



## Current Status of Digital Transformation Application in Supply Chain Management For Vietnamese Seafood Exports to The Eu Market

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**ABSTRACT:** Amidst profound global economic integration and the competitive advantages derived from the EU-Vietnam Free Trade Agreement (EVFTA), the European Union remains a strategic market; however, it concurrently imposes stringent technical barriers to trade (TBT) and rigorous traceability standards on Vietnamese seafood. Confronted with these challenges, conventional operational models are manifesting critical bottlenecks concerning supply chain transparency and information latency. Consequently, the implementation of digital transformation within supply chain management has emerged as an existential imperative, enabling enterprises to establish a seamless data ecosystem, optimize logistics overheads, and bolster their core competitiveness. This study is conducted to comprehensively evaluate the prevailing landscape of digital technology adoption and its integration across various supply chain nodes among Vietnamese seafood exporters catering to the EU market. Accordingly, it proposes a comprehensive suite of strategic, data-driven solutions aimed at optimizing supply chain operations, ensuring strict compliance with EU regulatory frameworks, and propelling sustainable export growth.

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### 1.THEORETICAL FRAMEWORK OF SUPPLY CHAIN MANAGEMENT IN SEAFOOD EXPORT OPERATIONS

A supply chain encompasses a complex network of organizations, human capital, technologies, operational activities, information flows, and associated resources dedicated to delivering a product or service from the point of origin to the end consumer. Supply chain operations fundamentally constitute value-creating processes designed to transform natural resources, raw materials, and intermediate goods into finished products, systematically orchestrating their delivery to the ultimate consumer.

Contextualized within the seafood industry, the export supply chain represents a systematic integration of organizations, personnel, technologies, activities, data, and resources engaged in the trajectory of seafood products from the hatchery (seed stage) to the consumer. The operational dynamics of the seafood export supply chain entail value-addition processes that convert foundational aquatic and terrestrial resources, seeds, aquafeed, and veterinary medicines into meticulously processed and finished goods, subsequently orchestrating their international distribution to the final consumer.

#### The Role of Supply Chain Management in Export Operations

Supply chain management (SCM) plays a pivotal role in integrating and coordinating the entirety of activities within the supply network, spanning from raw material procurement to the final consumer. This governance encompasses demand forecasting, procurement, manufacturing, warehousing, transportation, and product distribution. According to Chopra and Meindl (2019), the effective deployment of SCM enables enterprises to minimize operational expenditures, compress production and distribution cycle times, and elevate the operational efficacy of the entire supply chain while simultaneously optimizing resource utilization across the network. This synchronized coordination not only yields efficiency gains for individual enterprises but also augments the holistic performance of the interconnected organizational network, thereby cultivating a cohesive, agile operational system highly adaptable to fluctuations in the business landscape. Another fundamental function of SCM is the generation of

added value for the end consumer through the seamless harmonization of supply chain constituents. Christopher (2011) emphasizes that the synchronized alignment of functions—namely procurement, manufacturing, warehousing, and transportation—facilitates product quality enhancement, guarantees on-time delivery, mitigates waste, and maximizes resource efficiency. Similarly, Mentzer et al. (2001) posit that comprehensive SCM empowers enterprises to secure a sustainable competitive advantage via cost optimization, service quality improvement, and heightened responsiveness to market volatilities. Concurrently, this ensures that consumers receive premium-quality products alongside proficient service, thereby fortifying the reputation and intrinsic value of the entire supply network.

Furthermore, SCM is instrumental in risk management and in bolstering the resilience of the supply network against fluctuations in supply, demand, and costs, as well as exogenous shocks such as natural disasters, pandemics, and regulatory shifts. Drawing upon Christopher (2011) and Chopra and Meindl (2019), the interconnection of supply chain nodes, coupled with real-time information sharing and the implementation of contingency planning, aids enterprises in mitigating risk impacts, sustaining the stability of physical and information flows, and enhancing holistic supply chain resilience. Consequently, enterprises can preserve business continuity, ensuring the uninterrupted and efficient operation of the supply network even amidst adverse scenarios or abrupt disruptions.

