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Road Freight Quality Management in Industry 4.0: International Experience and Perspectives in Kazakhstan

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Abstract: This article explores the evolution of road freight transport in the context of Industry 4.0, focusing on management practices and technological advancements in transport and logistics companies' management information systems. By analyzing the latest international practices in road freight quality management within Industry 4.0 through regression and correlation methods, a model highlighting the significant influence of quality over price and institutional factors on the development of information and communication technology (ICT) goods exports was developed. It showcases how digital frameworks, alongside AI and big data, can enhance road freight quality in Industry 4.0, establishing a digital ecosystem for transport and logistics quality management. This study introduces a novel perspective on managing road freight transport as a digital ecosystem, offering insights into improving ICT goods exports in Kazakhstan by enhancing management information systems. It suggests a new management information system organization scheme to increase road freight quality management efficiency and ensure quality in Industry 4.0 settings.

Keywords: quality cargo transportation; digitalization transportation; ecosystems logistic services; Kazakhstan; ICT goods exports; management information systems; quality factors in transportation; auto freight transportation in industry 4.0

JEL Classification: F00; L91; M20; N70; R40

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1. Introduction

Industry 4.0 is a new technological landscape that has caused a profound transformation of global economic ties and relations. In this process, the sectoral and geographical structure as well as the procedure for the implementation of international trade are changing. Revolutionary technological shifts are taking place in the transport and logistics complex. AI makes it possible to solve complex problems of optimizing transport logistics with high efficiency; provides intelligent support to dispatch services of air, water, and rail transport; and manages dynamically developing unmanned vehicles.

International road freight transport deserves special attention because, in many cases, it is the most preferable because it provides fairly fast transportation times (possibility of delivering perishable goods, such as food); it guarantees the safety of goods (possibility of delivering fragile goods); it is unnecessary to reload goods (which is inevitable with a combination of several modes of transport), leading to a minimal risk of loss of goods; and targeted delivery in an urban environment—or even an indispensable mode of transport—is possible (Dadsena et al. 2023; Günay 2023; Zanne et al. 2023).

The noted advantages make road freight transportation a popular mode of transport for the international delivery of goods. It is worth noting that railway transport, which is a very popular alternative, has limitations due to its connection to the railway infrastructure

(this infrastructure is not laid everywhere and also has different characteristics in different countries due to differences in standards). These limitations are overcome with the help of road transport, which, due to its high flexibility, allows cargo to be delivered anywhere within the continents.

In the context of Industry 4.0, the need for this mode of transport is ever-increasing (Report Linker 2023) as the transnational network business with production and distribution units in different countries actively, the pace of economic growth is accelerating, production capacity is being increased through automation, and the volume of external sales of goods is increasing (Ainalis et al. 2023; Elgazar et al. 2023; Farchi et al. 2023; Heinbach et al. 2022b; Zhou and Wan 2022). It is also worth noting that road freight transportation is especially useful, convenient, and beneficial for the movement of goods among neighboring countries included in customs unions due to participation in regional integration associations of countries. Examples include the EU and the Eurasian Economic Union.

The complexity of the digital modernization of international road freight transport lies in the fact that it must be planned and carried out taking into account the specifics of all economic systems through which the route of movement of goods passes, including the country both of the sender and of the recipient as well as, as a rule, transit countries. In most modern international trade practices, the countries through whose territory the path of movement of goods lies are involved in the Fourth Industrial Revolution to varying degrees. This causes serious differences in their telecommunications, transport, and logistics infrastructure.

The problem is that the existing vision of road freight transport in Industry 4.0 presented in the available literature explains technological support (Afrianto et al. 2020) and design requirements for telematics systems (Heinbach et al. 2022a) but does not fully cover the issues of transport management. While the available literature indicates that road freight transport is being given a new role in the context of Industry 4.0 related to transport and logistics support for the development of ICT (information and communication technologies) goods exports, it is not clear from the available publications how it plays this role. In this regard, the question of this study is what factors in road freight transport determine ICT goods exports and how to manage the quality of road freight transport in the context of Industry 4.0. Thus, neither the key areas nor the preferred technologies for the management of road freight transport, which are of key importance for the development of ICT (information and communication technologies) goods exports, are known.

In this article, we seek to fill the indicated gap in the literature to clarify the vision of the development prospects of road freight transport in the conditions of Industry 4.0, considering the areas of management and management information systems organization technologies of transport and logistics companies. The chosen goal determined the formulation of this study's several objectives. The first task is to define factors that influence road freight transport, specifically the development of ICT goods exports.

The second task is to determine the prospects for developing IT goods exports in Kazakhstan through improving road freight transportation quality management.

