ENGINEER

international scientific journal

ISSUE 3, 2026 Vol. 4
E-ISSN
3030-3893
ISSN
3060-5172



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ENGINEER

A bridge between science and innovation

E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 4, ISSUE 3

SEPTEMBER, 2026

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 4, ISSUE 3 SEPTEMBER, 2026

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The "Engineer" publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Tashkent State Transport University had the opportunity to publish the international scientific journal "Engineer" based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

Journal Engineer ISSN: 3030-3893 Volume:4| Issue:3| 2026

Received: 6 July 2026 | **Accepted:** 17 August 2026 | **Published:** 30 September 2026

Network diagnosis and governance-coupled optimization in seaport–dry port multimodal transport corridors under the Maritime Silk Road

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Abstract: Research into seaport–dry port corridors has tended to focus on the design of the physical network on the one hand and the coordination of governance on the other. It is hard to maintain this separation in well-established Maritime Silk Road corridors. A corridor might have routes, inland nodes and digital platforms, and still not function smoothly at the rail/dry-port interface. This article therefore tackles corridor optimization as a problem of diagnosis and governance. It looks at the case of Ningbo-Zhoushan Port in a gateway province on China's eastern coast, and examines its relevance for Central Asian and landlocked economies relying on seaports, inland hubs, railways, customs facilities and digital platforms. The empirical basis comprises aggregated port planning and port transport-operation data from both the annual and quarterly perspectives as well as publicly available policy and industry material for contextual interpretation. The overarching question is pragmatic, and that is: If the side of the seaport is relatively on schedule, but the coordination on the inland rail side is not, where should optimization be targeted? The analysis links node-structure diagnosis, quarterly interface diagnosis and governance interpretation. To make the imbalance observable, the paper uses a Corridor Coupling Imbalance Gap (CIG), calculated as the difference between the mean completion rate of maritime-side indicators and the rail-freight completion rate at each quarter end. The evidence shows a stable three-part planned node structure for 2025–2026, but the 2025 rolling data also show that rail freight lagged maritime-side indicators for three consecutive quarters, with CIG reaching +10.20 percentage points in Q3. The main issue is thus not general seaport capacity. It lies in the translation from gateway capacity to inland consolidation, digital orchestration, and timely cross-actor intervention. The article proposes a governance-coupled optimization agenda organized around differentiated gateway roles, dry-port-centered consolidation, event-level digital coordination, and rolling warnings. Its contribution is to turn corridor optimization from a question of route expansion into a more precise diagnostic method for seaport–dry port governance.

Keywords: Maritime Silk Road, Seaport–Dry Port Transport Corridor, Multimodal Transport, Network Diagnosis, Governance-Coupled Optimization, Corridor Coupling Imbalance Gap, China–Central Asia Connectivity, Ningbo-Zhoushan Port

1. Introduction

Under the Maritime Silk Road, the competitiveness of a seaport is no longer determined only at the quay. Vessel calls and berth capacity still matter, but they do not by themselves explain whether port functions can be carried inland in a stable and governable way. The more difficult question is whether inland nodes, rail services, customs procedures, and digital coordination are managed as parts of the same transport system. The importance of this is particularly notable for landlocked and double-landlocked economies which rely on the performance of foreign seaports and the reliability of the corridors behind them for access to maritime trade. This trend is seen in the development of dry ports, sea–rail connections, customs extensions, and digital booking platforms. The basic point of the dry-port and port-regionalization literature is already made, that the port becomes a corridor system and has multiple frontiers, operational ones, rather than only one, the waterfront [1–3].

The challenge is that it is easier to plan for expansion where this is visible in the corridors than operational coordination. Routes can be counted and dry-port nodes can be announced, platforms can be connected and new services can be reported. These are significant accomplishments, but are not necessarily indicative of the alignment of cargo consolidation, train formation, customs clearance, yard readiness, and slot allocation in day-to-day operations. A corridor might therefore be operationally uneven, but still be very large in space. This is the key to Maritime Silk Road corridors, as the transport performance relies on interorganisational interaction between seaports, inland logistics nodes, customs regimes, railways, platform providers and cargo owners [4, 5].

The Zhejiang-Ningbo-Zhoushan case is a practical example to analyse this tension. Zhejiang is a coastal gateway province in eastern China, connecting maritime shipping, port-based industrial bases, inland dry ports, rail transportation and digital logistics platforms. The importance of the case to the international transport community is not to demonstrate the case as an example to emulate. Instead, it indicates the possibility of coordination pressure at inland rail/dry-port interfaces in even a fairly developed coastal gateway system. The available public Zhejiang transport policy, planning and industry materials for contextual interpretation indicate that by September 2024, the Ningbo-Zhoushan Port had developed 107 sea–rail routes, of which 26 were scheduled trains, and 37 inland dry-port nodes,

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https://doi.org/10.56143/3030-3893-2026-3-78-86

covering 16 provincial-level areas and 67 prefecture-level cities. The Four-Port digital platform had connected more than 100 systems and aggregated more than 11,000 logistics data items, the Sixth Port Area platform had integrated the port–customs–shipping processes and the port had reported benefits from the increased efficiency of sea–rail operations. These are large numbers that reflect significant corridor development. Meanwhile, the same contextual materials indicate pressure on the rail side in the Jinhua–Yiwu support area, high station utilization, and a relatively small but relevant cost disadvantage in some subsidized rail services compared with direct road transport [6].

