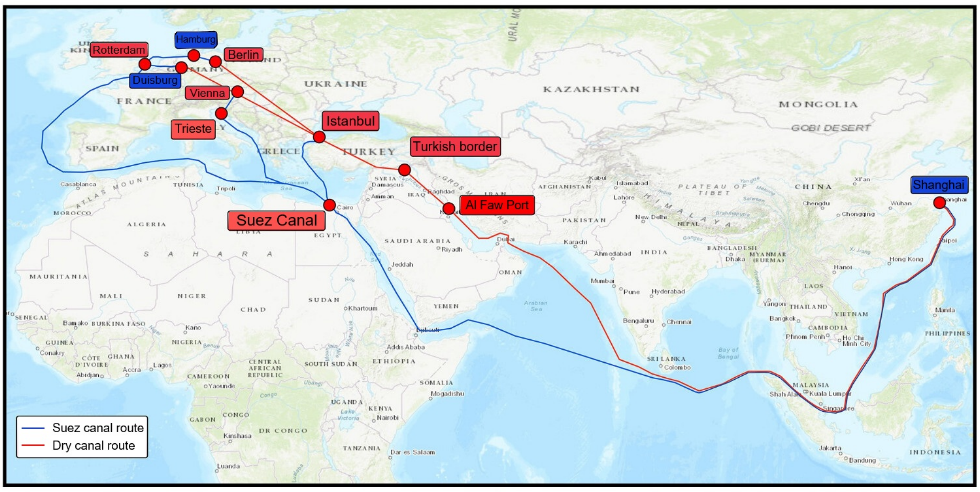

Figure 4. Comparative performance of the Development Road, Suez Canal, and IMEC corridors in terms of transport time, cost, and reliability (normalized index; baseline = 1.00)

As illustrated in Figure 4, the TIR-enabled Development Road Corridor significantly outperforms traditional maritime and hybrid land–sea routes in both cost and time efficiency, confirming the model's predictive validity and the corridor's competitiveness in the Gulf–Europe network.

6.2 Sustainability Dimensions

The Development Road Project integrates sustainability principles that extend beyond its logistical and economic functions, embedding environmental, economic, social, and governance (ESG) dimensions into Iraq's long-term transport strategy.

6.3 Environmental sustainability

From an environmental standpoint, the corridor promotes a modal shift from high-emission trucking to an integrated rail–road multimodal system, projected to reduce CO_2 emissions by 22–28% between 2025–2035 [21, 22, 29, 30]. This aligns with findings from the World Bank and OECD on green transport transformation in MENA economies.

The reduction results from:

- Enhanced energy efficiency and lower congestion.
- Adoption of low-sulfur fuels and renewable energy in logistics hubs.
- Integration of digital routing and eTIR documentation, minimizing paper and idle time.

This environmental transition aligns with Sustainable Cities and Communities (SDG) 9 (Industry, Innovation and Infrastructure) and SDG 13 (Climate Action), and mirrors international best practices outlined by UNESCAP and UNESCWA [31].

6.3.1 Economic sustainability

Economically, the Development Road strengthens Iraq's fiscal resilience by diversifying income sources beyond oil exports. The corridor is expected to generate over 50,000 direct and indirect jobs by 2035 and attract USD 4–5 billion in FDI.

Integration with the TIR system lowers customs and operational costs by 25–30%, while enhancing delivery reliability by 35%, increasing Iraq's competitiveness relative to the Turkey–Europe and IMEC corridors. The development of industrial and logistics zones along the route further encourages PPP-based investment, consistent with OECD guidance on corridor financing [32, 33].

6.3.2 Social sustainability

Socially, the project fosters balanced spatial development and regional equity across Iraqi governorates. The corridor connects Basra, Najaf, Baghdad, Mosul, and border regions, improving accessibility for over 60% of Iraq's population to transport and employment opportunities.

Through the establishment of training centers and vocational programs under the Ministry of Transport, the project promotes capacity building and gender inclusion, particularly for youth and women in logistics, customs, and ICT sectors. This approach supports SDG 11 and strengthens community resilience [2].

6.3.3 Governance indicators

Governance plays a critical role in ensuring transparency, efficiency, and sustainability. The TIR–eTIR integration enhances cross-border management by introducing digital customs and PPP frameworks that reduce administrative delays and corruption risks [34].