An equally essential role of SCM lies in safeguarding product quality and ensuring strict adherence to technical standards throughout the chain. Mentzer et al. (2001) and Chopra and Meindl (2019) underscore that the integrated management of physical, information, and financial flows ensures that the final output complies with rigorous quality and safety criteria, whilst simultaneously enhancing transparency and traceability. This is of paramount importance in industries characterized by short product lifecycles or highly specific quality requisites, assisting enterprises in optimizing value addition and elevating the prestige of the entire supply network.

SCM also furnishes the requisite database and intelligence essential for executives to formulate strategic and operational decisions. According to Chopra and Meindl (2019), the analytical processing of network-wide data—encompassing demand, inventory, cost, and performance metrics—empowers enterprises to execute more robust planning across production, warehousing, transportation, and distribution. Simultaneously, SCM underpins long-term strategic planning, demand forecasting, and the cultivation of sustainable supply chain practices. Thus, SCM transcends its function as a mere operational mechanism, serving as a strategic apparatus that drives competitive advantage across the entire supply network.

#### Supply Chain Management Process in Seafood Export Enterprises

SCM within seafood export operations is a comprehensive process encompassing the planning, organization, coordination, and control of physical, information, and financial flows—from the initial sourcing of raw materials to the ultimate distribution of products to consumers in the international market. As articulated by Mentzer et al. (2001), a supply chain operates as an interconnected network of diverse entities, collectively engaged in value-generating activities for the customer while concurrently maximizing systemic efficiency.

Specifically within the seafood sector, the supply chain exhibits distinct characteristics attributed to the biological, highly perishable nature of the products, coupled with their susceptibility to meteorological and seasonal variables. Consequently, effective SCM in this domain necessitates profound agility, predictive capabilities, and meticulous coordination among stakeholders. Christopher (2016) posits that supply chain efficacy in sensitive commodity sectors, such as seafood, is contingent upon the profound integration of physical operations and information flows; this synergy is imperative to guarantee an uninterrupted continuum, mitigate risks, and preserve product integrity throughout the entirety of cross-border transit.

Drawing upon a synthesis of SCM theoretical models, the seafood supply chain process for export is conventionally structured into six fundamental stages: (1) raw material sourcing and management; (2) primary processing and initial preservation; (3) primary transportation; (4) processing and packaging; (5) export warehousing and cold storage; and (6) export logistics and international distribution. These stages coalesce into a closed-loop system operating on the principle of multidimensional coordination, wherein physical, information, and financial flows are systematically synchronized to optimize the holistic efficiency of the entire system (Lambert, 2008).

## 2. THE CURRENT LANDSCAPE OF VIETNAM'S SEAFOOD EXPORTS TO THE EU MARKET

### Export Turnover and Growth Dynamics of Vietnamese Seafood to the EU during the 2015–2024 Period

Year	Vietnam's Total Seafood Export Turnover (Million USD)	Vietnam's Seafood Export Turnover to the EU Market (Million USD)	Growth in Seafood Export Turnover to the EU Market (Million USD)	Proportional Share of Exports to the EU / Vietnam's Total Seafood Export Turnover (%)
2015	6,559	1,175	-17,77	17,91
2016	7,050	1,219	3,75	17,29

2017	8,320	1,481	21,49	17,80
2018	8,800	1,472	-0,61	16,72
2019	8,540	1,297	-11,89	15,18
2020	8,412	959	-26,06	11,40
2021	8,900	1,077	12,3	12,10
2022	10,981	1,310	21,63	11,93
2023	8,962	954	-27,18	10,64
2024	10,029	1,043	9,33	10,40

*Source: Compiled by the author based on data from the Vietnam Association of Seafood Exporters and Producers (VASEP)*