This juxtaposition provides the introduction for the article. It is not a question of whether or not a mature corridor requires optimization – in some general sense. When the maritime side is broadly stable, and the inland rail interface is not, a more important question is where should attention be directed for intervention? This is also a question which is not only relevant for the Zhejiang case. Inland terminals and dry ports need more than facilities to establish a reliable international logistics network for the transport systems of the Maritime Silk Road, including the China–Central Asia transport system. Previous studies provide some components that can be built upon. Some research focuses on terminal networks, location decision, break even distance and design of dry ports [7–10]. A second one relates to collaborative governance, institutional alignment and digital coordination [4, 5, 11]. Less developed is an approach that allows managers to find a place in the interface where the spatially mature corridor is not syncing.

The article thus develops a diagnostic, governance-coupled view of a port-centred seaport–dry port system. Zhejiang-Ningbo-Zhoushan is not necessarily representative of other Chinese corridors, or other Maritime Silk Road corridors. This synthesis incorporates evidence on node structure from annual plans, execution data from quarterly rolling indicators, and contextual policy evidence regarding the reach of nodes inland, capacity pressure, digital platforms, and monitoring architecture. The idea isn't to make a full math model of transport network. It is to offer a management oriented approach to identify the choke point, explain the role of different nodes and how network redesign and governance intervention should be connected.

2. Literature Review

The initial part of the argument is based on studies of dry-port and inland-port. Such studies demonstrate the inland terminals can move some seaport functions away from the maritime area, alleviate the pressure around the seaport and provide access to the hinterland [2, 12–14]. But the expansion isn't something that you can achieve with just positioning a terminal on a map. A dry port depends on rail infrastructure, terminal facilities, institutional structures and the development of transport routes [15, 3, 16]. A key take-away from inland-port research is that inland ports have the potential to reshape regional logistics, but if the governance and service integration are weak, inland ports can end up as passive extensions of seaports [17].

Another set of research is related to intermodal transport network design and terminal optimisation. This literature is helpful because it discusses the impact on competitiveness of intermodal freight transport [18, 7, 8, 19] as the result of terminal location, capacity, modal balance, and break-even distance. More recent studies also speak about how seaport–dry port networks can be designed to be robust, sustainable and resilient in the face of uncertainty [9, 10]. But this research frequently assumes that once the network structure is designed, coordination will follow. This is not always true in reality during the operation of a corridor. As much as the physical network can be well-designed, performance can still be poor if the gateway, rail station, customs process and the digital platform are not managed as a single operating chain.

The collaborative governance research provides insight into the sources of this problem. In order to be effective, inter-organisational action must involve meaningful participation, shared motivations and collective capacities [4, 5]. Multimodal transport corridors are a good fit for this problem area, as there are many actors: the port authorities, the rail operators, customs authorities, logistics operators, inland terminals, platform operators, and cargo owners. While such actors are not involved in a single hierarchy, they do need to act in a coordinated manner in the same direction of the flow of cargo. Thus, the issue of governance is a practical one. It has to do with who is responsible for which role and when information is provided and when it is needed in order to avoid a small delay at one interface turning into a larger blockage [20, 21].

Digitalisation adds another layer to this situation. Heilig and Voß [11] state that the transaction costs can be lowered, as well as gaining service visibility, by means of port information systems, platform-based coordination and digitally-integrated gate operations. But, connectivity of data does not imply connectivity of operations. While yard operations, train assembly, customs sequencing, and slot allocation remain only partly aligned, digital platforms may only accelerate the exchange of documents instead of boosting the performance of the corridor. Digital tools must thus be integrated into a governance mechanism, which translates data into action [22, 23].

This results in a very practical gap in the literature. While a lot has been written about dry ports, intermodal networks, and collaborative governance – it is not clear how network redesign and governance redesign should link up. This article endeavors to fill this void by recognizing the corridor as a multi layer functioning system. It holds that corridor diagnosis should be initiated with the distinction between the structure, the tests of operational interfaces and finally the linkage of governance responses to the imbalances found.

