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ENHANCING TRUCK FREIGHT MANAGEMENT VIA DIGITAL TRANSPORT AND LOGISTICS ECOSYSTEMS

Abstract. The Republic of Kazakhstan is prioritizing the digitalization of its transportation and logistics sector as a strategic approach to sustainable economic growth and enhancing the quality of life for its citizens. Guided by the decrees and messages from the President of Kazakhstan, the nation is focusing on developing its transit potential and incorporating modern technologies to streamline transport and logistics processes. The emphasis is on increasing the efficiency of transportation activities, developing transit and multimodal potential, and ensuring the security and stability of transport connectivity. This initiative aims to raise the transportation and logistics sector's contribution to the GDP and establish Kazakhstan as a central transit hub in the region.

Recent advancements in digital ecosystems, which include technologies like the Internet of Things (IoT), artificial intelligence (AI), and blockchain, are set to revolutionize the truck freight transportation industry. These technologies promise enhanced efficiency, improved supply chain visibility, and reduced environmental impacts. Kazakhstan's efforts in digitalizing its transport and logistics complex, including recommendations for implementing digital transport corridors and developing an integrated information and logistics platform, signify a critical step toward realizing these benefits. This approach will not only enhance the transparency and efficiency of management processes but also reduce costs and improve service quality for end-users, contributing significantly to the nation's economic growth and regional integration.

Keywords. Digitalization in transportation, logistics sector innovation, efficiency enhancement in freight transportation.

Introduction.

Improving the management of automobile freight transportation in Kazakhstan through the development of digital ecosystems for transportation and logistics services is a key factor for sustainable economic growth and improving the quality of life for the population. In recent years, the government of Kazakhstan has been actively working on implementing strategies and programs aimed at developing the transportation and logistics sector, including through digitalization.

The basis for these efforts has been the decrees and messages from the President of the Republic of Kazakhstan, which emphasize the need to develop the country's transit potential and introduce modern technologies into the management of transport and logistics processes. In particular, the President's message of September 1, 2020, highlighted the importance of adapting to the new realities of the global economy and using digital technologies to enhance the efficiency of all spheres of society's life, including the transportation and logistics complex [1].

Following the strategic development plans of the country, Kazakhstan is actively working on improving infrastructure and management in the field of transportation and logistics services. Key initiatives, such as doubling teachers' salaries and improving healthcare, demonstrate a comprehensive approach to the development of human capital and infrastructure, which also applies to the transport services sector [2].

The concept of developing the transportation and logistics potential of the Republic of Kazakhstan until 2030 emphasizes the aim to increase the efficiency of transportation activities, develop transit and multimodal potential, and strengthen the security and stability of transport connectivity. The document pays attention to the development of a competitive market for transportation and logistics services and related industries [3].

These efforts are aimed at achieving the goal of increasing the share of the transportation and logistics sector in the country's GDP structure, as well as strengthening Kazakhstan's position as a key transit hub in the region. The development of digital ecosystems in transportation and logistics services will enhance the transparency and efficiency of management processes, reduce costs, and improve the quality of services for end users.

Materials and methods.

This study adopts a mixed-methods research design, combining quantitative data analysis with qualitative insights to assess the impact of digital ecosystems on truck freight management in Kazakhstan. The approach allows for a comprehensive understanding of the current state of digitalization in the transport and logistics sector and the identification of barriers to its implementation.

Quantitative Data: Official statistics and reports from Kazakhstan's Ministry of Industry and Infrastructure Development, the National Statistics Bureau, and international logistics performance indexes were analyzed.

Qualitative Data: Semi-structured interviews were conducted with stakeholders in the logistics sector, including government officials, transport and logistics companies' executives, and industry experts.

The collected data were analysed using the following methods:

Descriptive Analysis: Quantitative data were analyzed to describe the current state of Kazakhstan's transport and logistics sector, including freight turnover trends and logistics performance indicators.

Comparative Analysis: Kazakhstan's logistics performance and digitalization efforts were compared with international benchmarks and case studies to identify gaps and opportunities for improvement.

Results and discussion.

The transportation and logistics sector is a key element of Kazakhstan's economic growth and development, providing a link between European and Asian markets thanks to its strategic geographic location. The sector plays an important role in improving trade relations and stimulating economic integration in the region.

Here's the chart with English labels and annotated data points for the dynamics of freight turnover by type of transport from 2007 to 2023. Each data point is marked with its corresponding value, providing a clear view of the trends over the years for total freight turnover, railway transport, and automobile and urban electric transport.