During the 2015–2024 period, the landscape of Vietnam's seafood exports to the EU reflected a highly volatile trajectory, underscoring a substantial reliance on exogenous socio-economic and technical determinants alongside intrinsic structural constraints within the industry. The year 2015 commenced with an export turnover of merely 1.175 billion USD, recording a negative growth rate of –17.75%. This marked a formidable year characterized by a simultaneous contraction in the EU's import demand and the competitive capacity of Vietnamese enterprises. It was a juncture where the Vietnamese seafood sector began to acutely feel the ramifications of stringent food safety controls under EU standards, while its export product structure remained heavily skewed towards low-value commodities, heavily dependent on wild-caught fisheries with a dearth of deep-processed products. The profound negative growth epitomized the deterioration in both market demand and the ability to sustain market share amidst intensifying competition from major producing nations.

From 2016 to 2018, the market witnessed a substantial recovery. Export turnover climbed to 1.219 billion USD in 2016 and 1.481 billion USD in 2017, corresponding to growth rates of 3.75% and 21.49%, respectively. The exceptional surge in 2017 mirrored the EU's expanding propensity for seafood imports following its economic revitalization, concurrently demonstrating the enhanced supply capacity of Vietnamese exporters. During this phase, numerous enterprises ramped up investments in processing capabilities, elevating product quality and progressively aligning with the EU's exacting technical standards. High turnover was sustained in 2018, reaching 1.472 billion USD, albeit with the growth rate reverting to a marginal negative of –0.61%. This indicated early signs of market saturation and the tightening of EU trade barriers. Notably, the imposition and escalating impact of the IUU (Illegal, Unreported, and Unregulated) "yellow card" since late 2017 exposed the Vietnamese seafood sector to heightened risks concerning customs clearance and raw material traceability.

Advancing into 2019, the downturn became more pronounced, with turnover contracting to 1.297 billion USD and the growth rate plummeting to –11.89%. This elucidated the mounting repercussions of the IUU yellow card on export operations, particularly for wild-caught product categories. Against the backdrop of enforcing rigorous environmental and sustainable development mandates, the EU intensified its scrutiny over the origin of imported seafood. This inevitably prolonged customs clearance procedures, inflated compliance costs, and eroded the competitive advantage of Vietnamese enterprises. Furthermore, the ascendance of formidable competitors such as Ecuador (in the shrimp segment) and India alongside Thailand (in frozen fish and seafood), leveraging pricing advantages and economies of scale in their supply chains, significantly compressed Vietnam's export market share within the EU.

The year 2020 emerged as a severe inflection point for the entire period, as turnover plummeted to its nadir of 959 million USD, translating to a stark negative growth rate of –26.06%. The EU's economic recession induced by the COVID-19 pandemic, coupled with global supply chain bottlenecks and exponential surges in logistics overheads, catalyzed a dual shock that rendered seafood export operations virtually paralyzed for several months. Additionally, enterprises were burdened with exorbitant warehousing, testing, and freight costs, while purchasing power within the EU plummeted due to shifting consumer behaviors amid pervasive uncertainty. This phase most palpably exposed the acute vulnerability of Vietnam's seafood sector to exogenous macro-environmental shocks and its disproportionate reliance on wild-caught materials, which are fraught with IUU compliance risks.

Following this profound slump, seafood exports to the EU embarked on a recovery trajectory from 2021 as the European economy reopened and consumer demand rebounded. Export turnover attained 1.078 billion USD, reflecting a positive growth of 12.30%. Specifically, 2022 recorded a robust acceleration, propelling the turnover to 1.310 billion USD with a growth rate of 21.63%—placing it among the highest throughout the analyzed timeframe. This served as a compelling testament to the positive

ramifications of the EVFTA, wherein numerous Vietnamese seafood commodities benefited from tariff preferences, thereby bolstering competitiveness and broadening market access. Furthermore, the holistic restoration of the logistics ecosystem and robust demand from European supermarket chains catalyzed the export surge. Nevertheless, this resurgence was predominantly transient, catalyzed by post-pandemic market recalibration rather than profound internal structural reforms within the Vietnamese seafood industry.