3. Research methodology

The material for this study is of an empirical type in two senses. The first group are the publicly available materials of transport policies, transport planning and transport industry in Zhejiang Province, China, including the transport policy of Zhejiang Province on multimodal freight development, the transport plan on integrated freight-hub construction, the application of intelligent multimodal transport and the monitoring of logistics-hubs. These materials are used to set the policy tone, institutional context, digital foundation, and inland-hub context of a coastal gateway province. They are not considered as a quantitative stand-alone dataset. The second category of information is the annual and quarterly port planning and transport-operation information, particularly the execution indicators of port operations for 2025 as a rolling information, and the annual company plans for 2025–2026 for Ningbo-Zhoushan Port. The numbers for 2026 are considered to be planned numbers, not actual numbers. The values relating to the company are only reported in an aggregated manner. The analysis does not reveal any operational data at the firm level,

https://doi.org/10.56143/3030-3893-2026-3-78-86

origin-destination matrices at the shipper level, terminal level slot records, or micro level cost traces.

The analysis is carried out in the context of four interrelated operations. The first is to decompose the company cargo plan into three parts, which are the cargo plan of the Ningbo base, the cargo plan of the Zhoushan base and the cargo plan of the external terminals, and compare the cargo plan proportions in 2025 and 2026 and then analyze the cargo specialization of each node group. The second is a so-called rolling interface diagnosis. It is based on five performance indicators for 2025: total throughput of cargo, container throughput, rail freight, tally volume and pilotage voyages. Progress is measured against a quarterly linear mark of 25%, 50%, 75% and 100% of the annual plan. The third operation determines the Corridor Coupling Imbalance Gap (CIG) and thus renders the operational aspect of coupling transparent. The fourth explains the pattern observed in terms of route reach, inland-node capacity, digital integration, cost conditions and the architecture for monitoring.

The design has been purposefully kept simple. It does not try to build a complete O-D transport network or to solve a large-scale model for optimization with shipper level microdata. That decision is not merely data-driven; it is methodological. The problem addressed by the article is not with the building of the formal optimization model itself, but before it is ever created: If one interface is underperforming and the rest of the corridor is on track, what optimization is needed? There are several layers to the answer to that question, it's not just a chart of flows, there is structure, execution and governance. This reasoning applies elsewhere, outside Zhejiang. For instance, a reader with an interest in dry-port development in Central Asia may wonder if a corridor weakness is a lack of gateway capacity, a lack of consolidation in the interior, or a lack of reliability of rail services, customs delays, or a lack of digital to physical orchestration. All values plotted in the figures were checked against the annual node-plan percentages and the 2025 rolling completion table. Schedule gaps were calculated as cumulative completion percentage minus the 25%, 50%, 75%, and 100% quarter-end linear benchmarks.

For the CIG indicator, Mq denotes the mean completion rate of the maritime-side indicators in quarter q: cargo throughput, container throughput, tally volume, and pilotage voyages. Rq denotes the rail-freight completion rate in the same quarter. The indicator is calculated as CIGq = Mq - Rq. A positive value means that maritime-side execution is ahead of rail-interface execution, indicating an imbalance between gateway-side robustness and rail–dry-port coordination. The indicator is not presented as a full coupling-coordination model or as a causal coefficient. It is used as a diagnostic proxy, intended to make an otherwise abstract coupling problem visible, comparable, and reproducible. Table 1 summarizes the evidence blocks that support the diagnosis.

Table 1

Data architecture, provenance, and analytical use

Evidence block	Main variables / values used	Source status and reproducibility note	Use in the paper
Public policy, planning, and industry materials from Zhejiang Province, China	Contextual values on corridor reach and digital foundations: 107 sea–rail routes; 26 scheduled trains; 37 inland dry-port nodes; 16 provincial-level areas; 67 prefecture-level cities; more than 100 linked digital systems; more than 11,000 logistics data items	Publicly available contextual materials; used to describe the coastal gateway-province setting and policy/digital environment, not as a direct quantitative dataset.	Contextualizes corridor scale, spatial maturity, institutional-digital setting, and why the case has relevance beyond Zhejiang.
Annual company plans (2025–2026)	Node-group planned shares; cargo specialization by Ningbo base, Zhoushan base, and external terminals	Aggregated company planning data; 2026 values are planned, not realized.	Supports node-structure diagnosis and gateway differentiation
Quarterly rolling plan data (2025)	Cargo throughput; container throughput; rail freight; tally volume; pilotage voyages	Aggregated quarterly completion data; gaps calculated against a 25/50/75/100 benchmark.	Supports rolling interface diagnosis and CIG calculation
Inland hub and port–rail interface evidence	Jinhua–Yiwu station pressure; approximately 650,000 TEU regional railway container-handling capability; about RMB 20 cost difference per 40-foot container; 17.49 million tonnes of port-station rail volume	Public planning and industry evidence; used as explanatory context, not causal estimates.	Supports the interpretation of likely rail-interface pressure
Monitoring and digital-operation evidence	More than 100 linked systems; more than 11,000 logistics data items; 16 automatically collectable monitoring indicators	Public digital-platform and monitoring materials; used to distinguish data connectivity from event-level operational orchestration.	Supports a transparent case-study design while limiting unsupported generalization beyond the

https://doi.org/10.56143/3030-3893-2026-3-78-86

Evidence block	Main variables / values used	Source status and reproducibility note	Use in the paper
			reported aggregated values.