The graph presents the dynamics of freight turnover by type of transport from 2007 to 2023, detailing three main categories: Total, Railway Transport, and Automobile and Urban Electric Transport. Here's an overview:

Total Freight Turnover shows a general upward trend from 2007 to 2019, with a peak in 2019 at approximately 609,341 million ton-kilometres (mln tkm). After 2019, there's a noticeable dip in 2020 and 2021, followed by a sharp decrease in 2022, and a slight recovery in 2023.

Railway Transport follows a similar upward trajectory, indicating steady growth in its contribution to the total freight turnover. The volume starts at around 200,558 mln tkm in 2007,

peaking in 2023 at 326,812 mln tkm. This category exhibits resilience, especially in the later years, showing a continuous increase even when the total freight turnover declines.

Automobile and Urban Electric Transport presents a different pattern. After a period of significant growth from 2007 to a peak in 2019 (182,696 mln tkm), there's a drastic reduction in freight turnover for this category in 2022 and 2023, dropping to around 29,337 and 29,841 mln tkm, respectively. This sharp decline suggests a major shift or possibly data collection/reporting changes in these years.

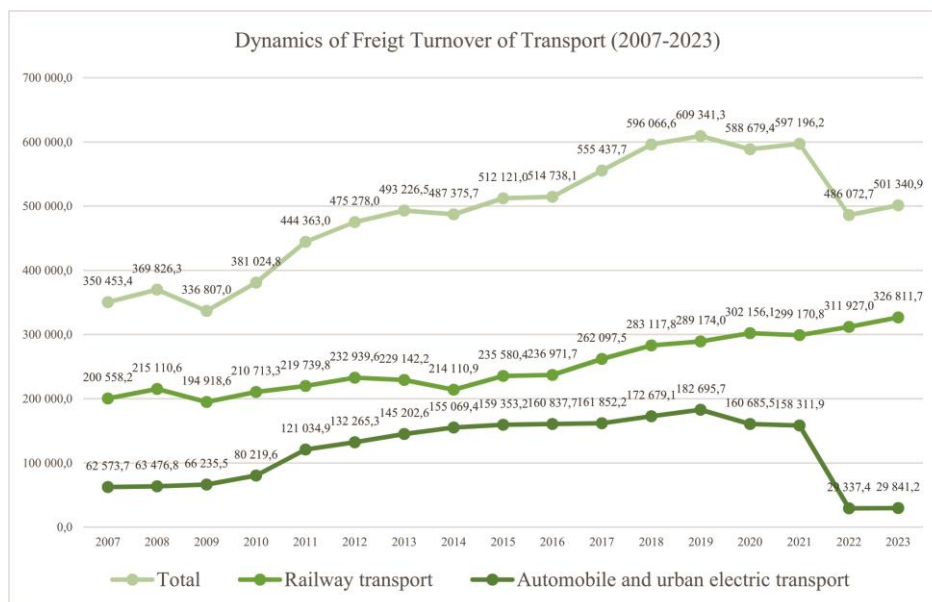


Figure 1 - Freight Turnover dynamics by type of transport, 2007-2023 years [4]

Notably, the graph is marked by annotations indicating the freight turnover values for each year and category, providing a detailed numeric reference at a glance. The years 2020 to 2023 show particularly interesting shifts: while railway transport continues its growth, automobile and urban electric transport suffer a significant reduction, contrasting with the overall trend and highlighting shifts in transportation preferences, policies, or external factors affecting freight movement.

This graph encapsulates the complex dynamics of freight transportation over the period, illustrating not just the growth and fluctuations in volume but also hinting at underlying economic, regulatory, and possibly technological changes impacting these sectors.

The graph now shows the share of each transport type in the total freight turnover as a percentage, using a stacked bar chart for each year from 2007 to 2023. This visualization method provides a clear representation of how the composition of freight turnover by transport type changes over time:

Railway Transport Share forms the base layer of each bar, highlighting its growing dominance in the freight market, especially in the latter years. The increase in railway transport's share reflects its increasing importance in the freight sector.

Automobile and Urban Electric Transport Share is shown above the railway layer, marking its contribution to the total freight turnover. The significant drop in this share in the final years stands out, indicating a major shift away from these modes of transport for freight purposes.

Other Transport Share accounts for the remaining portion of the freight turnover not covered by railway or automobile and urban electric transport. This segment could include air, maritime, and other forms of transport not explicitly detailed in the provided data.

