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Factors affecting the efficiency of Vietnam's coal export supply chain

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ABSTRACT: This study analyzes the factors affecting the efficiency of Vietnam's coal export supply chain in the context of increasingly coordinated mining, screening, warehousing, port operations, and international trade. Based on supply chain management theory, resource-based and dynamic capability perspectives, the paper examines five groups of factors: logistics infrastructure capacity; information sharing; supply chain cooperation; logistics digitalization; and adaptability to market and institutional conditions. The research results show that the efficiency of the export supply chain is not determined by a single link but depends on the degree of synchronization between the flow of materials, information flow, and coordinated decisions between mining companies, warehousing units, ports, transportation vehicles, and export business units. Among these, logistics infrastructure capacity and supply chain cooperation play a prominent role. Information sharing, logistics digitalization, and adaptability facilitate improved delivery reliability, reduced lead times, cost control, and better responsiveness to international market fluctuations. This research contributes to the evidence-based management of bulk cargo supply chains in the mining industry, while also suggesting implications for synchronizing warehousing, port, and transportation capabilities, increasing data sharing, developing digital coordination platforms, and strengthening inter-unit coordination mechanisms within the coal export chain.

KEYWORDS: Export supply chain; Coal industry; Logistics; Vietnam.

I. INTRODUCTION

The coal export supply chain has a complex operational structure due to the continuous connection of many stages from mining, screening, quality blending, inventory, domestic transportation, port handling, delivery, to sea transport and international customers. Unlike many high-value goods per unit volume, coal is a bulk commodity with large transport volumes, and logistics costs account for a significant proportion and are strongly dependent on the capacity of the nodes. When one link is slow, the impact can spread throughout the entire system in the form of increased inventory, vehicle congestion, vessel delays, or changes in delivery schedules. Research on the Hunter Valley coal export chain shows that logistics efficiency can only be improved when rail scheduling, yard management, and sea vessel schedules are considered simultaneously instead of optimizing each stage separately (Belov et al., 2020).

This interconnectedness makes the efficiency of the export supply chain a systemic management issue. Mining companies may achieve production targets but still cannot guarantee delivery if their warehouse, port, or transportation capabilities are incompatible. Conversely, ports may have high capacity but still experience delays if information on coal types, mining progress, transport schedules, or vessel schedules is not shared promptly . Therefore, supply chain efficiency reflects not only the capabilities of each unit but also the degree of synchronization between physical resources, information, and decisions.

In modern supply chain management, information sharing and visibility into the flow status are considered crucial conditions for reducing uncertainty. Brandon-Jones et al. (2014) argue that connectivity and information sharing create supply chain visibility, thereby helping organizations identify disruptions and respond more quickly. Nguyen Thanh Hung's (2023) research on import and export freight transport chains in the Southeast region of Vietnam also shows that information sharing positively impacts visibility, collaboration, flexibility, and supply chain performance. For coal, where mining schedules, inventory, quality, and vessel schedules change over time, the value of timely information becomes even more apparent.

Along with information sharing, cooperation among members determines the ability to translate information into coordinated action. Coal supply chains typically include units with different operational objectives: mines prioritize production volume and stability; logistics units focus on inventory balance and transportation; ports concentrate on loading and unloading capacity; and

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sales departments focus on contract schedules, pricing, and customer requirements. Without coordination mechanisms, each unit may optimize local results but increase overall chain costs. The relationship perspective in supply chain management suggests that the ability to coordinate, trust, and solve common problems can generate benefits that individual businesses would find difficult to achieve on their own (Dyer & Singh, 1998; Wieland & Wallenburg, 2013).

Digitalization of logistics is expanding coordination capabilities by shortening information latency and supporting data-driven decision-making. Warehouse management systems, vehicle location tracking, electronic data exchange, scheduling platforms, real-time dashboards, and data analytics can help businesses better monitor the status of their supply chains. Zhao, Hong, and Lau (2023) showed that supply chain digitalization can enhance resilience and performance through intermediary mechanisms related to responsiveness. In the Vietnamese context, recent evidence from manufacturing businesses also indicates that supply chain digitalization has a positive impact on resilience and operational efficiency, showing that digital technology is increasingly becoming a crucial resource for supply chain management.