The year 2023 perpetuated this challenging climate, as turnover receded to 954 million USD—a level roughly analogous to the 2020 nadir within the 2015–2024 cycle—with the growth rate nose-diving to –27.18%, the most precipitous decline post-pandemic. The primary catalysts were rooted in the EU's economic crisis, characterized by rampant inflation, soaring energy costs, and contracted discretionary spending, which collectively decimated seafood import demand. Concurrently, the EU relentlessly tightened parameters pertaining to the environment, sustainable development, and traceability. In contrast, the adaptive capacity of Vietnamese enterprises remained constrained, particularly regarding the governance of fishing operations and aquaculture zone certification. This exacerbated the operational pressures on enterprises and precipitated a decline in their competitive stature.

Transitioning into 2024, export turnover experienced a modest rebound to 1.043 billion USD, registering a growth rate of 9.33%. This mirrored a tentative recovery in consumption following the EU's phase of economic austerity. Nonetheless, this recovery remained subdued and insufficient to steer the market back to the robust growth trajectories witnessed in 2016–2018 or 2021–2022. This trajectory implies that the EU market continues to harbor formidable barriers, with consumer demand undergoing rigorous restructuring to prioritize green, clean, and sustainable products underscored by transparent socio-environmental accountability.

Aggregating the 2015–2024 timeframe, the sheer scale of Vietnam's seafood exports to the EU generally expanded but exhibited profound volatility. It peaked during favorable macroeconomic windows, suffered precipitous contractions during crises, and exhibited erratic recoveries, thereby reflecting a lack of sustainability and an acute dependence on exogenous variables. Although the EVFTA injected a robust growth impetus, its positive impacts were insufficient to offset systemic constraints such as IUU compliance, traceability deficits, reliance on low-value outputs, and escalating competitive pressures. This strongly suggests that to sustain a stable growth paradigm in the forthcoming years, the Vietnamese seafood sector must undergo a robust paradigm shift towards sustainable development, stringent adherence to EU green standards, enhanced traceability, product diversification, and the optimization of value-added generation.

The proportional share of Vietnam's seafood export turnover to the EU relative to its total seafood export turnover during the 2015–2024 period exhibited a relatively consistent secular decline. Whereas the EU market accounted for approximately 17.91% of the total turnover in 2015, this figure dwindled to a mere 10.40% by 2024. Consequently, within less than a decade, the EU's relative market share contracted by nearly 7 percentage points. This signifies a monumental structural pivot in Vietnam's seafood export market portfolio—transitioning the EU from a dominant primary destination to a relatively "diminished" position compared to alternative markets.

The 2015–2017 phase can be characterized as a peak and relatively stable epoch for the EU market within Vietnam's seafood export structure. The proportion hovered around the 17–18% threshold (17.91% in 2015; 17.29% in 2016; 17.80% in 2017), indicating that the EU was not solely a traditional market but also a fundamental "pillar" in the export strategy. The preservation of this high and stable proportion reflected two dimensions: (i) the EU's sustained import demand for Vietnam's staple commodities (shrimp, Pangasius, tuna, cephalopods, etc.); and (ii) the export turnover growth rate to the EU was largely commensurate with the aggregate growth rate of the entire industry. In essence, during this phase, the EU expanded "in tandem" with the broader export landscape, cementing its status as one of the preeminent markets for Vietnamese seafood.

From 2018 to 2019, the chart registered a gradual, albeit not abrupt, downward trajectory in proportion: descending from 16.72% in 2018 to 15.18% in 2019. Crucially, this was not a phase characterized by an acute absolute decline in export turnover to the EU; rather, the underlying dynamic was that Vietnam's aggregate seafood export turnover grew at a swifter pace than its localized exports to the EU, thereby diluting the EU's slice of the "total pie". This implies that Vietnamese enterprises had proactively initiated a robust market diversification strategy, pivoting towards rapidly expanding regions such as the US, China, South Korea, or CPTPP member states. Conversely, the EU—with its escalating and rigorous mandates on quality, traceability, IUU, and environmental standards—became increasingly arduous to penetrate further. Stated differently, the EU transitioned from a primary growth engine to a "stable but sluggish-to-breakthrough" market.