The last and third task is related to the formation of a new strategic vision for improving road freight transportation in Industry 4.0—based on quality management in digital ecosystems of transport and logistics services.

The results of this study show the coverage of missed moments in determining the factors affecting international road freight transportation and the importance of qualitative indicators in the implementation of activities. Since Industry 4.0, digital technologies in every industry, in particular trucking by motor vehicle, have played a large role in automating and analyzing with new digital tools. The authors put forward questions and hypotheses, which in turn were confirmed by various analysis indicators during this study.

2. Literature Review

One of the main manifestations of the Fourth Industrial Revolution is the emergence of innovative information and communication technologies, from the high-speed internet (5G)

to the Internet of Things. Accordingly, industrial enterprises that produce ICT goods as the most high-tech ones have been established and are increasing their production capacities. ICT goods include computer equipment, electronics and their components, etc. (Mijailovic et al. 2022).

The advantages of road freight transportation for the delivery of internationally traded, that is, exported, ICT goods are the minimum risks of transportation as well as the possibility of implementing complex logistics schemes involving the shipment of part of the goods in different countries along the route and the ability to separate the transported goods into several warehouses within the city limits (Audonin et al. 2020; Günay 2023). Also, road transport follows its schedule (without referencing station, airport, or port schedules, for example), established by agreement between the customer and the contractor, and thanks to this, it can most fully fulfill the customers' wishes (Chatti 2020).

Therefore, Wang et al. (2022) and Woźniak et al. (2022) made a strong scientific argument that international road freight transport under Industry 4.0 is the basis for the development of ICT goods exports. Together, the available publications do not specify under what conditions international road freight transport is suitable and preferred for the export of ICT goods (Table 1). This gap in the literature raises the following research question: RQ1: What factors of road freight transport determine ICT goods exports? The available scientific papers present potential answers to RQ1.

Table 1. Factors Suitable for Exporting Goods Other than ICT Goods.

Factor Type	Factor	Factor in the Literature
Institutional factor	Ease of arranging competitively priced shipments	Prasad and Singh (2020), Tadesse et al. (2022)
Price factor	The efficiency of the customs clearance process	Tostes et al. (2022), Tyagi and Goyal (2021)
Quality factors	Quality of trade- and transport-related infrastructure	Butkus et al. (2023), Sénquiz-Díaz (2021)
	Competence and quality of logistics services	Gaudenzi et al. (2021), Ricardianto et al. (2023)
	The frequency with which shipments reach the consignee within the scheduled or expected timeframe	Cuppett et al. (2022), Ghansah et al. (2023)
	Ability to track and trace consignments	Gomez et al. (2019), Wang et al. (2019)

Note. Compiled by the author.

The table shows most answers related to quantitative factors. Prasad and Singh (2020) and Tadesse et al. (2022) noted that the choice in favor of road freight transport, when other modes of transport are also available for ICT goods exports, is largely determined by the price factor: ease of arranging competitively priced shipments.

Tostes et al. (2022) and Tyagi and Goyal (2021) pointed out that international freight transport supports the development of ICT goods exports under the condition of the efficiency of the customs clearance process, that is, under the favorable influence of the institutional factor. In contrast, other authors have drawn attention to the importance of quality factors, including:

- the quality of trade and transport-related infrastructure (Butkus et al. 2023; Sénquiz-Díaz 2021),
- the competence and quality of logistics services (Gaudenzi et al. 2021; Ricardianto et al. 2023),
- the frequency with which shipments reach the consignee within the scheduled or expected timeframe (Cuppett et al. 2022; Ghansah et al. 2023), and
- the ability to track and trace consignments (Gomez et al. 2019; Wang et al. 2019).

From the managerial point of view, the efficiency of the customs clearance process is within the competence of the state regulation of international trade. Therefore, if the insti-

tutional factor is of decisive importance, then the export of ICT goods will be inaccessible to corporate management by trucking companies. Poor manageability would make road freight transport less competitive with other modes of transport.

However, this (poor handling) does not seem to be the case in reality because road haulage is very popular around the world, particularly for the export of ICT goods. It is worth emphasizing that this was happening even in the face of tightening international economic sanctions in 2022–2023, when the institutional environment is unfavorable for international trade. In this regard, it can be assumed that the efficiency of the customs clearance process is, although certainly important, not decisive for international road freight transport in the export of ICT goods.

Motor transport companies can only influence the factors of price and quality, but their simultaneous optimization is usually difficult. Lower prices naturally reduce quality, and vice versa, an increase in quality dictates the need to increase prices. Considering that ICT goods are usually complex and fragile equipment, it seems that with a low quality of transport services, the export of ICT goods is fundamentally unprofitable.