Source: compiled by the author from publicly available transport policy, planning, and industry materials from Zhejiang Province, China, and aggregated Ningbo-Zhoushan Port planning and transport-operation datasets. Public materials are used as contextual evidence for a coastal gateway-province case; the quantitative indicators are calculated from aggregated planning and operational values reported in the tables and figures. Values are used for diagnostic interpretation, not for firm-level performance disclosure or causal estimation.

4. Results and discussion

Stable node structure and differentiated gateway roles

The two annual company plans refer to a stable overall structure. They split the system into three node groups. For those outside China, these groups can be explained based on their functions: the Ningbo base has the gateway and control role in the port system, the Zhoushan base is more geared towards bulk business, and the external terminals represent affiliated or inland-facing capacity linked to the larger corridor. In the 2025 plan, the shares of cargo throughput for the company's bases are 47.1% for the Ningbo base, 21.4% for the Zhoushan base and 31.5% for external terminals. In the 2026 plan, the corresponding shares were 47.3%, 21.8%, and 30.9%. The key is that there wasn't a significant macro-level rebalancing. This brings focus away from the instability of structure, and to the performance of interfaces within a relatively stable planned structure.

This discovery is important because it has to do with the commodity structure. Ningbo is fairly diversified with metal ores being the biggest identified flow, but the node is not dependent on one single cargo flow. Zhoushan has a more metal-ore and oil orientation to align with its bulk and liquid cargo operations. The external terminal group is more inland and affiliated, and it also has a higher proportion of coal and mineral materials and plays a secondary role for steel products. These differences are not to be viewed as "background information". They suggest that the analysis of corridor optimization should not start from the premise that all of the port or affiliated nodes have the same multimodal function. A corridor may include one strategic label, and have multiple functional subsystems. The same applies to the international dry-port systems, with inland nodes being able to share a corridor identity but not necessarily have the same operational role.

It is important for governance and for transport planning. If the roles of nodes are different, the governance must also be different. The main gateway role of Ningbo won't be automatically transferred to the bulk base or the affiliated inland-facing system. In thinking about nodes, it is easy to forget that there is an operational pressure somewhere. Figure 1 therefore uses the two annual plans to show both the stability of the three-part node-group structure and the limited role drift between 2025 and 2026.

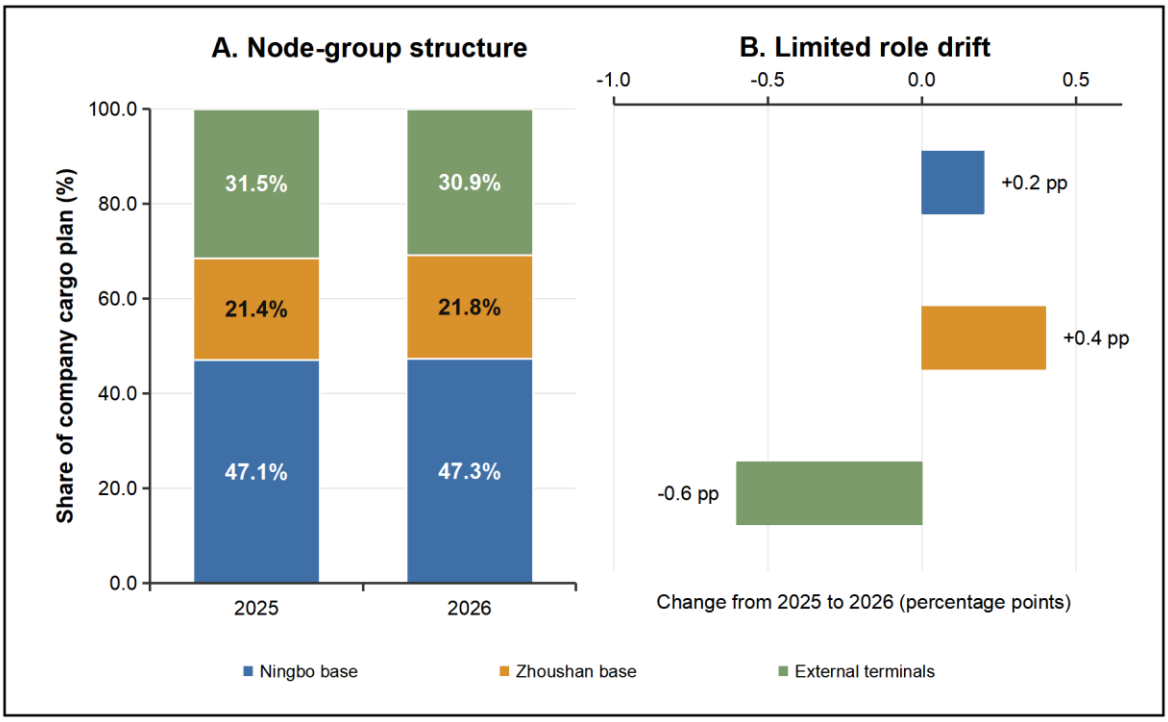


Fig. 1. Stable node-group structure and limited role drift between the 2025 and 2026 company plans.