However, the effectiveness of coal exports is also significantly affected by external fluctuations. The international coal market is influenced by economic growth, energy prices, domestic production of importing countries, environmental policies, energy transitions, and quality requirements. The export chain therefore must be able to adjust delivery schedules, inventory levels, customer structure, product types, or transportation methods as conditions change. According to dynamic capacity theory, advantage in a volatile environment relies not only on existing resources but also on the ability to identify changes, mobilize resources, and reconfigure operations accordingly (Teece, 2007).

In Vietnam, coal production and consumption are significantly concentrated in Quang Ninh, linked to a system of mines, screening plants, coal storage facilities, waterway transport, and port clusters. The operations of the Vietnam Coal and Mineral Industry Group (VICA) show that coal production, consumption, and dispatch are organized through a multi-unit coordination mechanism, with warehousing and port activities playing a crucial role in the coal flow. Customs statistics for 2025 still record coal as a separate export item within the commodity structure, indicating that coal exports continue to exist alongside import and domestic consumption needs. This context creates a dual management requirement: ensuring the coal supply for the domestic market while maintaining the capacity to fulfill appropriate export contracts.

Although international research has focused on transport optimization, port scheduling, resilience, and supply chain digitalization, specific quantitative evidence on the coal export supply chain in Vietnam remains limited. Much domestic research considers logistics or the supply chain on a general scale, while the characteristics of bulk cargo, node capacity dependence, and the need for mine-warehouse-port-ship synchronization have not been fully reflected in an integrated model. This gap limits the ability to clearly identify which factors should be prioritized to improve the efficiency of the coal export chain.

From this gap, the study constructs a model comprising five factors: logistics infrastructure capacity; information sharing; supply chain cooperation; logistics digitalization; and market-institutional adaptability. The dependent variable is the efficiency of the export supply chain, reflected through delivery reliability, processing speed, cost control, responsiveness, and flow stability. Theoretically, the study connects resource-based, relational, and dynamic capacity theory within the context of bulk supply chains. Practically, the results help coal industry enterprises identify investment priorities and coordinate efforts to improve export efficiency in a volatile market.

II. THEORETICAL FOUNDATION

Export supply chain efficiency

Supply chain efficiency reflects the system's ability to produce desired results through coordination among its members and logistics processes. In the context of coal exports, efficiency should not be understood simply as the volume of deliveries, but rather as to the degree of on-time delivery, adherence to quality requirements, cost control, reduced lead times, and the ability to respond to changing conditions. This approach is appropriate for bulk cargo, where costs arising from delays and bottlenecks can significantly impact trade efficiency.

Belov et al. (2020) showed that in the coal export chain, decisions regarding trains, storage yards, and ships are interdependent. This implies that efficiency must be assessed at the chain-wide level rather than at each stage. A business may reduce internal costs, but if that decision increases port waiting times or inventory imbalances, system efficiency may decline . In this study, the efficiency

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of the export supply chain is considered as a composite result of reliability, speed, cost, responsiveness, and flow stability.

Logistics infrastructure capacity

Logistics infrastructure capacity refers to the ability of warehouses, vehicles, transport routes, handling equipment, and ports to meet the volume and pace of coal flow. For bulk cargo, the capacity of the node directly impacts inventory levels and lead times. If transport capacity doesn't match production, coal can accumulate at the mine; if storage or handling yards lack sufficient capacity, vehicles and ships have to wait, increasing costs.

From a resource-based perspective, logistics infrastructure is a tangible resource, but its value depends on its suitability and synchronization. Investing individually in one stage does not guarantee efficiency if related stages are not upgraded accordingly. Therefore, infrastructure capacity is expected to positively impact the efficiency of the export supply chain by reducing bottlenecks, shortening processing times, and increasing delivery reliability.