This stacked bar chart offers a comprehensive overview of the evolving landscape of freight transport, emphasizing the relative shifts in transport modality preferences and the significant changes occurring in the most recent years.

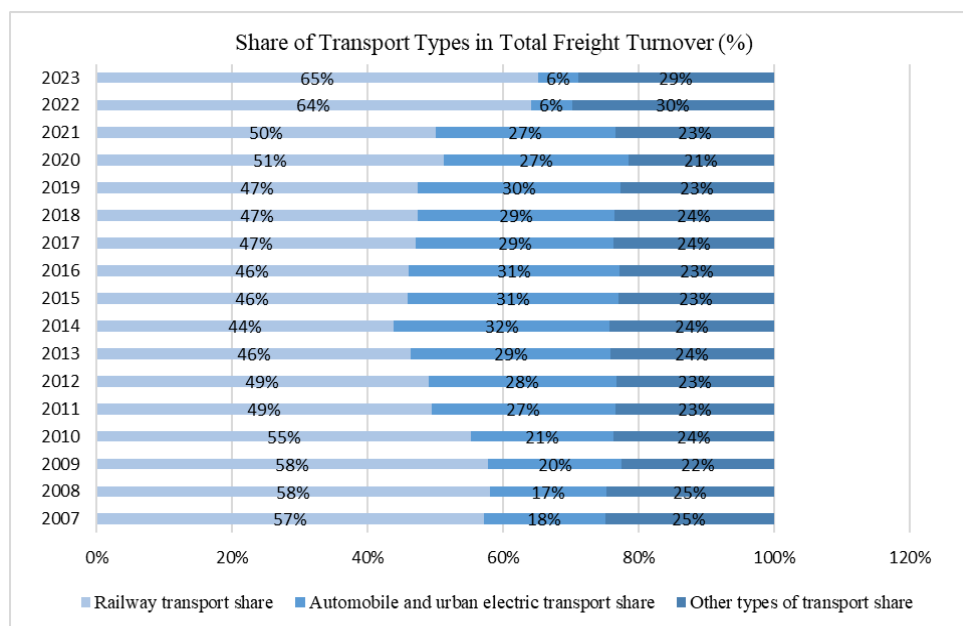


Figure 2 - Share of Automobile and Urban electric in the total Freight turnover in Kazakhstan

Table 1 presents Kazakhstan's position in the Logistics Performance Index (LPI) for the years 2018 and 2023, across various components including Overall LPI, Customs, Infrastructure, International Shipments, Logistics Competence and Quality, Tracking and Tracing, and Timeliness. The change in rank and score for each component is also provided, offering insights into the country's logistics performance over these five years.

Table 1 - Kazakhstan's position in the LPI according to its indicators

Components	2018		2023		+/-	
	Rank	Score	Rank	Score	Rank	Score
LPI Overall	71	2.81	79	2.7		
Customs	65	2.66	74	2.6	-9	-0.06
Infrastructure	81	2.55	80	2.5	-1	-0.05
International Shipments	84	2.73	91	2.6	-7	-0.13
Logistics Competence and Quality	90	2.58	81	2.7	+9	+0.12
Tracking and Tracing	83	2.78	80	2.8	+3	+0.02
Timeliness	50	3.53	93	2.9	-43	-0.63
Note – complied by the author [5]						

Kazakhstan's overall LPI rank fell from 71st in 2018 to 79th in 2023, with a corresponding decrease in score from 2.81 to 2.7. This suggests a slight deterioration in the country's logistics efficiency relative to other nations.

Customs: The efficiency in customs procedures saw a decrease, with the rank moving from 65th to 74th and the score dropping by 0.06 points. This indicates a relative slowdown in customs processing compared to other countries.

Infrastructure: The rank for infrastructure experienced a minor decrease from 81st to 80th, and the score slightly decreased by 0.05 points. This suggests that while there may have

been some improvements, they were not enough to significantly alter Kazakhstan's comparative position in terms of logistics infrastructure.

International Shipments: The ease of arranging competitively priced international shipments worsened, as indicated by a fall in rank from 84th to 91st and a score decrease of 0.13 points. This could reflect challenges in maintaining or reducing shipping costs or in accessing shipping options.

Logistics Competence and Quality: Surprisingly, this is one area where Kazakhstan showed significant improvement, jumping from 90th to 81st in rank and increasing its score by 0.12 points. This improvement suggests a better perception of the competence and quality of logistics services within the country.