Based on this argument and the above literature, we propose hypothesis H1, that ICT goods exports are more determined by the quality factors of international road freight transport than by price and institutional factors. To test the hypothesis put forward in this article, a systematic economic and mathematical modeling of the dependence of ICT goods exports on the price factor, the institutional factor, and the totality of quality factors is carried out. The listed factors are compared based on their degree of significance, which makes it possible to determine the main ones.

Organization of Management Information Systems to Improve the Quality of Road Freight Transport in the Context of Industry 4.0. This article draws on the concept of management information systems in road freight quality management. Numerous published scientific papers (Popkova and Sergi 2020; Popkova et al. 2021) indicate that the current context of Industry 4.0 has opened up new opportunities for improving the quality of road freight transport. However, the range of specific management practices that can improve the quality of road freight transport in the conditions of Industry 4.0 is not outlined, which is why these practices remain unknown.

This gap in the literature raises the following research question: RQ1: What factors of road freight transport determine ICT goods exports?

The available scientific papers present alternative potential answers to the question posed by RQ1.

Answers related to quantitative factors are mainly offered. Thus, Prasad and Singh (2020) and Tadesse et al. (2022) note in their research that the choice in favor of road freight transportation when other modes of transport are also available for ICT goods exports is largely determined by the price factor: ease of arranging competitively priced shipments.

In turn, Tostes et al. (2022), Tyagi and Goyal (2021) indicate that international freight transport supports the development of ICT goods exports under the condition of the efficiency of the customs clearance process, that is, under the favorable influence of the institutional factor. In contrast, other authors pay attention to the importance of quality factors, including:

- Quality of trade and transport-related infrastructure (Butkus et al. 2023; Sénquiz-Díaz 2021);
- Competence and quality of logistics services (Gaudenzi et al. 2021; Ricardianto et al. 2023);
- Frequency with which shipments reach the consignee within a scheduled or expected timeframe (Cuppett et al. 2022; Ghansah et al. 2023);
- Ability to track and trace consignments (Gomez et al. 2019; Wang et al. 2019).

From a managerial point of view, the efficiency of the customs clearance process is within the competence of state regulation of international trade. Therefore, if the institutional factor is crucial, then the export of ICT goods will be inaccessible to corporate governance by trucking companies. Low handling would make road freight transportation less competitive compared to other modes of transport.

But it seems that this is not the case in reality, since road freight transport is very popular around the world, in particular for the export of ICT goods. It is worth emphasizing that this is happening even in the context of tightening international economic sanctions in 2022–2023, when the institutional environment is unfavorable for international trade. In this regard, it can be assumed that the efficiency of the customs clearance process, although certainly important, is not crucial for international road freight transport for the export of ICT goods.

The trucking companies themselves can only influence price and quality factors, but their simultaneous optimization is usually difficult: lowering prices naturally reduces quality, and vice versa—improving quality dictates the need to raise prices. Given that ICT goods are usually complex and fragile equipment, it seems that with the low quality of transport services, the export of ICT goods is fundamentally unprofitable.

Based on this argument and the above literature, this article puts forward the H1 hypothesis that ICT goods exports are more determined by quality factors of international road freight transport than price and institutional factors. To test the hypothesis put forward in this article, a systematic economic and mathematical modeling of the dependence of ICT goods exports on the price factor, the institutional factor, and a combination of quality factors is carried out. The listed factors are compared according to their degree of importance, which allows us to determine the main ones.

3. Materials and Methodology

All the tasks set out in the article are solved using an appropriate methodology based on a sample that includes all 186 countries (this is a complete sample of countries for which there are no data gaps) for which the digital economy is statistically recorded in the Institute for Management Development (IMD 2023) materials. The sample takes into account the experience of developed and developing countries from all parts of the world, making the sample applicable and useful for studying international practice.

Statistical data were published in the first half of 2024 and reflect the results of 2023. Because Industry 4.0 was introduced in 2011, a decade would be more appropriate to identify the exact relationship.

The first task is to conduct a factorial analysis of the impact of road freight transport on the development of ICT goods exports. Using the method of correlation analysis, the relationship (cross-correlation) is determined, and using the method of regression analysis (as one of the most reliable methods of economic statistics), the dependence of ICT goods exports and the percentage of total goods exports (we will introduce the designation: Good export ICT (World Bank 2023a)) are determined on the components of the logistics performance index (1 = low, 5 = high):

- the ease of arranging competitively priced shipments (price factor; we introduce the notation LPIP1 (World Bank 2023d)),
- the efficiency of the customs clearance process (institutional factor; we introduce the notation LPIC1 (World Bank 2023e)),
- the quality of trade and transport-related infrastructure (quality factor; we introduce the notation LPIQ1 (World Bank 2023g)),
- the competence and quality of logistics services (quality factor; we introduce the notation LPIQ2 (World Bank 2023c)),
- the frequency with which shipments reach the consignee within the scheduled or expected timeframe (quality factor; we introduce the notation LPIQ3 (World Bank 2023f)), and
- the ability to track and trace consignments (quality factor; we introduce the notation LPIQ4 (World Bank 2023b)).

