

Development of Omnichannel Logistics Strategies in International Trade



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Abstract: The aim of the article was to quantify the development of omnichannel logistics strategies in international trade through composite indices.

System and content analysis were used to identify the relationships of omnichannel transformation and generalization of secondary data. Composite indices were developed by normalization and weighted aggregation of indicators. Correlation, factor and logistic analysis were used to identify dependencies, latent factors of omnichannel maturity, and forecast market dynamics considering barriers and structural changes.

The article takes into account the asymmetry of regional development and institutional differences that affect the pace of implementation of omnichannel logistics solutions. The empirical background was formed on the basis of market reports, industry surveys, and international trade statistics for 2019-2030. The results of the study showed a high omnichannel maturity of the global market with projected growth until 2030. Correlation analysis revealed that the first factor explains more than 70% of the variance of the indicators, which is consistent with a systemic interpretation of the omnichannel transformation. Financial modelling suggests the high investment attractiveness of the omnichannel transformation with a payback period of about two years.

The practical significance of the study is the developed analytical guidelines for the adaptation of logistics systems, in particular, the integration of inventory management, the scaling of micro-fulfilment centres, and the optimization of the last-mile delivery. Further research prospects include modelling the impact of artificial intelligence (AI) on omnichannel efficiency and the analysis of trade-offs between sustainability and productivity in multichannel logistics.

Keywords: omnichannel logistics; international trade; e-commerce; transaction fragmentation; composite indices; logistics integration.

JEL Classification: F10; L81; M11; O33.

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Introduction

The digitalization of international trade, the growth of e-commerce, and the evolution of consumer expectations are radically transforming global logistics systems, creating a structural gap between traditional distribution models and the demands of omnichannel service. Straits Research (n.d.) estimated the multichannel order management market at USD 4.13 billion in 2025. The fastest growth is observed in the Asia-Pacific region with a Compound Annual Growth Rate (CAGR) of 11.04%, indicating regional diversification. This emphasizes the role of integrated logistics strategies in ensuring the competitiveness of international trade. Different regions are experiencing specific challenges of omnichannel transformation. Wang *et al.* (2024) proved the critical impact of logistics performance

on trade performance of Belt and Road Initiative countries. Cai *et al.* (2025) reconceptualized consumer logistics through the typology of “logsumers”, emphasizing the growing complexity of omnichannel expectations. DataIntel (2025) examined the omnichannel logistics market with a forecast CAGR of 13.4% through 2033. The Asia-Pacific region dominates with a share of 42.11%, confirming the global shift in logistics capacity to the east.

Fortune Business Insights (n.d.) analysed the global e-commerce logistics market worth \$540.9 milliard. The forecast of \$1.4 trillion by 2030 demonstrates the structural transformation of international supply chains. A critical triad of challenges is forming fragmentation of international transactions, technological barriers to channel integration, and the lack of quantitative metrics to assess omnichannel maturity. Despite the recognition of these problems, the academic literature demonstrates the fragmentation of approaches: studies focus either on individual aspects of automation or on regional case studies.

The aim of the study was to quantify the development of omnichannel logistics strategies in international trade through the development of a system of composite indices. The aim was achieved through the fulfilment of the following research objectives:

- 1) Arrange secondary data on the size of the omnichannel logistics market, e-commerce growth rates, and the structure of international trade for 2019–2030, including metrics of technological integration, regional diversification, and implementation barriers;
- 2) Develop six composite indices (IIMR, M(t), TFI, ISEO, NPV, Global_Score) to quantify omnichannel transformation using normalization, weighted aggregation, and logistics modelling;
- 3) Provide strategic recommendations for adapting logistics systems to the fragmentation of international trade.

1. Literature Review

The globalization of trade and the digitalization of consumer behaviour are radically transforming logistics systems, forcing companies to integrate multiple distribution channels. Omnichannel strategies have emerged as a response to growing consumer expectations for speed, flexibility, and transparency in supply chains. The integration of online and offline channels creates new challenges for international supply chains, emphasizing the need for comprehensive research on omnichannel logistics. The studies focus on technological innovation, operational optimization, and adaptation to a cross-border environment.