Tracking and Tracing: The ability to track and trace consignments saw a modest improvement, with the rank improving from 83rd to 80th and a slight increase in score. This improvement reflects better transparency and information availability in logistics operations.

Timeliness: The timeliness of shipments reaching consignees saw the most significant decline, with the rank plummeting from 50th to 93rd and the score decreasing by 0.63 points. This dramatic drop could indicate significant delays in shipping and logistics operations, affecting the reliability of supply chains.

While there are improvements in logistics competence, quality, and tracking and tracing capabilities, significant declines in timeliness, along with decreases in customs efficiency, infrastructure, and the cost competitiveness of international shipments, raise concerns. The drastic drop in timeliness is particularly alarming, as timely delivery is crucial for the efficiency of supply chains and overall customer satisfaction. To enhance its logistics performance, Kazakhstan may need to focus on improving its shipping and customs procedures, investing in infrastructure, and addressing the underlying issues causing delays in shipments.

Management of automobile transport as a separate industry is currently carried out by the Ministry of Industry and Infrastructure Development (Figure 3). The industry's infrastructure is under the jurisdiction of the Road Committee, while freight and passenger transport services and their control are divided between the Motor Transport Department and the Transport Control Department. Local executive bodies play a significant role in managing the industry. Through the Passenger Transport and Road Departments, the Akimats organize and conduct competitions for the right to carry out passenger transportation on urban and suburban routes.

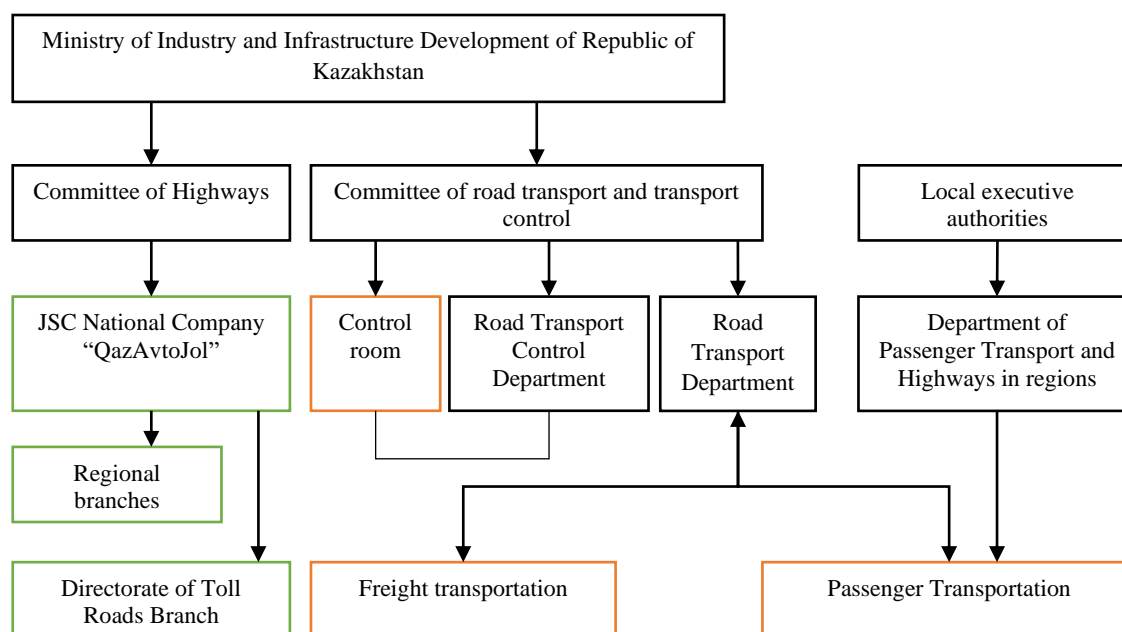


Figure 3 - Automotive transport management system [6]

The management model depicted suggests a highly hierarchical structure, which could slow decision-making, especially in urgent situations due to multiple layers that may need to be navigated. Overlapping responsibilities between departments and committees could result in duplicated efforts, leading to confusion over who is accountable for various tasks. The decision-making power appears to be centralized, potentially decreasing the system's agility and adaptability to the unique conditions and needs of local regions. This centralization also raises concerns about the effectiveness of communication and coordination across various branches and departments, which is vital for efficient transport service management.