Hypothesis H1 is recognized as proven if at least some correlation coefficients of ICT goods exports with quality factors turn out to be higher than the correlation coefficients of ICT goods exports with price and institutional factors and if the regression coefficients turn out to be positive for at least some quality factors.

To determine the prospects for the development of ICT goods exports in Kazakhstan through improving the quality management of road freight transportation, the maximum values of factor variables (digital/technological skills = 10 and use of big data and analytics = 10) are substituted for the quality function of road freight transportation in the context of industry 4.0 from management information systems, and the growth rate of indicators is determined compared to 2023. Based on the obtained regression equations, the growth rate of the resulting variables is determined compared to 2023. The product of each of the indicators in Kazakhstan in 2023 with its growth rate is found.

The last task of forming a new strategic vision for improving road freight transportation in Industry 4.0 based on quality management in digital ecosystems of transport and logistics services is qualitatively revised, taking into account the results of economic and mathematical modeling.

4. Results

4.1. A Factor Analysis of the Impact of Road Freight Transport on the Development of ICT Goods Exports

To solve the first problem of this study and determine the impact of road freight transport on the development of ICT goods exports, a factor analysis of it (an exploratory factor analysis that confirms predetermined factors) is conducted. The method of correlation analysis (these factors are determined based on the results of a literature review based on relevant literature) was determined and shown in Figure 1 as the cross-correlation coefficient.

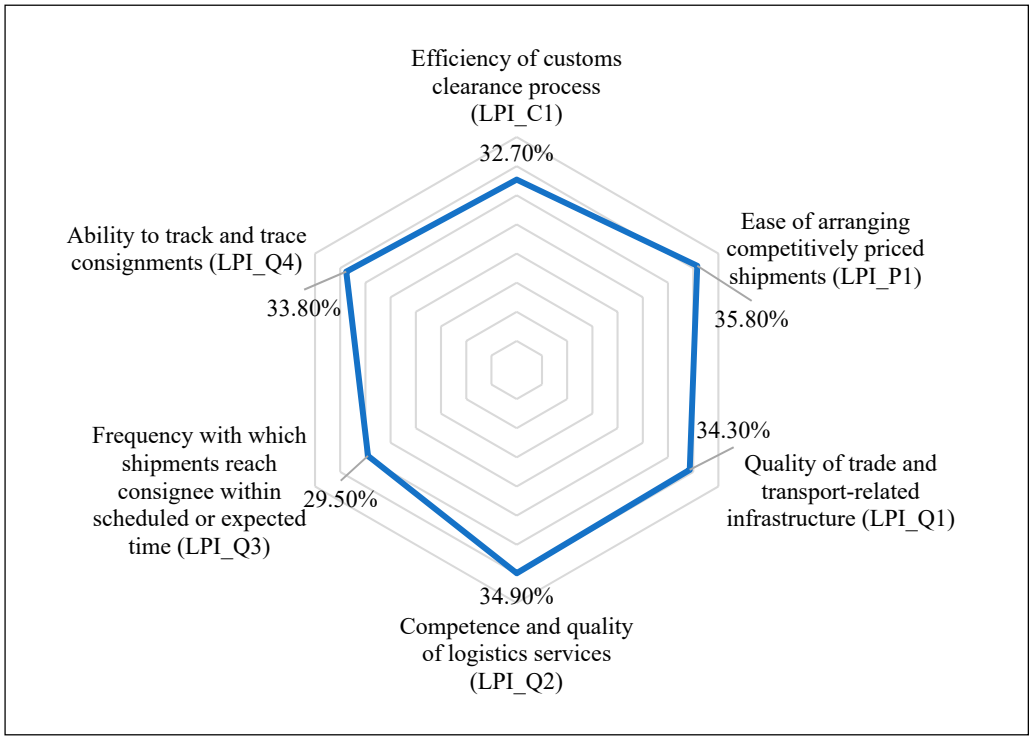


Figure 1. Correlation of Transport and Logistics Factors with ICT Goods Exports. (Note. Calculated and built by the authors).