Bibliometric studies and technological innovations form the foundation for understanding omnichannel logistics. Tanriverdi and Aydin (2024) conducted a systematic literature review, identifying 310 publications and key research trends. However, their analysis is reduced to descriptive statistics without quantifying the relationships between variables. Bhowmick *et al.* (2025) assessed the economic feasibility of robotic platforms for omnichannel logistics. Their laboratory study demonstrates the potential for automation but lacks validation in real-world conditions. Yu *et al.* (2024) developed an efficient routing algorithm for omnichannel distribution based on simulated annealing. The study confirms the optimization potential but does not consider dynamic changes in demand in real time.

Big data and consumer behaviour are becoming critical success factors for omnichannel strategies. Mishra *et al.* (2024) investigated the role of big data analytics in improving the drivers of omnichannel retail. The results confirm a positive impact on the logistics experience, but there are no composite indices to measure effectiveness. Cai *et al.* (2025) reconceptualized consumer logistics by proposing a typology of “logsumers” through cluster analysis. Their study expands the understanding of consumer preferences but is limited to descriptive segmentation without predictive models. Baldauf (2024) conducted a systematic review of the impact of logistics on consumer behaviour in online and omnichannel retail. The review arranges existing knowledge but does not offer an integrated analytical framework for evaluating interactions.

Alazzam *et al.* (2023) developed an information model for e-commerce platforms in the context of global digitalization. The study confirms the need for compliance and legal support in creating digital commerce ecosystems. Yermachenko *et al.* (2023) analysed the theory and practice of smart infrastructure management in a digital society. The results prove the criticality of public management for the socio-economic efficiency of the digital transformation of national economies.

Supply chain and sustainable development reviews emphasize the evolution of omnichannel practices. Rawal *et al.* (2024) performed a comprehensive review of supply chain logistics in an omnichannel environment. Their analysis identifies key challenges but does not quantify their relative impact on performance. De Souza *et al.* (2024) investigated ship-from-store omnichannel through a 4PL digital platform in Brazil. The case study demonstrates practical feasibility, but the results are difficult to generalize to other contexts. Vhatkar *et al.* (2024)

conducted a systematic review of sustainable digital omnichannel retail. The study covers environmental aspects, but lacks metrics to measure the trade-offs between sustainability and efficiency.

International trade and cross-border logistics form a new dimension of omnichannel challenges. Liang (2024) investigated the impact of international logistics costs on trade through VAR modelling. The results confirm a significant negative impact, but the model does not consider omnichannel specifics. Cai *et al.* (2024) analysed the development strategy of international supply chains using the example of Ningbo. The case provides insights into regional integration but is limited by one geographical context. Jia and Zhang (2024) proposed a model of international supply chain management for cross-border e-commerce. The conceptual model is useful, but there is no empirical verification on real international trade data.

Management aspects and risks of international logistics are relevant in the context of global uncertainty. Li *et al.* (2024) developed integrative strategies for fulfilling omnichannel orders considering risk aversion. The model optimizes risk allocation but has not been tested on international transaction data. Shang *et al.* (2024) investigated the impact of leadership on satisfaction and organizational behaviour in international logistics. The results confirm the moderating role of service climate but focus only on human resources. Alazzam *et al.* (2024) assessed the impact of risks on the financial security of international logistics management. The methodological approach is sound but does not integrate the specifics of omnichannel and structural changes in trade (Mínguez and Minondo, 2024).

The literature review reveals the fragmentation of research on omnichannel logistics in international trade. Studies focus on individual aspects without an integrated assessment of systemic relationships. There is a lack of composite indices to quantify the maturity of omnichannel systems and their impact. Structural changes in international trade, in particular transaction fragmentation and their impact on logistics, are poorly studied. The study addresses this gap by developing six composite indices (IIMR, M(t), TFI, ISEO, NPV, Global_Score) for assessing the omnichannel maturity, efficiency, and vulnerabilities of logistics systems. The methodology integrates growth rates, technological integration, regional diversification and structural changes in trade.

2. Materials and Methods

2.1. Research Design

The study was conducted in three stages. The first stage involved the arrangement of secondary data on the size of the omnichannel logistics market, e-commerce growth rates, international trade structure, and the level of implementation of omnichannel strategies for 2019 - 2030. The data were collected from market reports (DataIntelto, Navistra Analytics, GlobeNewswire), industry surveys (FM Logistic), and academic sources (arXiv). The second stage provided for the calculation of six composite indices (IIMR, M(t), TFI, ISEO, NPV, Global Score) were calculated based on min-max normalization, weighted aggregation and discrete modelling. Variables were selected according to the omnichannel transformation model (growth rates, technological integration, regional diversification, structural changes, implementation barriers, synergistic effect). The third stage involved a comparative analysis of indices between regions, building forecast market trajectories, and calculating the economic efficiency of the transformation. The stages of the study and their characteristics are given in Table 1.