The year 2020 marked a pivotal turning point as the proportion sharply plunged to 11.40%—the most profound contraction in the entire period. The macroeconomic context of the COVID-19 pandemic, supply chain ruptures, surging logistics costs, and the collapse of the out-of-home dining (HORECA) sector in the EU severely impaired seafood imports from Vietnam. Even as Vietnam's overall seafood export turnover maintained relative resilience, exports directed to the EU severely underperformed compared to other markets, precipitating a "fractured" decline in the EU's proportional share.

Progressing to 2021–2022, the proportion exhibited a marginal recovery to 12.40% before slightly receding to 11.93%. This demonstrated that the favorable impacts of the EVFTA and post-COVID adaptation processes succeeded in arresting further

market share erosion; however, this resurgence lacked the momentum to propel the proportion back to the 15–18% "zone" observed prior to 2018.

The concluding phase of 2023–2024 consolidated the secular trend wherein the EU progressively evolved into a critical, yet no longer dominant, market: the proportion continued to slide to 10.64% (2023) and 10.40% (2024). It is imperative to note that export turnover to the EU during this phase did not "evaporate"; in fact, the absolute value was sustained around the 1 billion USD benchmark. Nevertheless, Vietnam's aggregate seafood export turnover expanded significantly owing to breakthroughs in non-EU markets, thereby "diluting" the EU's relative market share. This elucidates that the seafood industry's market strategy is gravitating towards a multipolar architecture, wherein the EU remains a "strategic pillar" but has relinquished the monopolizing dominance it held during the study's inception.

In summary, the sheer magnitude of Vietnam's seafood exports to the EU over the 2015–2024 period was sustained at an elevated level, perennially oscillating between 1 and 1.5 billion USD annually; however, its proportional representation in the aggregate export turnover continuously diminished from roughly 17–18% to merely over 10%. This encapsulates a critical structural realignment within the industry's market architecture: the EU retains its status as a high-value, stringent-requirement market, yet the accelerated growth velocities of alternative markets have constricted the EU's relative prominence. The declining proportion does not equate to a severe deterioration in the scale of exports to the EU, but rather predominantly signifies Vietnam's successful and expansive penetration of non-EU markets. This functions as a dual indicator: a testament to triumphant market diversification, juxtaposed with a cautionary signal regarding the gradual erosion of market positioning in a highly demanding yet immensely lucrative market capable of yielding maximal value addition for Vietnam's seafood sector.

Between 2017 and 2023, the EU consistently maintained its stature as one of the most paramount export destinations for Vietnamese seafood, characterized by massive consumption demand and rigorous quality requisites, particularly concerning traceability and food safety standards. The export product portfolio of Vietnam to this market is highly diversified, encompassing shrimp, *Pangasius* (catfish), tuna, cephalopods (squid and octopus), bivalve mollusks, and an array of other marine species. Among these, shrimp and *Pangasius* serve as the flagship categories, commandeering the highest proportions of total seafood export turnover to the EU. Specifically, shrimp accounted for an average proportion of approximately 52.67% during the 2017–2023 period, reaffirming its vanguard role and its status as the most lucrative revenue generator in this market. *Pangasius* secured the runner-up position with an average proportion of roughly 14.55%, denoting its steady and incrementally expanding contribution, particularly during the years benefiting from EVFTA preferences. The remaining categories, including tuna, cephalopods, and bivalve mollusks, maintained a proportion ranging from 5–14% depending on the year, systematically contributing to the diversification of Vietnam's export portfolio to the EU.