As Figure 1 shows, the correlation (using the Pearson method, the values of correlation coefficients for the convenience of their interpretation are converted into percentages, that is, into coefficients of determination) of ICT goods exports with quality factors turned out to be similar to or higher than the correlation with price and institutional factors. Therefore, the correlation of ICT goods exports with the ease of arranging competitively priced shipments (LPI_P1) was the highest and amounted to 35.8%; with competence and quality of logistics services (LPI_Q2), 34.9%; with quality of trade and transport-related

infrastructure (LPI_Q1), 34.3%; with ability to track and trace consignments (LPI_Q4), 33.8%; and with frequency with which shipments reach consignee within the scheduled or expected timeframe (LPI_Q3), 29.5%.

For comparison, the correlation of ICT goods exports with the price factor (ease of arranging competitively priced shipments) was 35.8%, and with the institutional factor (efficiency of the customs clearance process), it was 32.7%. Table 2 shows the results of the regression analysis of the dependence of ICT goods exports on transport and logistics factors. The precondition for regression analysis is passing the Fisher's F test, as indicated with a significance level of 0.30. This indicates the significance of the model in general.

Table 2. Regression Analysis of the Dependence of ICT Goods Exports on Transport and Logistics Factors.

Analysis of Variance					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Regression	1,870,352	6	311,725	5.086	0.000
Residual	10,419,988	170	61,294		
Total	12,290,340	176			

Coefficients								
	Unstandardized Coefficients		**Standardized Coefficients**	***t***	**Sig.**	**Correlations**		
	B	**Std. Error**	**Beta**			**Zero-Order**	**Partial**	**Part**
(Constant)	−8.701	4.751		−1.831	0.069			
LPI_P1	6.217	3.209	0.344	1.938	0.054	0.358	0.147	0.137
LPI_C1	0.488	3.864	0.031	0.126	0.900	0.327	0.010	0.009
LPI_Q1	1.211	4.329	0.091	0.280	0.780	0.343	0.021	0.020
LPI_Q2	3.981	5.186	0.270	0.768	0.444	0.349	0.059	0.054
LPI_Q3	−7.304	3.658	−0.456	−1.997	0.047	0.295	−0.151	−0.141
LPI_Q4	1.213	3.863	0.082	0.314	0.754	0.338	0.024	0.022

Note. Calculated and compiled by the author using IBM SPSS Statistic.

The results show that, together, all the factors of logistics efficiency with an R2 coefficient equal to 0.152 are positive indicators. The beta values LPI1, LPIQ1, and LPIQ3 are particularly significant, determine the export of ICT goods by 39.0%, and allow us to compile the following multiple linear regression equation (the standard error is 7.829052):

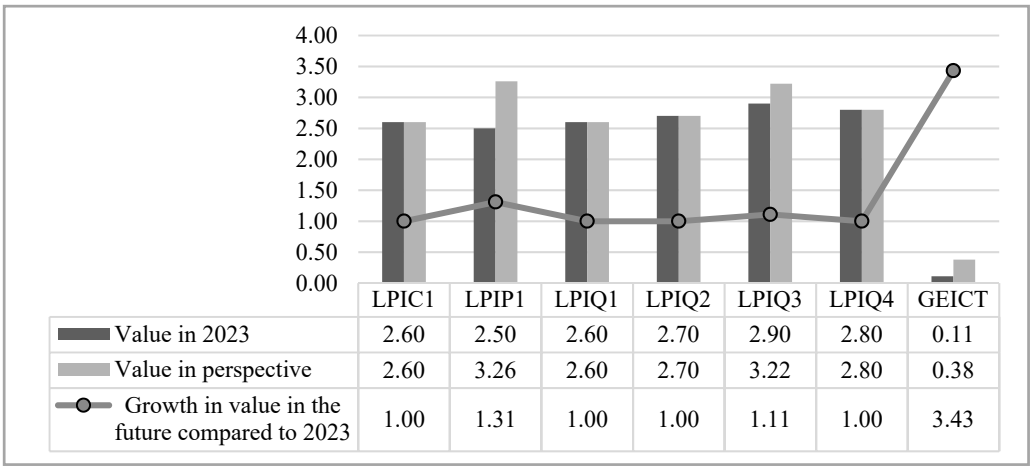
$$GEICT = -8.701 - 0.488 \times LPIC1 + 6.217 \times LPIP1 + 1.211 \times LPIQ1 + 3.981 \times LPIQ2 - 7.304 \times LPIQ3 + 1.213 \times LPIQ4 = 0.557434 \quad (1)$$

Equation (1) is reliable at a significance level of 0.30 and indicates that with a 1-point increase in the ease of arranging competitively priced shipments, ICT goods exports increase by 6.217%. With a 1-point increase in the efficiency of the customs clearance process, ICT goods exports increased by 0.488%. With a 1-point increase in the quality of trade- and transport-related infrastructure, ICT goods exports increased by 1.211%. With a 1-point increase in the competence and quality of logistics services, ICT goods exports increased by 3.981%. With a 1-point increase in the ability to track and trace consignments, ICT goods exports increased by 1.213%. The quality factor (the frequency with which shipments reach the consignee within the scheduled or expected timeframe) does not have a positive impact on the development of ICT goods exports.