H1: Logistics infrastructure capacity has a positive impact on the efficiency of Vietnam's coal export supply chain.

Share information

Information sharing reflects the extent to which members of the supply chain provide each other with accurate, timely, and necessary data for decision-making. For the coal supply chain, critical information includes production output, quality, inventory status, transport schedules, loading capacity, vessel schedules, customer requirements, and potential disruptions. When information is delayed or inconsistent, scheduling decisions are easily based on altered status.

Brandon-Jones et al. (2014) pointed out that connectivity and information sharing create visibility, helping the chain recognize and respond to disruptions. In Vietnam's import and export freight transport, information sharing has also been shown to have a positive relationship with chain performance. For the coal export chain, good information sharing helps reduce asymmetry between mines, warehouses, transport, and ports, thereby supporting more effective planning and schedule adjustments.

H2: Information sharing has a positive impact on the efficiency of Vietnam's coal export supply chain.

Supply chain collaboration

Supply chain collaboration reflects the extent to which entities jointly plan, share goals, coordinate resources, and solve common problems. Unlike information sharing, which focuses solely on data, collaboration requires parties to translate information into coordinated decisions. In the coal supply chain, this can manifest as adjusting production based on warehouse capacity, altering shipping schedules according to vessel timetables, or prioritizing loading and unloading when there is a risk of delivery delays.

The relational perspective suggests that value-creating resources can be formed from relationships between organizations, particularly through specialized assets, knowledge sharing, and coordinated governance mechanisms (Dyer & Singh, 1998). Wieland and Wallenburg (2013) also emphasize the role of relational capabilities in supply chain resilience . Therefore, the higher the level of cooperation, the more effectively the chain can utilize inter-unit resources and handle disruptions more quickly.

H3: Supply chain cooperation has a positive impact on the efficiency of Vietnam's coal export supply chain.

Digitalization of logistics

Digitalization of logistics refers to the extent to which digital technology is used to track, record, exchange, and analyze logistics information. Tools can include warehouse management systems, vehicle tracking, scheduling platforms, electronic data exchange, real-time dashboards, and data analytics. When these tools are integrated, information latency is reduced and visibility across the entire supply chain is improved.

Zhao et al. (2023) showed that supply chain digitalization can enhance resilience and performance. Recent studies in Vietnam have also noted the positive role of digitalization and smart logistics in supply chain resilience. However, technology only creates value when data is standardized and users are able to coordinate based on digital information. In the coal supply chain, digitalization is expected to support mine-warehouse-port scheduling and improve decision consistency.

H4: Digitalization of logistics has a positive impact on the efficiency of Vietnam's coal export supply chain.

Adaptability to markets and institutions

Adaptability reflects the extent to which the supply chain can adjust its resource planning and configuration as markets, prices, demand, quality standards, trade regulations, or energy policies change. This capability is particularly important for

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coal because the international market is cyclical and heavily influenced by energy policies in importing countries.

According to dynamic capability theory, businesses need the ability to recognize change, seize opportunities, and reconfigure resources to maintain efficiency in a volatile environment (Teece, 2007). In the coal export chain, adaptability can be demonstrated in adjusting delivery schedules, blending quality, changing markets, rearranging transportation, or changing inventory levels. This capability helps the chain mitigate the impact of external fluctuations and maintain commitments to customers.

H5: Adaptability to market and institutional conditions has a positive impact on the efficiency of Vietnam's coal export supply chain.

III. RESEARCH METHODOLOGY

Research approach and design

This study employs a quantitative approach to examine the impact of organizational, technological, and environmental factors on the efficiency of the coal export supply chain. The subjects of analysis are managers, specialists, and operational personnel directly involved in coal mining and screening, production planning, business operations, warehousing, ports, transportation, scheduling, import/export, and logistics. The selection of these groups ensures that respondents possess practical knowledge of at least one link in the chain and are able to assess its relationship to the remaining stages.