The model also does not delineate how technology is incorporated, a critical component of contemporary transport management. With departments operating in silos, integrating new technologies or processes could face resistance due to uneven rates of change acceptance across the organization. Furthermore, there's an apparent lack of indicated mechanisms for ensuring accountability and transparency, which are foundational for maintaining public trust and efficient operations.

A comprehensive review and potential reorganization of the system's operations could streamline processes, bolster coordination, and improve the transport management system's overall adaptability to the evolving demands of the transportation sector.

The barriers and problems outlined in the analysis:

1) Outdated Infrastructure and the Need for Modernization - Many sections of the railway and road networks require modernization and expansion to meet contemporary safety and possibility requirements.

2) High Dependence on Transit Transport - Kazakhstan's economy heavily depends on revenues from transit freight, making it vulnerable to external economic shocks and changes in global transport flows.

3) Logistical Barriers and Customs Issues - Difficulties with customs clearance and logistical barriers at borders complicate cross-border transportation, increasing the time and cost of cargo delivery.

4) Insufficient Development of Technology and Innovation - There is a lack of widespread implementation of digital technologies and innovative solutions in the management of logistics and transport processes.

Recommendations for Implementing Digital Transport Corridors.

1. Development of an Integrated Information and Logistics Platform: Establish a comprehensive platform that integrates advanced information technology and logistics management to enhance the efficiency of transport corridors. This platform should support electronic transport documents, and intelligent transport systems, and provide detailed information on multimodal cargo and passenger flows.

2. Formation of the Kazakh Segment within the Euro-Asian Corridors: Spearhead the creation of a national segment within the broader Digital Euro-Asian Transport Corridors. This initiative will ensure Kazakhstan plays a pivotal role in facilitating transcontinental and intraregional logistics operations, leveraging its strategic geographical position.

3. Creation of a National Information Service System: Develop a sophisticated information service system at the national level. This system should enable effective transit shipments and comprehensive control and monitoring of cargo flows throughout the Eurasian continent. The focus should be on real-time data exchange and analytics to improve decision-making processes.

4. Integration of National Multimodal Electronic Logistics Platforms: Promote the harmonization of national logistics platforms across the participating countries. These platforms should be capable of managing diverse cargo flows transported via different modes - maritime, railway, road, and air. The aim is to ensure seamless service provision throughout the Digital Transport Corridors, facilitating smoother and more efficient cargo and passenger transportation.

5. **Emphasis on Collaboration and Interoperability:** Encourage active collaboration between all stakeholders involved in the transport corridors. This includes governments, transport and logistics companies, technology providers, and international organizations. Interoperability of systems and standards is crucial for the successful implementation of the Digital Transport Corridors concept.

Implementing these recommendations will significantly enhance the efficiency, reliability, and sustainability of transport corridors, contributing to the economic growth and integration of the Eurasian continent.

An eCargo system is a comprehensive digital platform that automates and streamlines the end-to-end processes involved in cargo transportation. It encompasses functionalities such as electronic documentation, real-time tracking and tracing of freight, automated billing and payments, and data analytics for performance monitoring. By integrating Internet of Things (IoT) technologies, Artificial Intelligence (AI), and blockchain, eCargo systems offer a secure, efficient, and scalable solution to manage cargo movements across different modes of transport—road, rail, sea, and air.

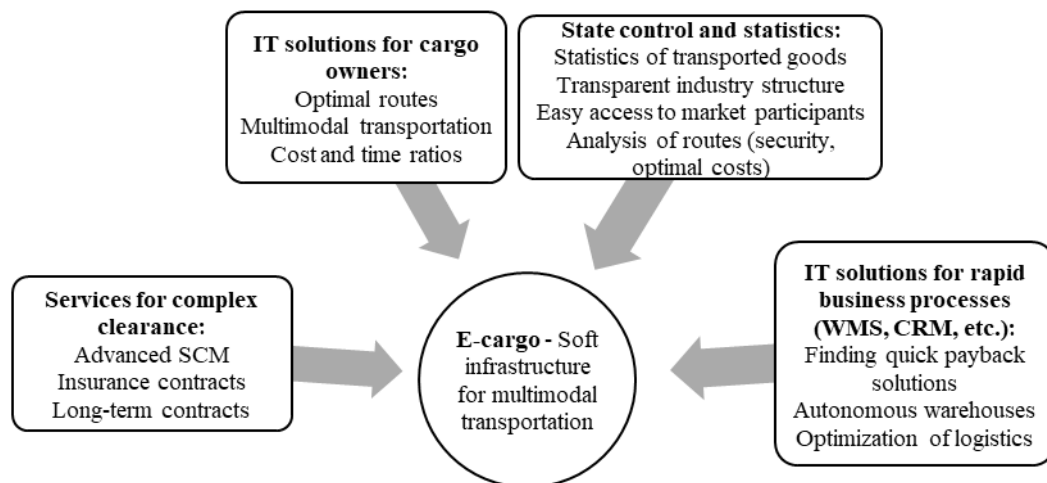


Figure 4 - Advantage of implementing an E-cargo system in the Freight transport sector