Therefore, all the correlation coefficients of ICT goods exports with quality factors turned out to be higher than the correlation coefficients of ICT goods exports with the institutional factor, and the correlation with the frequency with which shipments reach the consignee within the scheduled or expected timeframe turned out to be higher than with the price factor. At the same time, the regression coefficients turned out to be positive under such quality factors as the quality of trade- and transport-related infrastructure and the frequency with which shipments reach consignees within the scheduled or expected timeframe. This proves hypothesis H1.

4.2. Prospects for the Development of ICT Goods Exports in Kazakhstan through the Improvement of Quality Management of Road Freight Transport

To solve the second problem of this study and determine the prospects for the development of ICT goods exports in Kazakhstan through the quality management of road freight transportation, the maximum values of factor variables (HM = 10 and AI = 10) are substituted into Equations (2) and (4), and the growth rate is determined as an indicator compared to 2023. The gain in HM was 1.47; the gain in AI was 1.87; the gain in LPIQ was 1.31; and the gain in LPIQ was 1.11. Based on Equation 1, the GEICT growth rate was determined compared to 2023: 3.43. The product of each of the indicators in Kazakhstan in 2023 and the rate of its growth were found (Figure 2).



	LPIC1	LPIP1	LPIQ1	LPIQ2	LPIQ3	LPIQ4	GEICT
Value in 2023	2.60	2.50	2.60	2.70	2.90	2.80	0.11
Value in perspective	2.60	3.26	2.60	2.70	3.22	2.80	0.38
Growth in value in the future compared to 2023	1.00	1.31	1.00	1.00	1.11	1.00	3.43

Figure 2. Prospects for the Development of ICT Goods Exports in Kazakhstan by Improving the Quality Management of Road Freight Transport. (Note: Calculated and built by the authors).

As Figure 2 shows, improving the organization of management information systems through a combination of human and AI management will improve the quality of road freight transport in Kazakhstan. The quality of trade- and transport-related infrastructure will increase from 2.50 points in 2023 to 3.26 points, and the frequency with which shipments reach the consignee within the scheduled or expected timeframe will increase from 2.90 points in 2023 to 3.22 points. Thanks to this, ICT goods exports in Kazakhstan will increase from 0.11% to 0.38% of total goods exports.

The value of the perspective shown in Figure 3 is that it proposes benchmark values for statistical indicators of the quality management of road freight transport. These control values can be used when drawing up a "road map" for the development of ICT goods exports in Kazakhstan.

4.3. Strategic Vision for Improving Road Freight Transport in Industry 4.0 Based on Quality Management in the Digital Ecosystems of Transport and Logistics Services

To achieve the third objective of this study and form a new strategic vision for improving road freight transport in Industry 4.0 based on quality management in digital ecosystems of transport and logistics services, the existing management information system organization scheme for improving the quality of road freight transport in Industry 4.0 is qualitatively revised by taking into account the results of economic and mathematical modeling. Figure 3 shows the improved scheme of this organization.

Figure 3 is formed based on the results of testing hypothec, supplemented by the author's reflection. As Figure 3 shows, the improved scheme's main feature and novelty is that the management information system for the quality management of road freight transport is a digital ecosystem of transport and logistics services. This means a broader understanding of the management information system. (a) It involves a much wider range of communications throughout the entire process of transport and logistics services, and

(b) it is endowed not only with the functions of planning and executing commands but also with the function of enhanced quality control and the function of adjusting the scheme of transport and logistics services as needed.