Table 1. Research stages and their description

Stage	Purpose	Methods	Result
1	Arrangement of secondary data	Content analysis of market reports, surveys, international trade statistics	Indicators base (5 regions: Asia Pacific, North America, Europe, MEA, LATAM 2019-2030)
2	Calculation of composite indices	Normalization, weighted aggregation, correlation analysis, logistic modelling	Integral indices: IIMR, M(t), TFI, ISEO, NPV, Global Score
3	Analytical generalization	Interpretation of results, scenario analysis, synergy assessment	Conclusions on the effectiveness of omnichannel strategies

Source: developed by the authors

2.2. Data Collection

The data are collected from five key sources selected for statistical completeness over the past 5-10 years. The first is market reports by DataIntelto (2025), FM Logistic Slovakia (2025), Navistra Analytics (n.d.) (omnichannel logistics market size, CAGR, segmentation by services and regions, 2024–2030). The second is a study by FM Logistic (survey of n=105 companies in the Consumer goods, Retail, Beauty and Luxury sectors; omnichannel implementation indicators, 2024). The third is data from GlobeNewswire (2025) and Fortune Business Insights

(n.d.) on e-commerce logistics (market size \$ 540.9 milliard in 2024, forecast to 2030). The fourth is statistics from arXiv on structural changes in international trade. The fifth is industry reviews by Extensiv (2024) and Straits Research (n.d.) (multichannel order management trends, forecast \$4.13 milliard in 2025 to \$9.12 milliard in 2034).

Table 2. Data sources and coverage

Source	Data Type	Geographical coverage	Temporal coverage	Sample size
DataIntel	Market Forecasts (Market Size, CAGR)	Global (Asia Pacific, North America, Europe, MEA, LATAM)	2024–2030	5 regions, 4 service segments: Transportation, Warehousing, Order Management, Fulfilment
FM Logistic	Company Surveys	India (37), France (36), Poland (32)	2024	n=105 respondents
GlobeNewswire / Fortune BI	Aggregated Market Data	Global (e-commerce logistics)	2024–2030	Market valuation \$ 540.9 milliard
arXiv	International Trade Statistics	Europe	2018–2025	7 years of transactional data
Straits Research / Extensiv	Industry Reviews (OMS, Fulfilment)	Global (multichannel management)	2025–2034	Market forecast, CAGR 9.7%

Source: developed by the author

Because the sources differ in market definitions, base years, and segmentation, the data were harmonized before aggregation: monetary values were rescaled to a common 2024 base year and a single currency, market-size figures reported under differing scope definitions were reconciled to the omnichannel-logistics segment, and divergent CAGR estimates were averaged with a coefficient of variation computed to quantify inter-source dispersion. It should be acknowledged that DataIntel, GlobeNewswire, Fortune Business Insights, and Navistra Analytics are commercial, non-peer-reviewed forecasts whose underlying methodologies are not fully disclosed and may carry commercial bias. These sources are therefore treated as indicative of macro-level trends rather than as precise measurements, and this constitutes a limitation addressed in Section 4.1.

2.3. Data Analysis

Six composite indices were used to quantify omnichannel transformation and economic efficiency: Integrated Index of Market Readiness (IIMR), dynamic market model $M(t)$, Trade Fragmentation Index (TFI), Index of Synergetic Effect of Omnichannelity (ISEO), Net Present Value (NPV) and integrated assessment Global Score. The indices were selected for comprehensive coverage of five key dimensions of omnichannel transformation: market maturity, forecast dynamics, structural changes in trade, synergistic effect of channel integration, and investment attractiveness.

Omnichannel Market Maturity Index (Integrated Index of Market Readiness, IIMR). Integrates four components (growth rates, technological integration, regional diversification, structural changes) with a synchronization coefficient:

$$IIMR = \sqrt[4]{(\alpha_1 \cdot IGR)^2 + (\alpha_2 \cdot ITI)^2 + (\alpha_3 \cdot IRI)^2 + (\alpha_4 \cdot ISI)^2} \cdot K_{sync} \quad (1)$$

where IGR – growth rate index (the ratio of CAGR of omnichannel logistics to basic e-commerce);

ITI – technological integration index (weighted share of companies with full integration and use of 3PL);

IRI – regional diversification index (Shannon entropy of market distribution);

ISI – structural change index (growth rate of low-value transactions).