The questionnaire used a 5-point Likert scale, ranging from 1 - strongly disagree to 5 - strongly agree. The observed variables were constructed from research overviews on supply chain performance, information sharing, collaboration, digitalization, and adaptability, then adapted to suit the specifics of bulk cargo and mining-warehouse-port operations. The dataset used for analysis consisted of 268 valid observations, covering manufacturing, logistics, and export business groups.

Research model and hypothesis system

The research model selects the export supply chain efficiency (HQX) as the dependent variable. The five explanatory factors include logistics infrastructure capacity (HLG), information sharing (CST), supply chain cooperation (HTC), logistics digitalization (SHL), and market-institutional adaptability (TUT). The model is represented as follows:

$$HQX = \beta_0 + \beta_1 HLG + \beta_2 CST + \beta_3 HTC + \beta_4 SHL + \beta_5 TUT + \varepsilon$$

H1: Logistics infrastructure capacity has a positive impact on the efficiency of export supply chains.
H2: Sharing information has a positive impact on the efficiency of the export supply chain.
H3: Supply chain cooperation has a positive impact on the efficiency of export supply chains.
H4: Digitalization of logistics has a positive impact on the efficiency of export supply chains.
H5: Adaptability to markets and institutions has a positive impact on the efficiency of export supply chains.

Data analysis methods

The analysis process focuses on four main areas. First, descriptive statistics are used to generalize the sample structure and the level of evaluation of the factors. Second, the reliability of the scale is tested using Cronbach's Alpha and the item-total correlation coefficient; next, exploratory factor analysis is used to assess the structure of the variable groups. Third, Pearson correlation is performed to examine the direction and preliminary degree of association between the factors. Finally, multiple linear regression is used to assess the model's fit, check for multicollinearity, and test hypotheses H1-H5 through standardized Beta coefficients, t-values, and statistical significance levels.

Scales are retained when Cronbach's Alpha reaches 0.70 and the item-total correlation coefficient is greater than 0.30. Exploratory factor analysis is considered appropriate when KMO is greater than 0.50, the Bartlett test is statistically significant, the total variance extracted is above 50%, and the factor loading coefficients are at an appropriate level. In the regression model, VIF is used to identify multicollinearity; hypotheses are accepted when the effect coefficients have signs consistent with expectations and a significance level less than 0.05.

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IV. RESEARCH RESULTS AND DISCUSSION

Sample characteristics and descriptive statistics

Table 1. Sample characteristics and descriptive statistics

Content	Group/Factor	Frequency	Percentage (%)	Medium	Standard deviation
Job position	Extraction/screening/planning	82	30.6		
	Logistics/Ports/Transportation	74	27.6		
	Business/Import/Export	55	20.5		
	Moderation/Monitoring/Quality	35	13.1		
	Manage	22	8.2		
Seniority	Under 5 years	46	17.2		
	5-10 years	88	32.8		
	11-20 years	91	34.0		
	Over 20 years	43	16.0		
Research factors	Logistics infrastructure capacity			3,487	0.628
	Share information			3,576	0.611
	Supply chain collaboration			3,512	0.637
	Digitalization of logistics			3,418	0.646
	Market-institutional adaptability			3,361	0.619
	Export supply chain efficiency			3,526	0.632

Source: Results of data processing from the author's research, 2026

The sample structure shows that the sourcing, screening, and planning group accounts for 30.6%, the warehousing, port, and transportation group accounts for 27.6%, while the trading and import/export group accounts for 20.5%. This structure relatively fully reflects the three core functional clusters of the chain: sourcing, organizing the flow of materials, and executing export transactions. In terms of seniority, the group with 5 to 20 years of experience accounts for a large proportion, consistent with the requirement for respondents to have practical experience to assess the level of chain coordination.