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Note. Left panel values show planned node-group shares of company cargo throughput. Right panel values show 2026 planned share minus 2025 planned share in percentage points. Ningbo and Zhoushan refer to two main sub-gateway groups within the Ningbo-Zhoushan port system.

The two panels in Figure 1 make the same point from different angles. The left panel shows that the company-level node structure remained broadly stable across the two annual plans. The right panel shows only small year-on-year changes for each node group. This supports a more focused interpretation: the main optimization issue is not a shifting macro-structure, but the way a stable structure performs at specific interfaces. Figure 2 then disaggregates the 2026 company plan by cargo specialization and node-group throughput scale to examine whether the stable structure also contains differentiated cargo roles.

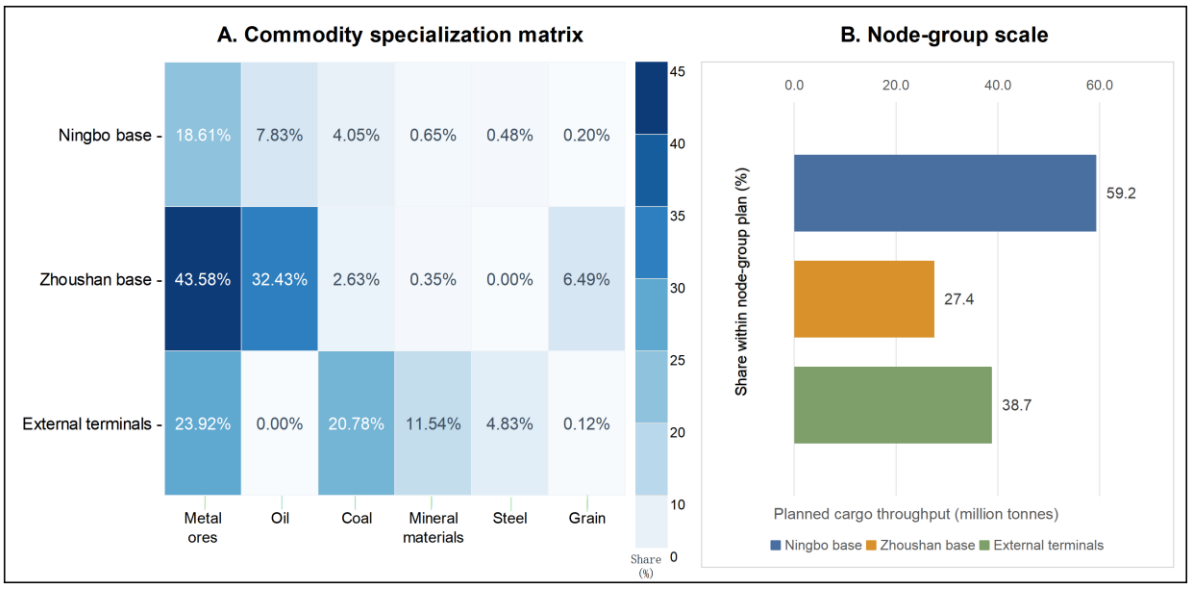


Fig. 2. Gateway specialization matrix and throughput scale in the 2026 company plan

Note. Matrix values represent cargo-category shares within each node-group plan. The throughput scale is in million tonnes, and is an indicator of planned cargo throughput. Ningbo base and Zhoushan base as well as external terminals are not interchangeable locations and are treated as functional gateway groups.

Figure 2 agrees that the three node groups are not suitable for being compressed to a generic port function. Ningbo is the principal control gateway, Zhoushan is bulk-oriented and the external terminal system is more inland-facing. The governance implication is simple: It would not make sense to have the same optimization rule applied to all nodes. The general takeaway for an international reader is that any plan for the corridors should first identify gateway control nodes, bulk-specialized nodes, and inland-facing consolidation nodes, and then propose corridor optimization measures.

Rolling interface diagnosis: maritime robustness, rail-interface lag

The quarterly production-planning data for 2025 shows a more detailed operational picture than the annual-planning information alone. There was a relatively strong trend in cargo throughput, container throughput, tally volume and pilotage voyages. In Q2, cargo throughput was 51.0% of annual plan and tally volume was 51.9%, which are close to or above the 50% linear rate. In Q4, all 4 maritime-side indicators were over 100% of annual plans. This is not a typical weak corridor. It shows that the seaport-side operating system was able to sustain the annual plan.