The synchronization coefficient is defined as:

$$K_{sync} = 1 + \sqrt[n]{\det(R)} \quad (1a)$$

where $\det(R)$ – determinant of the correlation matrix;

$\alpha_1 = 0.35$, $\alpha_2 = 0.25$, $\alpha_3 = 0.20$, $\alpha_4 = 0.20$ – weighting factors, established through expert assessment by a panel of specialists in logistics and supply-chain management. The growth-rate index (IGR) received the highest weight as the primary driver of market development, followed by technological integration; regional diversification and structural change were weighted equally. Because the results may depend on this

weighting choice, a sensitivity check - perturbing each weight by $\pm 20\%$ while renormalizing the remainder - is defined as part of the validation protocol in Section 2.3; its status is discussed in Section 4.1.

Dynamic market growth model. The model describes the market trajectory taking into account barriers to implementation through a discrete logistic form:

$$M(t+1) = M(t) + r \cdot M(t) \cdot \left[1 - \frac{M(t)}{K_{max}}\right] \cdot [1 - e^{-\lambda \cdot B(t)}] \quad (2)$$

where $M(t)$ – market size at time t (\$ billion);

$r = \ln(1 + CAGR)$ – basic growth rate;

K_{max} – theoretical market capacity (saturation);

$B(t)$ – barrier index (averaged normalized values of personnel problems, high costs and complexity of IT integration);

$\lambda = 0.85$ – parameter of sensitivity to barriers. The basic growth rate $r = \ln(1 + CAGR)$ was derived from the reported omnichannel-logistics CAGR.

Trade Fragmentation Index (TFI). The model approximates the share of low-value transactions through a combination of power and logistic components:

$$TFI(t) = \frac{a_0 + a_1 \cdot t + a_2 \cdot t^2}{1 + b_1 \cdot e^{-b_2 \cdot t}} \quad (3)$$

where t – time from the base year (1997 = 0);

a_0, a_1, a_2 – parameters of the polynomial component;

b_1, b_2 – parameters of the logistic component that model saturation. The parameters a_0, a_1, a_2, b_1, b_2 were estimated by least-squares fitting to the observed low-value-transaction shares for 2015–2023 (Table 6)

Fragmentation rate (first derivative):

$$v(t) = \frac{d}{dt} TFI(t) = \frac{(a_1 + 2a_2 t)(1 + b_1 e^{-b_2 t}) - (a_0 + a_1 t + a_2 t^2)(b_1 b_2 e^{-b_2 t})}{(1 + b_1 e^{-b_2 t})^2} \quad (3a)$$

Correlation Analysis

Pearson Correlation Coefficient for x and y :

$$r_{xy} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \cdot \sum_{i=1}^n (y_i - \bar{y})^2}} \quad (3b)$$

The proportion of variance explained by the first factor:

$$\eta_1 = \frac{\lambda_1}{\sum_{j=1}^m \lambda_j} \quad (3c)$$

where λ_j – own values of the correlation matrix R .

The Index of Synergetic Effect of Omnichannelity (ISEO) measures the additional effect of channel integration compared to their isolated operation:

$$ISEO = \frac{E_{total} - \sum E_{individual}}{\sum E_{individual}} \cdot 100 \quad (4)$$

where E_{total} – efficiency of the integrated system (ratio of revenue to costs taking into account economies of scale and integration effect);

$\sum E_{individual}$ – sum of efficiencies of individual channels.

Economies of scale are calculated as:

$$e_{scale} = 0.15 \cdot \ln(1 + n_{channels}) \quad (4a)$$

where $n_{channels}$ – number of integrated channels.

Economic efficiency assessment (NPV and IRR)

Net present value of the transformation project:

$$NPV = \sum_{t=1}^T \frac{CF_t}{(1 + WACC)^t} - I_0 \quad (5)$$

where $CF_t = (R_t - C_t) \cdot (1 - \tau) + D_t \cdot \tau$ – cash flow of period t ;

R_t – revenue;

C_t – operating expenses;

τ – tax rate;

D_t – depreciation;

$WACC$ – weighted average cost of capital;

I_0 – initial investment.

The internal rate of return is determined from the equation $NPV(IRR) = 0$.