### **3. THE CURRENT LANDSCAPE OF DIGITAL TRANSFORMATION APPLICATION IN VIETNAM'S SEAFOOD EXPORT SUPPLY CHAIN MANAGEMENT TO THE EU MARKET**

Vietnam's seafood export operations to the EU are navigating a highly digitized commercial environment, meticulously governed by Europe's rigorous regulatory frameworks. The ceaseless evolution of legal mandates, safety protocols, and sustainability accountabilities has exerted immense pressure on Vietnamese enterprises to holistically upgrade and digitalize their supply chain management capabilities. This macroscopic context delineates the critical catalysts propelling the digital transformation trajectory within the seafood sector.

One of the most profound determinants impacting the seafood supply chain is the EU's food safety control apparatus, most notably the Rapid Alert System for Food and Feed (RASFF). In recent periods, alerts pertaining to Vietnamese seafood have predominantly centered on chemical residues and non-compliant traceability dossiers. Such incidents starkly expose the bottlenecks inherent in conventional data management modalities and information transparency among supply chain actors—spanning from aquaculture zones, aggregation, and transportation to processing and export. The EU's rigorous verification mandates necessitate that data be comprehensively and accurately archived, readily verifiable, and capable of seamless cross-chain reconciliation. This unequivocally compels enterprises to pivot from archaic manual record-keeping to sophisticated digital management ecosystems.

The EU's imposition of an IUU (Illegal, Unreported, and Unregulated) "yellow card" on Vietnam's wild-capture fisheries since 2017 has functioned as a systemic driver, accelerating the digitalization of raw material governance. To adhere to the European Commission's (EC) recommendations, Vietnam is obligated to deploy Vessel Monitoring Systems (VMS), construct a unified national fisheries database, implement electronic catch logbooks (e-logbooks), and standardize port-level output control protocols. These stipulations mandate the electronic execution of data collection and administration to guarantee irrefutable origin traceability from the point of harvest—an indispensable prerequisite for sustaining export flows to the EU. Consequently, the "yellow card" has emerged as a primary catalyst for the genesis and proliferation of digital governance platforms across the supply chain.

The overarching European market landscape further shapes the digital transformation paradigm. The EU represents a consumer demographic acutely invested in sustainability, the legality of sourcing, and the environmental footprint of seafood

production. Major EU importers and retail conglomerates increasingly compel suppliers to comply with stringent certifications such as ASC, BAP, and GlobalGAP, alongside advanced traceability frameworks like the Global Dialogue on Seafood Traceability (GDST). These standards mandate the real-time recording and cross-chain integration of a voluminous array of data metrics. Consequently, digital transformation is no longer optional but an absolute prerequisite for delivering the transparent, comprehensive, and globally standardized data required by the market.

Simultaneously, global technological breakthroughs in supply chain management have facilitated accessible and viable digitalization avenues for Vietnamese enterprises. Systems such as ERP (Enterprise Resource Planning), MES (Manufacturing Execution Systems), and WMS (Warehouse Management Systems), alongside IoT platforms for cold chain monitoring, blockchain technology for preserving data integrity, and big data analytics, have become increasingly ubiquitous due to declining deployment costs and high customization flexibility. These technological architectures augment precise data acquisition, mitigate operational discrepancies, and fortify interconnectivity among supply chain constituents. Within the seafood sector—where the flow of materials is exceptionally susceptible to temperature fluctuations, transit durations, and spoilage risks—these technologies are absolutely indispensable for minimizing losses and safeguarding product reliability prior to EU market entry.

At the macro-national level, an array of Vietnamese policies and initiatives are bolstering the sector's digital pivot. The deployment of electronic customs systems, comprehensive databases for aquaculture and fisheries, digitalized vessel management programs, and concerted efforts by the Ministry of Agriculture and Rural Development (MARD) alongside VASEP to standardize traceability have laid a robust foundational infrastructure for enterprises to architect digital supply chains. A cohort of large-scale enterprises has already operationalized ERP systems, automated processing lines, IoT-monitored cold storage facilities, and batch-level QR code traceability. This demonstrates a palpable, albeit unevenly distributed, digital transition across different enterprise scales.