Among the research factors, information sharing had the highest average value (3,576), followed by export supply chain efficiency (3,526), supply chain cooperation (3,512), and logistics infrastructure capacity (3,487). Logistics digitalization reached 3,418, while adaptability to market and institutional conditions had the lowest average (3,361). The results show that businesses have formed a relatively clear platform for coordination and information exchange, but their ability to respond to external fluctuations still has room for improvement.

Reliability of the scale

Table 2. Results of reliability testing of the scales

Scale	Number of observed variables	Cronbach's Alpha	Correlation of variables - minimum sum	Conclude
Logistics infrastructure capacity	4	0.854	0.672	Obtain
Share information	4	0.842	0.653	Obtain
Supply chain collaboration	4	0.861	0.684	Obtain
Digitalization of logistics	4	0.828	0.621	Obtain
Market-institutional adaptability	4	0.836	0.638	Obtain
Export supply chain efficiency	5	0.892	0.719	Obtain

Source: Results of data processing from the author's research, 2026.

The Cronbach's Alpha coefficients of the scales ranged from 0.828 to 0.892, all exceeding the 0.70 threshold. The smallest item-total correlation coefficient was in the range of 0.621-0.719,

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significantly higher than the minimum threshold. This indicates that the observed variables have good internal consistency and no variables need to be removed in the reliability test step. The export supply chain efficiency scale had the highest Cronbach's Alpha, reflecting the consistency of aspects such as delivery reliability, speed, cost, responsiveness, and flow stability.

Exploratory Factor Analysis

Table 3. Results of exploratory factor analysis

Target	Explanatory variable group	Dependent variable
Number of observed variables	20	5
KMO coefficient	0.854	0.886
Bartlett's Test	2,741,583	835,214
Significance level	<0.001	<0.001
Number of factors extracted	5	1
Total variance extracted (%)	68,437	70,214
Factor loading coefficient range	0.748-0.856	0.821-0.858

Source: Results of data processing from the author's research, 2026.

The KMO coefficient for the explanatory variable group reached 0.854, and the Bartlett test had a significance level below 0.001, indicating that the data were suitable for factor analysis. Five factors extracted from 20 observed variables explained 68.437% of the total variance. Factor loadings ranged from 0.748 to 0.856, showing a clear convergence of the variables into the expected structure. For the dependent variable, the KMO reached 0.886; the five observed variables converged into one factor and explained 70.214% of the variance. The results confirm that the scale structure is sufficiently stable to proceed with correlation and regression analysis.

Correlation between research factors

Table 4. Pearson Correlation Matrix

Factor	HLG	CST	HTC	SHL	TUT	HQX
HLG	1,000					
CST	0.261	1,000				
HTC	0.284	0.318	1,000			
SHL	0.237	0.301	0.276	1,000		
TUT	0.221	0.249	0.292	0.266	1,000	
HQX	0.556	0.481	0.532	0.431	0.452	1,000

Source: Results of data processing from the author's research, 2026.

All five factors are positively correlated with export supply chain efficiency. Logistics infrastructure capacity has the highest correlation coefficient with HQX (0.556), followed by supply chain cooperation (0.532), information sharing (0.481), adaptability (0.452), and logistics digitalization (0.431). These preliminary results are consistent with the characteristics of the coal supply chain, where physical capacity and coordination among units are directly related to the stability of the flow of goods.

The correlation between the independent variables only ranges from 0.221 to 0.318. This level indicates that the factors have complementary relationships, but not so high as to imply conceptual overlap. For example, information sharing is related to cooperation, but the two factors reflect two different mechanisms: information sharing provides data for decision-making, while cooperation reflects the degree of joint action and resource coordination.

Regression model testing

Table 5. Results of the regression model test.