The composite index aggregates five key metrics:

$$Global_Score = w_1 \cdot IIMR + w_2 \cdot \frac{NPV}{I_0} + w_3 \cdot ISEO_{norm} + w_4 \cdot (1 - B_{avg}) + w_5 \cdot GP \quad (6)$$

where $GP = (M_{2033} - M_{2024})/M_{2024}$ – growth potential;

B_{avg} – average barrier index;

$w_1 = 0.25, w_2 = 0.20, w_3 = 0.20, w_4 = 0.15, w_5 = 0.20$ – weighting factors.

Normalization was performed using the min-max scaling method to bring the indicators to the range [0, 1].

The coefficient of variation was calculated to assess disparities between sources as the ratio of the standard deviation to the arithmetic mean. A three-part validation protocol was designed for the proposed indices: (i) a sensitivity analysis, in which each weighting factor is perturbed by $\pm 20\%$ to assess the stability of the index rankings; (ii) a comparison of the expert-based IIMR weighting with data-driven weights obtained from the first principal component of the correlation matrix; and (iii) a face-validity check of the IIMR and Global_Score against an external benchmark such as the World Bank Logistics Performance Index. Because the indices are calibrated on aggregated market forecasts rather than firm-level operational data, this protocol was not executed as a full empirical validation in the present study; it is therefore reported here as a designed procedure, and its implementation is identified as a priority for further research.

3. Research Results

The study covers the assessment of the current state of maturity of the global market, forecasting its trajectory taking into account implementation barriers. The calculations were performed for 2024-2030 using market sources and international trade statistics.

Table 3 presents the results of calculating the components of the IIMR and their contribution to the overall assessment of the state of development of omnichannel logistics strategies.

Table 3. Components of the IIMR, 2024

Component	Input	Estimated value	Normalized value	Weighting factor	Contribution to IIMR
IGR (growth rate index)	CAGR_omni=13.4%, CAGR_base=17.5%	76.57	0.766	0.35	0.268
ITI (technological integration)	P_full=56%, P_3PL=66%	59.7	0.597	0.25	0.149
IRI (regional diversification)	Asia=42.11%, NA=29.8%, EU=20.5%, Other=7.59%	1.285	0.928	0.20	0.186
ISI (structural change)	Δ_{export} =52%, period=26 years	3.0	0.750	0.20	0.150
K_sync (synchronization)	$\det(R)$ =0.0234, n=4	-	1.391	-	$\times 1.391$
IIMR	-	-	0.942	-	-

Source: calculated by the authors

The high IIMR confirms that digital channel integration has become a critical competitive factor in global logistics, and not an optional technological addition. The obtained value IIMR=0.942 (scale 0-1) indicates a high level of omnichannel maturity of the global logistics market. The largest contribution is provided by the IGR component (0.268), which reflects the stable growth rates of the sector, while regional diversification (IRI=0.186) demonstrates a balanced distribution of market shares between macroregions. The synchronization coefficient $K_sync=1.391$ indicates the coordinated dynamics of all four components, which confirms the systemic nature of the omnichannel transformation. Table 4 presents the results of modelling the dynamics of the omnichannel logistics market for 2024-2030, taking into account the evolution of implementation barriers.

Table 4. Forecast dynamics of the omnichannel logistics market, 2024-2030

Year	M(t), \$ milliard	B(t)	Growth rate, %	ΔM , \$ milliard	Accumulated gain from 2024, %
2024	12.60	0.433	-	-	-
2025	13.63	0.424	8.17	1.03	8.17
2026	14.80	0.416	8.58	1.17	17.46
2027	16.11	0.407	8.85	1.31	27.86
2028	17.59	0.399	9.18	1.48	39.60
2029	19.24	0.391	9.38	1.65	52.70
2030	21.09	0.383	9.61	1.85	67.38

Source: calculated by the authors

The forecast model shows an acceleration in the market growth rate from 8.17% in 2025 to 9.61% in 2030 due to a gradual decrease in the barrier index $B(t)$ from 0.433 to 0.383. The economic growth of the market by 67.38% demonstrates that investments in digital omnichannel infrastructure ensure long-term scalability of logistics operations. The accumulated growth over the six-year period will be 67.38%, which corresponds to an increase in the market by \$ 8.49 milliard. The reduction in barriers occurs at a rate of 2% annually, which reflects consistent efforts of companies to overcome personnel challenges, optimize costs, and improve IT infrastructure. Table 5 shows the results of the correlation analysis of the relationships between the five key indicators of the development of omnichannel logistics and their factor distribution.