This was not the case with rail freight. It reached 21.1% in Q1, 41.6% in Q2, and 68.4% in Q3, producing schedule gaps of -3.9, -8.4, and -6.6 percentage points against the quarter-end benchmark. It did not reach parity until Q4, in which it was 100.2% of the annual plan. The main empirical result of the article is that the bottleneck was not distributed throughout the entire corridor. It was concentrated at the rail–dry-port interface and recovery occurred later in the year.

Governance-wise the asymmetry is more indicative than the year-end number. When indicators on the maritime side are on track and the rail freight side was underperforming for most of the year, then it is not likely that it is only a matter of capacity on the quays or weak demand. It is more consistent with constraints in inland consolidation, train scheduling, station utilization, slot coordination, and the binding of documents to actual operations. The corridor is connected, but it is not yet fully orchestrated at the rail–dry-port interface. Table 2 reports the quarterly values behind this reading, and Table 3 converts the same differences into the CIG indicator.

Table 2

Rolling completion of five core indicators in 2025 (% of annual plan)

Quarter	Cargo throughput	Container throughput	Rail freight	Tally volume	Pilotage voyages
Q1	25.1	23.6	21.1	25.1	25.6

Q2	51.0	49.2	41.6	51.9	53.7
Q3	77.0	75.9	68.4	80.0	81.5
Q4	102.3	102.6	100.2	105.6	108.7

Source: author's calculations from the compiled 2025 rolling transport-operation planning dataset. The linear benchmark is 25%, 50%, 75%, and 100% of the annual plan at the end of Q1, Q2, Q3, and Q4, respectively.

Table 3

Corridor Coupling Imbalance Gap between maritime-side execution and rail-freight execution in 2025

Quarter	Maritime-side mean completion (%)	Rail freight completion (%)	CIG (percentage points)
Q1	24.85	21.10	+3.75
Q2	51.45	41.60	+9.85
Q3	78.60	68.40	+10.20
Q4	104.80	100.20	+4.60

Source: author's calculations. Maritime-side mean completion is the arithmetic mean of cargo throughput, container throughput, tally volume, and pilotage voyages. CIG = maritime-side mean completion minus rail-freight completion.

The quarterly completion rates and CIG values show why the year-end recovery should not be over-read. Annual completion masks a coordination lag that lasted for three quarters. Figure 3 therefore pairs the rolling completion trajectories with the schedule-gap matrix, so that both the timing and the location of the rail-interface lag can be seen more clearly.

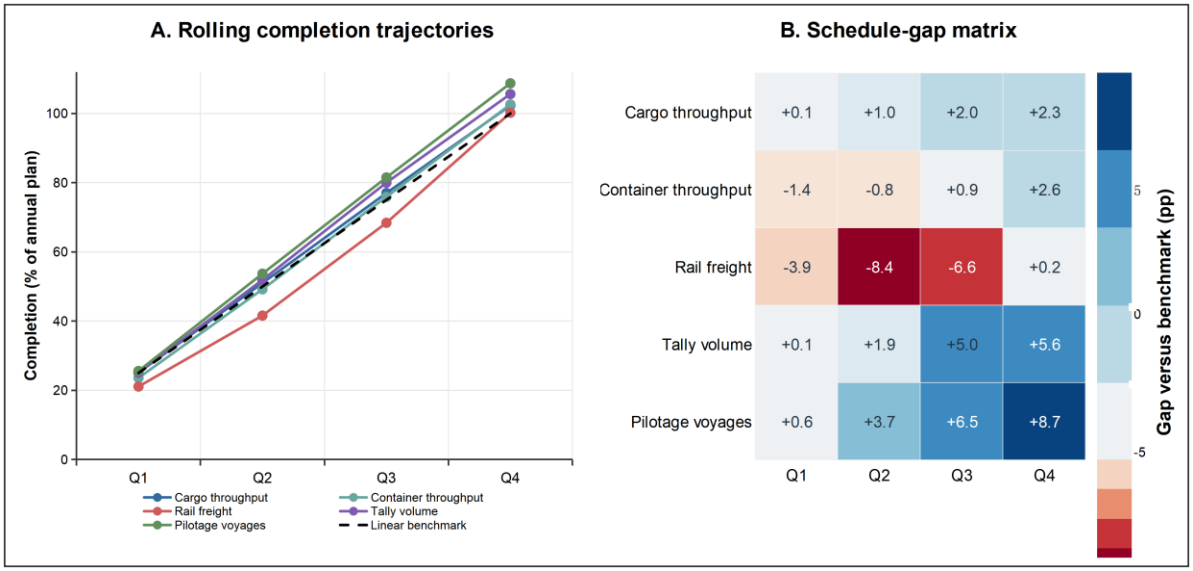


Fig. 3. Rolling completion trajectories and schedule-gap dynamics for the five core indicators in 2025

Note. The linear benchmark refers to quarter-end cumulative progress of 25%, 50%, 75%, and 100% of the annual plan. Schedule gap equals actual cumulative completion minus the corresponding benchmark; the related CIG values are reported in Table 3.