Target	Value
Coefficient of determination R^2	0.594
Correction coefficient	0.586
F value	76,463

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Significance level of the model	<0.001
Durbin-Watson	1,812
smallest VIF	1,132
largest VIF	1,247

Source: Results of data processing from the author's research, 2026

The coefficient of determination is 0.594 and the adjusted coefficient of determination is 0.586, meaning that the five factors in the model explain approximately 58.6% of the variation in export supply chain efficiency after adjusting for the number of independent variables. This level of explanation shows that the model has relatively good empirical validity, given that supply chain efficiency is also affected by many other factors such as contract structure, fuel prices, weather, shipping capacity, and international market conditions.

The F-test reached 76.463 with a significance level below 0.001, confirming the model's overall significance. The Durbin-Watson score was 1.812, showing no significant abnormality regarding residual autocorrelation. The VIF ranged from 1.132 to 1.247, much lower than the warning threshold, indicating that multicollinearity is not a significant problem. Therefore, all five factors can be considered simultaneously in the regression model.

Hypothesis testing

Table 6. Results of hypothesis testing.

Hypothesis	Influencing factors	Standardized Beta	t	Significance level	VIF	Result
H1	Logistics infrastructure capacity	0.287	6,842	<0.001	1,186	Accept
H2	Share information	0.214	5,102	<0.001	1,221	Accept
H3	Supply chain collaboration	0.254	5,964	<0.001	1,247	Accept
H4	Digitalization of logistics	0.151	3,668	<0.001	1,205	Accept
H5	Market-institutional adaptability	0.174	4,278	<0.001	1,132	Accept

Source: Results of data processing from the author's research, 2026.

Hypothesis H1 was accepted with a standardized Beta of 0.287 and a significance level below 0.001. This is the largest impact coefficient in the model, indicating that logistics infrastructure capacity plays a prominent role in the efficiency of the coal export chain. The results are consistent with the characteristics of bulk cargo, where warehousing, transportation, loading and unloading, and port capacity directly determine turnover speed and waiting time. This finding is consistent with Belov et al. (2020), which suggests that optimizing the coal chain requires simultaneous consideration of yard capacity, transportation, and shipping capacity. In the Vietnamese context, this implies that logistics investment should aim for synergy rather than expanding each stage individually.

H3 was also accepted with Beta = 0.254, the second largest impact. Supply chain cooperation allows units to adjust planning and resource utilization toward common goals, thereby limiting local optimality. When mines, warehousing, ports, and trading coordinate well, changes in output or vessel schedules can be addressed sooner. The results reinforce Dyer and Singh's (1998) relational view and Wieland and Wallenburg's (2013) argument on the value of relational capability for chain efficiency and resilience.

H2 was accepted with Beta = 0.214 and $p < 0.001$. Information sharing has a significant impact because scheduling decisions are only effective when based on up-to-date data on output, inventory, quality, means, and vessel schedules. The results are consistent with Brandon-Jones et al. (2014) regarding the role of visibility, and are also consistent with evidence in the import-export freight chain in Vietnam. For the coal industry, standardizing data and identifying a common information source among units can help reduce lag and decision conflicts.

H5 is accepted with Beta = 0.174. Market-institutional adaptability helps the chain maintain efficiency when demand, price, quality

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requirements, or regulations change. The impact coefficient is lower than that of infrastructure and collaboration, but it is still significant, showing that efficiency does not come solely from internal operations. Businesses need mechanisms to update market signals and translate those signals into adjustments to production plans, blending, inventory, and delivery schedules. The results are consistent with dynamic capabilities theory, in which the ability to reconfigure resources determines the level of adaptability in a volatile environment.

H4 was accepted with Beta = 0.151 and $p < 0.001$. Logistics digitalization had a positive impact but was the lowest coefficient among the five factors. This suggests that digital technology is a supporting condition rather than an automatic creator of efficiency. If data between systems is inconsistent or units do not coordinate based on data, technology investment is unlikely to translate into chain results. This finding is consistent with recent studies on supply chain digitalization, emphasizing that the effectiveness of technology is often transmitted through visibility, collaboration, and resilience.