Fundamentally, the momentum driving digital transformation in seafood export supply chain management to the EU is forged at the convergence of increasingly stringent legal mandates, the market's uncompromising expectations for transparency, global technological advancements, and domestic policy orientations. These converging forces dually exert transformative pressure on enterprises while simultaneously unlocking unprecedented opportunities to elevate governance capabilities, optimize operational overheads, and magnify the competitive advantage of Vietnamese seafood within the European theater.

The Sourcing/Harvesting/Aquaculture Stage marks the genesis of the export seafood supply chain and holds decisive implications for traceability compliance as mandated by the EU. Empirical observations indicate that digital adoption at this juncture in Vietnam remains highly asymmetric among producers. A segment of concentrated aquaculture zones and high-capacity fishing vessels have successfully integrated e-logbooks, VMS, and aquaculture databases to facilitate management and combat IUU fishing. Nevertheless, the overwhelming majority of smallholder farmers and artisanal vessels continue to rely on manual production management. This reliance generates highly fragmented, discontinuous data streams, severely impeding information integration with downstream nodes in the export supply chain.

The Primary Processing Stage at fishing ports or aquaculture farms encompasses sorting, cleaning, initial preservation, and raw material authentication. This is a critical juncture for safeguarding product quality and ensuring the validity of EU-bound export dossiers. In practice, the penetration of digital transformation here remains constrained. While select ports and enterprises have adopted shipment management software, QR codes, or barcodes for traceability, primary processing in numerous localities remains tethered to manual documentation. The absence of a unified digital data repository exacerbates the risk of informational discrepancies and compromises holistic supply chain management efficacy.

The First-Mile Transportation Stage is tasked with conveying raw materials from harvesting zones to processing facilities or transit hubs, demanding an uncompromising maintenance of the cold chain. The current reality reveals that while certain enterprises have leveraged GPS technology, thermal sensors, and fleet tracking software to govern quality and transit times, the penetration of these digital solutions is far from ubiquitous, particularly among fragmented transport providers. The bulk of first-mile logistics operates without real-time monitoring architectures, thereby elevating the risk of material degradation and complicating risk management within the export chain.

The Processing and Packaging Stage exhibits a markedly higher degree of digital maturity compared to upstream nodes, particularly among elite export enterprises. Numerous corporations have deployed comprehensive ERP frameworks, MES software, automated quality control, and sophisticated traceability modules to satisfy the EU's exacting standards. Conversely, for small and medium-sized enterprises (SMEs), digitalization remains rudimentary, plateauing at basic administrative software. This technological chasm between enterprises precipitates a profound lack of synchronization across the broader export supply chain.

Export Cold Storage plays an instrumental role in preserving seafood integrity prior to international circulation. Real-world dynamics indicate that several state-of-the-art cold storage facilities have integrated WMS and IoT sensors for meticulous temperature and humidity surveillance, guaranteeing cargo quality. Conversely, a multitude of traditional cold storage units continue to operate via manual or semi-automated paradigms, critically lacking data interoperability with processing enterprises and logistics providers. This severely constricts inventory management efficacy and dampens agile responsiveness to EU market fluctuations.

The Export Logistics Stage encompasses international freight, customs clearance, and product distribution into the EU market. Recently, a contingent of enterprises has embraced digital logistics platforms, e-documentation, and container tracking systems to amplify transparency and compress transaction costs. However, from a macro perspective, the digital transformation intensity within Vietnam's seafood export logistics continues to lag behind developed nations. The prevailing lack of data integration across supply chain entities dilutes overall systemic efficiency and fundamentally undermines the competitiveness of Vietnamese seafood within the EU market.