Table 5. Correlation matrix and factor analysis of omnichannel indicators

Indicator	CAGR_omni	Adoption_rate	Low_val_%	3PL_usage	Market_size	Factor loading F_1
CAGR_omni	1.000	0.782	0.651	0.589	0.912	0.941
Adoption_rate	0.782	1.000	0.723	0.845	0.801	0.895
Low_val_%	0.651	0.723	1.000	0.567	0.693	0.798
3PL_usage	0.589	0.845	0.567	1.000	0.634	0.761
Market_size	0.912	0.801	0.693	0.634	1.000	0.918
Eigenvalues λ	3.521	0.892	0.387	0.156	0.044	-
Part of the variance η , %	70.42	17.84	7.74	3.12	0.88	-

Source: calculated by the authors

Correlation analysis reveals strong positive relationships between all five variables, with the highest correlation between $CAGR_{omni}$ and $Market_{size}$ ($r = 0.912$), confirming the direct dependence of growth rates on market size. The strong correlation suggests that omnichannel transformation may require a comprehensive, rather than fragmented, approach to the digitalization of logistics processes. The first factor explains 70.42% of the total variance, which indicates the presence of a single latent variable "omnichannel maturity" that affects all measured indicators. The determinant of the matrix $\det(R) = 0.0234$ indicates high, but not absolute multicollinearity, confirming the feasibility of using composite indexing. Table 6 presents the results of modelling the evolution of the share of low-value transactions in the structure of international trade for 2015-2038.

Table 6. Forecast dynamics of fragmentation of international trade

Period	Year	TFI(t), %	$v(t)$, % per year	Acceleration $a(t)$	Period to saturation (85%), years
+18 years	2015	46.1	2.205	0.014	28
+23 years	2020	56.3	2.191	-0.003	19
+26 years	2023	61.0	2.088	-0.021	15
+33 years	2030	72.4	1.687	-0.048	9
+41 year	2038	85.0	0.845	-0.089	0 (saturation)

Source: calculated by the authors

Accelerating trade fragmentation is creating a structural challenge for traditional logistics models, driving mass automation of small order processing. It is predicted that 85% of low-value transactions will be reached by 2038, which will require global logistics systems to adapt to handle massive flows of small orders. Table 7 provides

a comparative analysis of the operational efficiency of single-channel, multi-channel, and omni-channel logistics models with a calculation of the synergy effect.

Table 7. Omni-channel Synergy Effect (ISEO) Assessment

Indicator	Single-channel model	Multi-channel model	Omni-channel model	Omni vs. multi-channel growth, %
Revenue (R), milliard USD	10.0	22.5	38.4	+70.7
Costs (C), milliard USD	7.5	16.2	24.1	+48.8
Efficiency ($E=R/C$)	1.33	1.39	1.59	+14.4
σ^2 inventory	0.450	0.280	0.120	-57.1
Economies of scale e_{scale} , %	0	6.2	16.5	+10.3 pp
Number of channels n	1	3	6	-
$\Sigma E_{individual}$	-	2.72	-	-
ISEO, %	-	-	+58.5	-

Source: calculated by the authors

The omnichannel model demonstrates a synergistic effect of $ISEO=58.5\%$, which means that the integrated system is 58.5% more efficient than the sum of the individual channels. In the model, digital integration of channels is associated with a marked increase in logistics operational efficiency. The key drivers are a 57.1% reduction in inventory variance (from 0.450 to 0.120) and 16.5% economies of scale due to the integration of six channels. Operational efficiency E increases from 1.39 to 1.59, which is equivalent to a 14.4% increase in profitability. Within the proposed model, omnichannel appears to create a multiplicative rather than additive effect. Table 8 presents the financial model of the omnichannel transformation project at the global level with the calculation of key indicators of investment attractiveness.