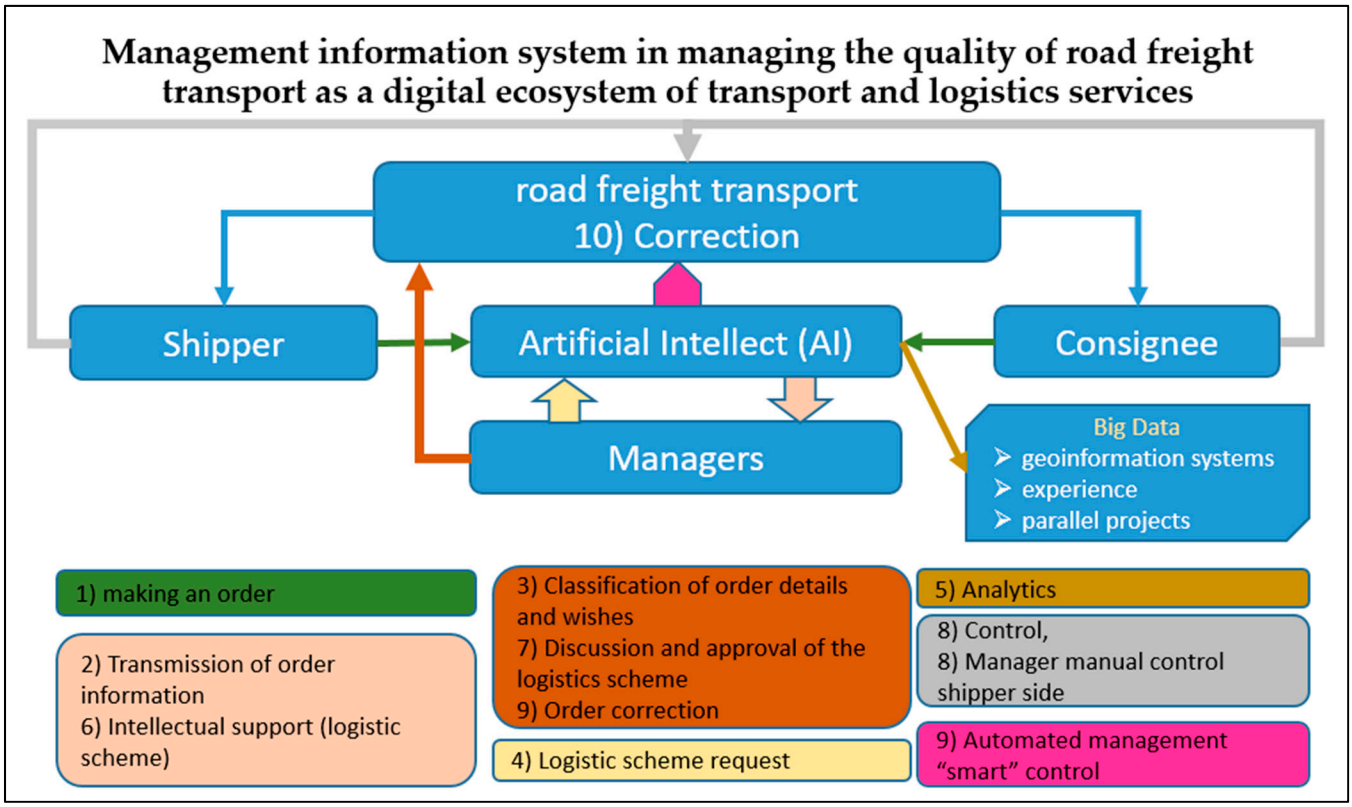


Figure 3. An Improved Management Information System Organization Scheme to Improve the Quality of Road Freight Transport in an Industry 4.0 Environment. (Note: built by the authors).

The scheme in Figure 3 revealed an improved quality management procedure for road freight transport in an Industry 4.0 environment in the management information system of a trucking company. This procedure assumes that at the first stage, the consignor and consignee are united in a common category of customers and place an order for transport and logistics services through the AI road transport company. In the second stage, AI passes information about the order to the manager. In the third stage, the manager specifies the order details and both customers' wishes.

In the fourth stage, the manager asks the AI for a logistics scheme, which should take into account all the wishes. In the fifth stage, AI develops a logistics scheme through big-data analytics. In the sixth stage, AI provides intelligent support to the manager by suggesting and adjusting the logistics scheme. In the seventh stage, the manager discusses and approves the logistics scheme with customers. In the eighth stage, AI performs automated management and "smart" control of road freight transportation; it is also controlled by the manager and customers.

In the ninth (optional) step, customers adjust the order. In the tenth stage, adjustments are made to the process of road freight transportation. In the proposed improved scheme, all the shortcomings of the existing management information systems organization scheme are overcome; that is, the following advantages are achieved:

- a comprehensive consideration of all stakeholders' interests and a general discussion of the order, allowing them to agree to correct interests that conflict with each other;
- uninterrupted operation of management information systems with minimal risks of technical failures because they are managed by a human manager;

- the possibility of flexible adjustment of the transport and logistics scheme in the process of road freight transportation;
- quality assurance due to its triple control by AI, manager, and customers.
- Due to the noted advantages, the new scheme is most preferable.

5. Discussion

The article's contribution to the literature lies in the development of the concept of management information systems in the quality management of road freight transport through the formation of a new vision of transport data in Industry 4.0. Table 3 shows a comparison of the new vision with the vision from the existing literature.