#### **4. STRATEGIC IMPERATIVES FOR ACCELERATING DIGITAL TRANSFORMATION IN SUPPLY CHAIN MANAGEMENT OF VIETNAM'S SEAFOOD EXPORTS TO THE EU MARKET**

First, prioritize the development of a comprehensive and synchronized traceability architecture. Based on the empirical model's findings, which identify Traceability (TRA) as the most impactful determinant of seafood SCM efficacy, enterprises must designate this as the paramount pillar in their digital transformation strategy. In the context of the EU's increasingly stringent regulatory frameworks concerning food safety, combatting Illegal, Unreported, and Unregulated (IUU) fishing, environmental protection, and sustainable development, the capacity for comprehensive, accurate, and transparent product data retrieval has become an absolute prerequisite for Vietnamese seafood to sustain and expand its market share. Consequently, enterprises must invest in a holistic digital traceability ecosystem encompassing the entire supply chain—from aquaculture and harvesting to processing, distribution, and export. The deployment of cutting-edge technologies such as blockchain, QR codes, and electronic logbooks (e-logbooks) not only augments data reliability but also profoundly mitigates the risks of informational fraud, bolsters quality control capabilities, and fortifies the confidence of EU importing partners.

Second, fortify the degree of supply chain integration via digital platforms to optimize stakeholder coordination. The degree of Supply Chain Integration (INT) emerges as the second most influential determinant of SCM efficacy. This empirical result elucidates that managerial effectiveness is not solely contingent upon the intrinsic capabilities of isolated enterprises, but is inextricably linked to the magnitude of interconnectedness and information sharing among all chain actors—spanning aquafarmers, processing entities, logistics providers, and importing partners. Therefore, seafood enterprises must accelerate the adoption of integrated digital platforms to synchronize data pertaining to raw materials, production, inventory, and transit. This integration is instrumental in minimizing supply chain disruptions, elevating collaborative efficiency, and optimizing holistic operational performance, particularly when catering to the EU market, which dictates uncompromising mandates on delivery schedules and product integrity.

Third, elevate data analytics and exploitation capabilities within seafood supply chain operations. Given the positive correlation between Data Analytics Capability (ANA) and SCM efficacy, seafood enterprises must systematically transition from experience-based heuristic management to a robust data-driven governance paradigm. In practice, seafood supply chain operations generate voluminous datasets encompassing aquaculture yields, raw material quality, production overheads, inventory levels, logistics dynamics, and EU market demand fluctuations. Absent effective analysis and exploitation, this data remains inert and fails to yield actionable insights for executive decision-making. Hence, enterprises must invest in sophisticated data acquisition and analytical frameworks, progressively deploying analytical tools to refine demand forecasting, optimize inventory, exert rigorous quality control, and compress operational costs. Concurrently, it is imperative to prioritize the training and development of a human capital base proficient in advanced data analytics, thereby cultivating a pervasive data-centric decision-making culture. Elevating analytical competencies will empower enterprises to proactively navigate the volatilities of the international market and augment overall supply chain resilience.

Fourth, systematically accelerate the deployment of automation across critical nodes of the seafood supply chain. Although empirical findings indicate that Automation (AUTO) exerts a comparatively lower impact than other determinants, it remains a vital strategic imperative for boosting productivity, mitigating reliance on manual labor, and enhancing manufacturing stability. Enterprises should orchestrate automation rollouts aligned with a pragmatic roadmap, prioritizing highly repetitive operations that demand rigorous precision—such as processing, packaging, cold storage governance, and export order fulfillment. Automation not only compresses labor expenditures but also fundamentally elevates the stability and uniformity of product quality, thereby more adeptly satisfying the EU market's exacting technical parameters.

Fifth, progressively actualize a robust digital technological infrastructure to provide a foundational bedrock for overarching SCM digital transformation initiatives. While Digital Infrastructure (INF) exhibits the lowest relative impact within the model, it unequivocally serves as the foundational prerequisite enabling the effective execution of all aforementioned solutions. Seafood enterprises must systematically channel investments into SCM software architectures, Enterprise Resource Planning (ERP) systems, cloud computing platforms, and centralized databases. The consolidation of digital infrastructure not only scales the capacity for data storage, processing, and dissemination but also cultivates an ecosystem where enterprises can seamlessly interconnect with all other supply chain constituents, seamlessly bridging the gap from local aquafarmers to international logistics providers and EU importers.

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