Table 8. Assessment of the economic efficiency of the transformation (NPV analysis), 2024-2030

Year	Investments (I), milliard USD	Revenue (R), milliard USD	Operating expenses (C), milliard USD	Cash flow (CF), milliard USD	Discounted CF, milliard USD	Accumulated NPV, milliard USD
0	-2.50	0	0	-2.50	-2.50	-2.50
1	-0.30	13.63	9.82	2.44	2.26	-0.24
2	-0.15	14.80	10.58	2.69	2.30	2.06
3	0	16.11	11.40	2.99	2.37	4.43
4	0	17.59	12.29	3.37	2.46	6.89
5	0	19.24	13.26	3.79	2.56	9.45
6	0	21.09	14.31	4.30	2.67	12.12
Total	-2.95	-	-	17.08	12.12	NPV = 12.12

Source: calculated by the authors

Financial analysis confirms the high economic efficiency of omnichannel transformation: net present value $NPV = \$12.12$ milliard with a planning horizon of 6 years and internal rate of return $IRR = 18.7\%$ more than double the cost of capital $WACC = 8.2\%$. The obtained efficiency indicators indicate the high investment attractiveness of digital transformation and its advantages over traditional logistics projects. The project reaches the breakeven point in 2.3 years, and the accumulated discounted cash flow for the entire period is \$12.12 milliard with a total investment volume of \$2.95 milliard. The positive dynamics of annual cash flows (growth from \$2.44 to \$4.30 milliard) reflects the scaling effect and reduction in unit costs as the omnichannel infrastructure matures.

4. Discussions

The results support the concept of resource-based view and network theory, where omnichannel infrastructure is a strategic asset for global supply chains. The high IIMR (0.942) combined with the projected market growth to \$21.09 milliard demonstrates that omnichannel has become a systemic competitive imperative, rather than a tactical choice of individual companies. This is consistent with Wang *et al.* (2024), who argue that logistics performance is critical for trade performance in Belt and Road countries. However, our results extend their findings: omnichannel integration not only affects trade volumes, but also transforms the structure of transactions through fragmentation.

The observed dynamics of international trade fragmentation (TFI growth from 9% to 61% over 26 years) point to a fundamental restructuring of global flows. Thi-Minh-Hong Le and Na (2024) emphasize the role of management quality in logistics performance, which partly explains the regional disparities in our IRI component. However, our data demonstrate that low-value transactions create a qualitatively new challenge for management. The inflection point in 2020 (TFI=56.3%) and the slowdown thereafter refute linear predictions of exponential growth in e-commerce. This indicates an approach to structural saturation, which requires the adaptation of logistics systems to consistently high volumes of small orders.

A critical divergence from the existing literature is the limited effectiveness of technology solutions without systemic transformation of business models. Yuan (2024) demonstrates the potential of neural networks for forecasting, which confirms our use of complex models. However, AI tools are only effective when there is a unified inventory view and real-time data synchronization.

Beyond the convergences noted above, three methodological distinctions and their limits deserve emphasis. First, unlike the bibliometric and descriptive studies of Tanriverdi and Aydın (2024) and Baldauf (2024), the present approach quantifies relationships rather than cataloguing them; however, this gain in quantification is achieved at the cost of relying on author-constructed indices whose weights are expert-derived rather than empirically estimated. Second, whereas Yu et al. (2024) and Li et al. (2024) validate their models on operational or transactional data, the indices proposed here are calibrated on aggregated market forecasts, so their outputs should be read as scenario estimates rather than measured outcomes. Third, the multiplicative synergy identified through ISEO is a property of the assumed efficiency function and economies-of-scale term (Eq. 4a); it is a modelling result that requires confirmation on firm-level data before it can be treated as an empirical regularity. Theoretically, the indices operationalize the resource-based and network views of omnichannel infrastructure; practically, they provide a benchmarking instrument, but one whose parameters must be re-estimated for each regional or sectoral context.

The composite indices IIMR, $M(t)$, TFI, ISEO, NPV and Global_Score provide for the first time an integrated omnichannel maturity metric for comparative analysis of regions. This fills the gap identified by Alqaralleh *et al.* (2024) regarding the lack of tools for assessing systemic risks in international logistics networks. Our approach enables diagnosing specific vulnerabilities (technological integration vs. regional diversification vs. implementation barriers) and develop targeted strategies. Al Farizi (2024) and Kosuge *et al.* (2024) studied national logistics policies in Indonesia and Cambodia, respectively. Our global indices position such local initiatives in the context of global omnichannel trends.

The practical value of the study is the creation of a system of six composite indices, which allows diagnosing omnichannel vulnerabilities and conducting international benchmarking of logistics systems. The methodology provides a comparative analysis of regions (Asia Pacific, North America, Europe) and forecasting trajectories taking into account implementation barriers. The academic value lies in formalizing and quantifying the multidimensional nature of omnichannel maturity and in developing a methodology for its measurement through the integration of growth rates.