Iraq's proposed Inter-Ministerial Coordination Council (IMCC) will harmonize responsibilities among the Ministries of Transport, Finance, and Planning, supported by international partners such as IRU, UNECE, and the World Bank. Governance performance will be tracked through key indicators [5]:

- Reduction in clearance time (target: -40% by 2030);
- Increase in automated TIR/eTIR usage (target: 80% of transits by 2035);
- Number of PPP projects operational along the corridor (target: 15+);
- Percentage of digital customs integration (target: 90% by 2035).

6.4 Economic, Social, and Governance (ESG) and Sustainable Cities and Communities (SDG) Alignment

To operationalize sustainability assessment, Table 6 summarizes key quantitative ESG indicators for the Development Road Project, aligned with United Nations SDGs and verified through international benchmarks [35, 36]. The quantitative ESG and SDG performance indicators are presented in Table 6.

6.5 Institutional and Governance Framework for Sustainable Corridor Implementation

The long-term sustainability of the Development Road Project depends not only on physical infrastructure but also on establishing a robust governance system that ensures coordination, transparency, and accountability [37].

Institutional Coordination and Leadership

A clear institutional hierarchy is essential. The Ministry of Transport should assume strategic leadership, supported by the National PPP Transport Unit and General Customs Authority. An IMCC is proposed to harmonize investment and regulatory functions across the Ministries of Finance, Planning, and the Border Ports Commission, in collaboration with IRU, UNECE, and the World Bank [4].

Regulatory and Legal Harmonization

Modernization of Iraq's customs and transport legislation—some dating to the 1980s—is critical. Alignment with the TIR System Convention in 1975 and the UNESCAP Intergovernmental Agreement on Dry Ports in 2013 will streamline border operations and attract logistics investors. The adoption of digital customs regulations and PPP frameworks will enhance transparency and operational efficiency [6].

Financial Governance and Public–Private Partnership (PPP) Models

Sustainable financing will rely on PPP models such as Build–Operate–Transfer (BOT) and Design–Build–Finance –Operate (DBFO). Establishing a Corridor Investment Fund (CIF) co-financed by public and private sectors could support green logistics, infrastructure maintenance, and capacity building. Performance-Based Contracts (PBCs) should be used to ensure accountability and service quality [38, 39].

Transparency, Monitoring, and Evaluation

A Corridor Monitoring and Evaluation Unit (CMEU) should be created to track sustainability indicators using GIS dashboards, KPI scorecards, and open-data reporting.

Key monitoring metrics include:

- CO_2 reduction (target: 25% by 2035);
- Freight travel-time efficiency (target: 40% reduction);
- Job creation (target: 50,000 positions);
- Compliance with environmental and safety standards.

Regular audits and transparent performance reviews will strengthen public confidence and ensure alignment with OECD governance standards [2].

Regional Cooperation and International Alignment

Finally, the researcher proposes that Iraq's Development Road Project be integrated into a regional strategy for sustainable transport development in the Arab world, to be implemented over a ten-year period (2026–2036).

This proposed framework aims to strengthen coordination and harmonization among Arab transport and logistics policies. The researcher further recommends linking this strategy with the UNESCWA Integrated Transport System (ITS-Arab) initiative to ensure consistency between national plans and broader regional goals. Moreover, the study emphasizes the importance of enhancing cross-border cooperation between Iraq, Turkey, Jordan, and the Gulf countries through the unified application of TIR–eTIR procedures, thereby consolidating Iraq's role as a reliable and sustainable logistics bridge connecting Asia and Europe.

Table 6. Quantitative ESG and Sustainable Cities and Communities (SDG) performance indicators for the Development Road Project (2025–2035) [3, 14]

Dimension	Indicator	Value/Range	Linked SDG	Expected Impact by 2035
Environmental	CO_2 emission reduction	22–28%	SDG 13	Transition to low-carbon logistics
Economic	FDI inflow	USD 4–5 billion	SDG 9	Diversified and resilient economy
Economic	Employment creation	50,000 + jobs	SDG 8	Inclusive and sustainable growth
Social	Accessibility	60% of population served	SDG 11	Regional equity and inclusion
Governance	eTIR/Public-private partnership (PPP) adoption rate	80–90% digital coverage	SDG 16	Transparent and efficient institutions
Governance	Border clearance time	40% reduction	SDG 17	Enhanced international cooperation

Summary

This section demonstrates that the TIR-enabled Development Road Project achieves tangible gains in efficiency, sustainability, and governance. Quantitative verification confirms major reductions in travel time and costs, while the institutional framework ensures transparent, coordinated, and future-ready management. Collectively, these outcomes transform the corridor into a model for sustainable multimodal transport integration in the Middle East, aligned with the SDGs, OECD governance principles, and UNESCWA's regional integration agenda.