The left panel of Figure 3 indicates that the maritime-side indicators stayed near or above the expected quarterly pace. The right panel shows that rail freight was the only indicator with a materially negative gap over a three-quarter period, although it recovered by year-end. The CIG values express the same imbalance more directly: maritime-side execution exceeded rail-freight execution by +3.75 percentage points in Q1, +9.85 points in Q2, +10.20 points in Q3, and +4.60 points in Q4. The indicator therefore makes the operational dimension of coupling concrete and shows that the rail–dry-port interface was most weakly coupled during the middle of the year.

Interpreting the mismatch: corridor scale, inland pressure, and uneven translation of digital capacity

The likely conditions behind the rail-interface lag can be interpreted by considering the public planning and industry evidence. The Zhejiang-Ningbo-Zhoushan setting is already large and spatially extensive, and is embedded in dense transport activity. By September 2024, Ningbo-Zhoushan Port had 107 sea–rail routes, including 26 scheduled trains, and 37 inland dry-port nodes covering 67 prefecture-level cities in 16 provincial-level areas. The reason why these figures are important is that they reflect the status of a mature corridor, and not that Zhejiang can be used as a universal model. It can be easier to add routes and nodes to such a corridor than to synchronise the interfaces between them. At this scale, the route expansion can no longer be the primary solution. The more nodes in a network, the more operational interfaces are generated, especially if they are located deep inside the network. These interfaces must then be sequenced, coordinated and managed.

There are also strong digital foundations in the case, but it seems that there is a disconnect between digital connectivity and event level orchestration. The Four-Port platform reportedly is able to integrate more than 11,000 data items, improve the efficiency of multimodal bookings by roughly 40%, and connects more than 100 systems. The Sixth Port Area platform is also said to boost the operational efficiency of the sea–rail by approximately 20%. These are important accomplishments. But a digital platform doesn't necessarily mean that train assembly, customs sequencing, yard readiness and gate operations are synchronised. Digitalisation helps to increase visibility, however this visibility needs to be translated into coordinated action as well.

The inland Jinhua–Yiwu support area seems to be under pressure. According to public planning documents the region's railway container capacity is approximately 650,000 TEU. Yiwu sea–rail station was able to process approximately 123,000 TEU of sea–rail transport in 2023. Overall utilisation was at around 80% and international trains and sea–rail trains took up almost 75% of the station's freight volume. These are not definitive and don't provide proof of a single cause, but they do indicate that there may have been limited spare capacity. This is significant as with tight capacity, even small sequencing issues or dispatch instability can impact the broader corridor.

Behaviour might also be affected by price signals. Despite local subsidy, rail transportation from Yiwu to Ningbo-Zhoushan is estimated to be approximately RMB 20 more expensive than direct road transport per forty-foot container. Though this is a small difference, it could be important for shippers should multimodal services be uncertain or there be additional coordination costs. Reliability and ease of booking, tracking, and execution can potentially make shippers more willing to pay a small premium for rail.

Pressure is also seen at the port–rail interface. Public planning documents show that the volume of port-station rail traffic amounted to 17.49 million tonnes or 7.9% of throughput in the port area and that existing facilities were capable of 1 million TEU of sea–rail traffic per year. Thus, the inland bottleneck should be interpreted in the context of the overall coordination challenge which also includes gateway capacity, consolidation in the inland, route planning, and digital-operational timing.

Finally, there is a baseline of monitoring in the corridor. Sixteen indicators can be automatically captured through IoT, including road and rail gate-system data, which are listed in public materials. This is crucial, as imbalances need not be noticed only in annual statistics if they are detected in near real time. The CIG indicator in this context helps to make an abstract coordination problem real and tangible, to discuss with port, rail, dry-port, customs and platform actors.

Discussion and Recommendations: From Network Expansion to Interface-Centered Optimization

Optimization of the Maritime Silk Road (MSR) corridor should not be started from the general question of how to expand the network, based on the results. Rather, it should be a more specific question – once spatial maturity is reached, which interface is reducing the performance of the network? In the Zhejiang-Ningbo-Zhoushan instance, it is not difficult to see. Stable and distinguishable gateway functions are exhibited in annual plans, while the structure of the corridor remains stable. Maritime side performances are good, as seen by rolling data. But the schedule-gap matrix and CIG values indicate that there is a weakness in the rail–dry-port interface. The operational optimization and governance reform must be linked here.