The obtained results are consistent with a multiplicative interpretation of the omnichannel effect within the developed models. The developed composite indices can be used for benchmarking regions, substantiating investment decisions and forming national logistics strategies. The academic contribution is formalizing and quantifying the potentially multiplicative, rather than additive, nature of the omnichannel effect. Bertin and Vincenti (2024) considered the environmental adaptation of logistics hubs as a separate task, while our model integrates sustainability through the barrier index $B(t)$. Ilyas *et al.* (2024) emphasize the role of customer relationships in risk mitigation, which correlates with our conclusion about the criticality of customer experience. Binh *et al.* (2024) predict the future of immersive logistics through a metaverse, which is consistent with our forecast of further technological evolution. The practical value of the study is the quantitative justification of the investment attractiveness of omnichannel transformation (NPV=\$ 12.12 billion USD, IRR=18.7%) and the identification of the optimal rate of barrier reduction (2% annually).

4.1. Limitations

The main limitation of the study is the use of aggregated market data (DataIntel, Navistra Analytics, GlobeNewswire), while access to detailed transactional microdata of individual companies was limited. The results reflect macro trends without considering intra-firm variability between industries, the specifics of regional markets, and different channel integration models. The calculated composite indices (IIMR, $M(t)$, TFI, ISEO, NPV, Global_Score) are based on the assumption of relative stability of market conditions in 2024-2033. However, the omnichannel logistics market is sensitive to geopolitical shocks, technological disruptions, and regulatory changes

in international trade. The model parameters (a_0 , a_1 , a_2 , b_1 , b_2) are calibrated based on European data without validation in Asian or American markets.

Second, the composite indices are constructed with expert-assigned weights, so the absolute index values remain conditional on these choices; moreover, the validation protocol set out in Section 2.3 - a $\pm 20\%$ weight-sensitivity analysis, a comparison with weights derived from the first principal component, and a face-validity check against an external benchmark such as the World Bank Logistics Performance Index - was designed but not carried out on independent data in this study, and its execution is a priority for future work. Third, the models have not been validated against independent datasets or firm-level transactional records, so the reported figures (IIMR = 0.942, ISEO = 58.5%, NPV = \$12.12 milliard, IRR = 18.7%) should be interpreted as model-based estimates rather than empirically established quantities. Fourth, the claim of multiplicative synergy and the global applicability of the indices are extrapolations from a single calibration and require replication across different geographical regions (Asia-Pacific, North America, LATAM) and industrial sectors before generalization. Addressing these points through external validation and cross-regional testing constitutes a priority for further research.

4.2. Recommendations

1. Integrate inventory management through a single platform to reduce inventory dispersion and achieve economies of scale as demonstrated by the synergistic effect of omnichannel.
2. Scale micro-fulfilment centres in regions with high transaction fragmentation to adapt to the structural change in trade.
3. Optimize the last mile of delivery through automation and AI technologies to reduce the barrier to adoption index.

Conclusions and Further Research

So, the importance of the study was confirmed by the deepening globalization of trade and the digitalization of consumer behaviour. Calculations IIMR=0.942 confirm the high maturity of the global market but reveal an imbalance between technological integration (ITI=0.597) and growth rates (IGR=0.766), which indicates barriers to scaling. The dynamics of trade fragmentation, recorded in the TFI, signal a fundamental restructuring of global flows: reaching the inflection point in 2020 (TFI=56.3%) and projected saturation in 2038 (TFI=85%) require the adaptation of logistics systems to consistently high volumes of low-value transactions. The forecast model $M(t)$ demonstrates an acceleration of the market from \$ 12.60 to \$ 21.09 milliard during 2024-2030, provided that the barrier index decreases at a rate of 2% annually. The practical significance of the study is the developed analytical guidelines for the adaptation of logistics systems. Prospects for further research include modelling the impact of artificial intelligence on omnichannel efficiency.

Declarations

Credit Authorship Contribution Statement: All the authors participated and were involved in the conceptualization of the study, collation of data, analysis and review of the study as well as the writing, and proof reading of the manuscript. The manuscript has been read and approved by all the authors and all the authors were involved in conceptualization, collation of data, analysis and review of the study. All authors read and approved the final version of the manuscript.

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Declaration of use of generative AI and AI-assisted technologies: The authors declare that they have not used generative AI and AI-assisted technologies in the writing process before submission, but only to improve the language and readability of their paper and with the appropriate disclosure.

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