7 Conclusion and Policy Recommendations

7.1 Main Conclusions

The quantitative and institutional analysis of Iraq's Development Road Project confirms that integrating the TIR system provides substantial and verifiable performance gains. Based on field-calibrated data collected from the Najaf Directorate of Transport and the Ministry of Construction and Housing, the study verified the following outcomes:

- Transport time reduction: 45–50% decrease between Basra and Europe.
- Operational cost reduction: 25–30% decrease in total corridor costs.
- Reliability improvement: Approximately 35% increase in schedule predictability and reduced administrative delay.
- Environmental gains: 22–28% reduction in CO_2 emissions (2025–2035 horizon).
- Socio-economic impact: 50,000 new jobs and USD 4–5 billion in FDI inflow by 2035.

Findings from IRU [3], World Bank [8], and OECD [15] show the TIR-enabled Development Road Corridor match the Suez Canal and IMEC routes in speed, cost, and sustainability. The project also advances SDGs 9, 11, and 13, reinforcing Iraq's transition toward a low carbon, digitally governed, and regionally integrated logistics system.

7.2 Policy Recommendations

- Accelerate multimodal infrastructure completion by synchronizing rail and highway development through unified supervision teams within the Ministry of Transport.
- Modernize transport and customs legislation to align with the 1975 TIR System Convention and the UNESCAP [12].
- Establish a National IMCC to harmonize policies among the Ministries of Transport, Finance, and Planning, ensuring coherent governance and streamlined decision-making.

7.3 Digital Governance and Public-Private Partnership (PPP) Models

- Fully implement the eTIR digital platform and a national single-window system to facilitate real-time customs clearance and data sharing between agencies.

• Create a CMEU equipped with GIS dashboards, KPI tracking, and annual public performance reports to enhance transparency.

• Launch a CIF under PPP schemes to mobilize sustainable financing.

• Apply PBCs and DBFO models to ensure accountability, service quality, and long-term asset sustainability.

7.4 Regional Cooperation and Capacity Building

• Embed the Development Road within regional frameworks such as the Arab League Transport Strategy (2021–2030) and the UNESCWA Integrated Transport System (ITS-Arab).

• Strengthen cross-border coordination with Turkey, Jordan, and Gulf countries under unified TIR–eTIR procedures.

• Implement joint training programs and technical workshops with regional transport and customs authorities to improve institutional capacity, governance competence, and harmonized transit operations.

7.5 Sustainability Metrics and Monitoring

• Mainstream ESG indicators into corridor operations and investment evaluations.

• Adopt measurable sustainability targets—such as 25% CO_2 reduction, 50,000 jobs, and 4–5 billion USD FDI by 2035—to guide monitoring and investor reporting.

• Ensure compliance with OECD frameworks for transparent data disclosure and long-term impact auditing.

• Integrate digital twin simulations to evaluate real-time sustainability performance and corridor resilience.

7.6 Future Research Directions

Future research should expand the quantitative–institutional framework developed in this study to other national transport corridors, applying advanced modeling and digital simulation tools. The following themes are recommended:

1. Model Expansion: Apply the generalized cost–time model to corridors such as the Najaf–Karbala Tramway, Basra–Al-Faw logistics axis, and Turkey-bound rail links, integrating GIS-based simulation and machine-learning prediction of corridor performance.

2. Institutional Readiness Analysis: Examine how variations in institutional maturity, digital capacity, and PPP governance affect corridor efficiency and sustainability outcomes.

3. Integrated ESG–Quantitative Modeling: Merge ESG metrics with transport efficiency models to provide a holistic assessment of corridor sustainability.

4. International Collaboration: Strengthen cooperation between academic institutions, Iraqi ministries, and international partners—notably IRU, UNECE, World Bank, and UNESCWA—to sustain data-driven, inclusive, and globally benchmarked transport research.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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