Table 3. The New Vision of Road Freight Transport in Industry 4.0 Compared to the Vision from the Existing Literature.

Research Questions (RQs)	Vision for Road Freight Transport in Industry 4.0			
	Existing Vision in Published Literature		The New Vision Proposed and Presented in This Article	
	Available Response to RQ	Reinforcement with Literature	New Response to RQ	Quantitative Measurement
RQ1: What factors of road freight transport determine ICT goods exports?	Quantitative factors		Quality factors (correlation):	
	The efficiency of the customs clearance process (institutional factor);	Tostes et al. (2022), Tyagi and Goyal (2021)	Quality of trade and transport-related infrastructure	34.30%
			Competence and quality of logistics services	34.90%
	Ease of arranging competitively priced shipments (price factor).	Prasad and Singh (2020), Tadesse et al. (2022)	The frequency with which shipments reach the consignee within the scheduled or expected timeframe	29.50%
			Ability to track and trace consignments	33.80%

Note. Source: author's development.

As Table 3 shows, the author's vision, supported by scientific arguments, provides a new answer to RQ1. In contrast to the existing vision, in the new vision of ICT, goods exports are determined not so much by quantitative factors (efficiency of customs clearance process [institutional factor, correlation: 32.70%, in contrast to Tostes et al. (2022); Tyagi and Goyal (2021)] and ease of arranging competitively priced shipments [price factor, correlation: 34.30%, in contrast to Prasad and Singh (2020); Tadesse et al. (2022)] and quality factors for road freight transport), namely

- quality of trade- and transport-related infrastructure (correlation: 34.30%, confirms Butkus et al. (2023); Sénquiz-Díaz (2021)),
- competence and quality of logistics services (correlation: 34.90%, confirms Gaudenzi et al. (2021); Ricardianto et al. (2023)),
- the frequency with which shipments reach the consignee within the scheduled or expected timeframe (correlation: 29.05%, confirms Cuppett et al. (2022); Ghansah et al. (2023)), and
- The ability to track and trace consignments (correlation: 33.80%, confirms Gomez et al. (2019); Wang et al. (2019)).

6. Conclusions

Therefore, it is appropriate to explain the results obtained in the article. The systematization and comprehensive analysis of the latest (for 2023) international experience clarified

the specifics and prospects for improving the quality management practice of road freight transport in Industry 4.0.

An econometric model of the impact of road freight transport on the development of ICT goods exports was compiled, which proved that it is largely determined by the quality factors of international road freight transport (namely quality of trade- and transport-related infrastructure; the frequency with which shipments reach the consignee within the scheduled or expected timeframe) rather than price (insignificant) and institutional factors.

The article's theoretical significance lies in the fact that it formed a new vision of road freight transport in Industry 4.0, including (a) selecting the most effective corporate governance measures for road freight transport in Industry 4.0 to fully support the development of ICT goods exports, (b) a new understanding of the management information system in the quality management of road freight transport as a digital ecosystem of transport and logistics services, (c) and a new organization scheme of the management information system to improve the quality of road freight transport in the conditions of Industry 4.0.

The practical significance of the author's conclusions and recommendations lies in the fact that they reveal the prospects for the development of ICT goods exports in Kazakhstan through the improvement of the organization of management information systems, which makes it possible to improve the quality of road freight transportation and thereby support the development of ICT goods exports. The managerial significance lies in the fact that the developed new organization scheme of the management information system will improve the efficiency of quality management in road freight transport and strengthen the guarantee of their quality in the conditions of Industry 4.0.

The social significance of the results obtained is that the proposed new strategic vision for improving road freight transportation, based on quality management in digital ecosystems of transport and logistics services through a hybrid organizational scheme that combines human and machine control, will allow trucking companies to save jobs in Industry 4.0, thereby raising the level of their corporate social responsibility.

The political significance of this study focuses on new opportunities, and countries can consider the introduction of innovations in road freight transportation in the context of Industry 4.0 as a factor of economic growth, especially in terms of increasing exports of ICT products. However, there may be concerns about the need for new regulation, data protection, and cybersecurity. Governments can assess how the digitalization of logistics affects international relations, especially within the framework of customs unions and regional integration associations.

A limitation of the results obtained is that the compiled perspective for the development of ICT goods exports by improving the quality management of road freight transport was developed for Kazakhstan and is applicable only in this economy. As a direction for further research, we propose a similar perspective for other countries, taking into account their specifics based on the compiled regression models. This will help improve quality management practices for road freight transport in various countries and thereby support the development of international road transport and global trade in ICT goods.

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