It's not so much about the local context as it is about the analytical logic of the case in Zhejiang. But dry-port development, rail connectivity and international freight corridors cannot function effectively if inland nodes are not coordinated with seaports and cross-agency operational decision-making, which is relevant to Uzbekistan and other Central Asian economies.

Four directions of optimization are indicated by this diagnosis. The roles for gateways should be well-defined. Gateways, control points, bulk-specialized bases and inland-facing terminals should be different in their way of operating. Second, the interface of the dry-port should be reinforced. The emphasis should not be on the construction of nodes for the sake of it, but on customs extension, assembly of trains, cargo consolidation and the synchronization of slots at robust inland nodes, particularly Jinhua–Yiwu. Third, digitalisation needs to go beyond data sharing to digital orchestration. All activities of booking, customs clearance, preparation of the train, yard readiness, and gate operations should be integrated into a coordinated process. Fourth, the use of rolling warning should be made institutional. If CIG values remain positive or gaps in rail freight schedules reoccur, systematic measures should be taken, and a quarterly process of review should be established.

This is an interpretation that relates collaborative governance to network diagnosis. Once a corridor becomes institutionally layered, location of the terminal and route design are no longer sufficient. The challenge is to find the disconnect between physical flows, governance and digital processes. So the rail–dry-port interface and the digital to physical interface are not just technical issues. They are the key units through which improvements to the governance of corridors can be made. The policy lesson is therefore not that every corridor should imitate the Zhejiang model. It is that every mature seaport–dry port corridor needs a mechanism for diagnosing where physical flows, institutional responsibilities, and digital events fall out of alignment. Table 4 summarizes this governance-coupled optimization agenda.

Table 4

Governance-coupled optimization agenda for a port-centered seaport–dry port corridor

Optimization layer	Primary problem	Recommended action	Expected effect
Gateway structure	Uniform treatment of heterogeneous port nodes	Differentiate main gateway control, bulk specialization, and affiliated/inland-facing terminal functions rather than treating all nodes as interchangeable.	Closer alignment between cargo structure, node function, and corridor planning; more transferable logic for other gateway-to-hinterland corridors.

Optimization layer	Primary problem	Recommended action	Expected effect
Dry-port interface	Inland consolidation and slot coordination lag behind seaport-side execution	Strengthen customs extension, train assembly, cargo consolidation, and slot synchronization at strong inland nodes	Lower rail-side delay and stronger port–dry-port synchronization
Digital orchestration	Document and data digitalization exceed event-level process integration	Link booking, customs release, yard status, train readiness, and gate data in one event chain	Lower interface friction and more reliable multimodal service execution
Rolling warning governance	Operational gaps and positive CIG values are detected too late	Use CIG and repeated schedule-gap signals as quarterly warning triggers for port, rail, dry-port, customs, and platform actors.	Faster correction before imbalance becomes structural

Source: synthesized from the empirical diagnosis in this study.

5. Conclusion

This article has examined corridor optimization as an operational and governance problem under the Maritime Silk Road. It does not separate network expansion from governance improvement. Instead, it asks where intervention should be directed when a seaport–dry port system is spatially extensive but unevenly synchronized. The Zhejiang–Ningbo-Zhoushan setting is used as a coastal gateway-province case. It also has broader relevance to corridors between maritime gateways and inland and landlocked hinterlands. The findings indicate that rather than route development, more emphasis should be placed on enhancing the role of the corridors' gateways, inland consolidation, digital orchestration, and rolling monitoring.

The four key findings are: First, the intended annual node structure is fairly static; it has little change in structure. Second, the rolling data for 2025 demonstrate high performance on the maritime side and less on the rail side. Third, the CIG indicator reveals this imbalance: the difference between the maritime-side and the rail-freight execution increased in Q3 to +10.20 percentage points. Fourth, policy and planning evidence indicates several plausible conditions behind the delay: corridor scale, inland station pressure, a marginal rail-cost disadvantage, and incomplete translation of digital capacity into field-level operational coordination.

It may be concluded that collaborative governance in a seaport–dry port system should be assessed by the effectiveness of interface management, not only by formal institutional links or the number of opened routes. Optimization is possible if it focuses on schedule discipline, inland assembly, customs extension, platform coordination and monitoring intervention. Dry ports should thus be interpreted not only as logistics nodes but as governance interfaces to transform the capacity of seaports into predictable inland transport performance.

This study has some limitations. It is constructed on one year of quarterly data and a one-port-centred corridor, and is intended as a diagnostic case study, not a universal rule. The analysis relies on aggregated planning and operational indicators and does not include shipper-level origin-destination matrices, terminal-level slot records, or micro-level cost traces. The indicator of CIG is not a causal model, but rather a simple proxy for the operational imbalance. Additional studies may be conducted using multi-year multi-corridor, shipper level, terminal level, and service reliability data.

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