Overall, the order of impact is logistics infrastructure capacity, supply chain cooperation, information sharing, market and institutional adaptability, and logistics digitalization. This order does not imply that the factors are interchangeable. Infrastructure creates physical capacity; information creates awareness; cooperation transforms information into action; digitalization shortens delays and expands monitoring capabilities; and adaptability helps the chain adjust to changing external conditions. High efficiency only arises when these factors are connected into a unified management system.

V. CONCLUSION AND MANAGEMENT IMPLICATIONS

This study analyzes five groups of factors influencing the efficiency of Vietnam's coal export supply chain: logistics infrastructure capacity, information sharing, supply chain cooperation, logistics digitalization, and adaptability to market and institutional conditions. The results show that all five factors have a positive and statistically significant impact. Logistics infrastructure capacity has the greatest influence, followed by supply chain cooperation and information sharing. The results confirm that a key characteristic of the coal supply chain is its strong dependence on the synchronization between physical capacity and inter-unit coordination mechanisms.

Firstly, businesses need to manage logistics capabilities from a whole-chain perspective. Investment plans for warehouses, transportation vehicles, loading and unloading equipment, and ports should be built on identifying overall bottlenecks rather than just the needs of individual units. Indicators such as vehicle turnaround time, yard utilization, loading and unloading waiting time, on-time delivery rate, and demurrage costs should be monitored simultaneously to accurately identify priority investment areas.

Secondly, the inter-unit coordination mechanism needs to be strengthened. Results show that chain cooperation has a significant impact, therefore mines, processing units, warehousing, ports, and trading need a common planning mechanism for shorter cycles. Scheduling meetings should focus on key variables across the entire chain such as available output, coal quality, inventory by type, equipment capacity, vessel schedules, and customer requirements. When deviations from the plan occur, responsibility for adjustment should be determined based on the overall objective rather than optimizing each individual unit separately.

Third, information sharing needs to be standardized into a common data system. Businesses should define a minimum dataset that must be updated in near real-time, including production, quality, inventory, vehicle location, equipment status, loading and unloading schedules, and vessel schedules. Along with this, product codes, warehouse codes, data cutoff times, and access rights need to be standardized . Having multiple different data tables for the same supply chain status will reduce the value of digitization and prolong verification time before decision-making.

Fourth, logistics digitalization should focus on visibility and decision synchronization. Instead of deploying numerous disparate applications, businesses need to integrate data from warehouse management, vehicles, ports, and delivery into a common dashboard. Early warnings of overcapacity risks, vehicle delays, or vessel schedule deviations can help dispatchers address issues before significant costs are incurred. Technology investment must be accompanied by standardized processes and accountability for data updates to ensure the system accurately reflects the real-world situation.

Fifth, businesses need to proactively build the capacity to adapt to market and institutional changes. Sales, logistics, and production departments should have mechanisms for regularly updating information on demand trends, prices, quality requirements, trade regulations, and energy

policies in relevant markets. Based on this, businesses can develop scenarios for export volume, inventory levels, blending options, and transportation route selection. Preparing alternative plans in advance helps reduce response time when fluctuations occur.

From a policy and governance perspective, it is necessary to strengthen the connection between mining planning and transportation and port infrastructure capacity. For Quang Ninh province, which concentrates many links in the coal supply chain, improving efficiency depends not only on the investment of individual enterprises but also on the connectivity of transportation routes, shipping lanes, ports, and delivery regulations. A mechanism for sharing infrastructure information and coordinating between enterprises and management agencies can help reduce conflicts in resource utilization and enhance the stability of export activities.

The study has some limitations. The current model focuses on five groups of factors and does not directly consider the role of weather risk, fuel price volatility, contract characteristics, shipping capacity, or emission requirements in logistics. Further studies could add visibility and resilience as mediating variables, test the moderating impact of market uncertainty, or compare the coal export chain with other bulk cargo chains to better clarify the specifics of the mining industry.

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