One of the primary reasons for adopting an eCargo system is its ability to dramatically improve operational efficiency and transparency in the logistics sector. By digitizing documents and processes, eCargo systems facilitate faster processing times, reduce errors associated with manual data entry, and ensure real-time tracking of shipments. This not only speeds up the supply chain but also provides stakeholders with accurate, up-to-date information, enhancing decision-making and customer satisfaction.

Implementing an eCargo system aligns with the global shift towards digitalization in the transportation and logistics sector. It promises not only to improve operational efficiencies but also to foster sustainability by optimizing routes and reducing carbon emissions. Furthermore, it enhances the competitiveness of logistics service providers by offering better service quality and reliability to their customers.

Smart materials for highways, especially those used for freight transportation, are increasingly being explored to enhance safety, efficiency, and sustainability. Among these innovations, photoluminescent paints stand out. They are designed to glow under specific conditions such as temperature changes, weather variations, and during nighttime. These paints charge themselves using solar energy during the day and emit light after dusk, offering several benefits:

Improved Visibility: Photoluminescent paints make road markings more visible in low-light conditions, helping drivers navigate roads more safely at night or during bad weather.

Energy Efficiency: By harnessing solar energy to charge and then glowing without requiring any additional power source, these paints contribute to energy savings and sustainability efforts.

Safety Enhancements: The enhanced visibility of road markings can significantly reduce the risk of accidents, particularly on freight routes where large vehicles operate and where visibility is crucial for safe manoeuvring.

Adaptability: These materials can adapt to various environmental conditions, ensuring consistent performance in diverse climates and geographic locations.

Sustainability: Using solar energy to power these materials aligns with global efforts to utilize renewable resources, reducing dependency on traditional, non-renewable energy sources.

This smart material is part of a broader category of innovations aimed at making highways safer and more sustainable, especially important for long-haul freight transportation where road conditions significantly impact safety and efficiency.

To create a simplified cost-benefit analysis for implementing smart highway technologies, such as photoluminescent paint, in the context of Kazakhstan we'll consider both direct costs (initial and ongoing) and the anticipated benefits. This analysis will help in understanding the financial implications and potential return on investment.

Assuming a hypothetical scenario where a 100-kilometre section of highway is to be upgraded:

To calculate the NPV, we need to discount the future benefits to their present value and subtract the initial costs. Assuming a 5-year analysis period and a discount rate of 5%:

$$NPV = \text{Initial Costs} + \sum \frac{\text{Annual Benefits}}{(1+r)^t} \quad (1)$$

Where:

r - is the discount rate (5%)

t - is the year

Hypothetical Values:

1) Initial Investment Costs: ₸500 million (covering materials, installation, and additional infrastructure for a hypothetical stretch of highway).

2) Annual Maintenance Costs: ₸10 million.

3) Annual Benefits:

4) Reduced Accident Rates: Savings of ₸150 million (considering reduced costs from accidents).

5) Lower Energy Consumption: Savings of ₸20 million.

6) Decreased Road Maintenance Costs: Savings of ₸30 million.

To keep the analysis straightforward, let's assume these costs and benefits remain constant over a 10-year analysis period, not accounting for inflation or discount rates.

This calculation will help us determine the financial viability of implementing smart highway technologies by comparing the present value of benefits against the costs.

$$NPV = 100\,000\,000 + \sum \frac{2000\,000\,000}{(1+0.05)^{10}} = 1\,326\,993\,865.$$

Therefore, the NPV of implementing the smart highway technologies, given the hypothetical values, is ₸1.4 billion over 10 years. This suggests that the project would provide a positive return on investment, assuming the accuracy of the provided estimates.

Conclusion.

The recommendations for implementing digital transport corridors and the exploration of smart materials for highways, such as photoluminescent paints, highlight a forward-looking approach to infrastructure development. These innovations not only aim to improve operational efficiency but also to address safety and sustainability concerns, which are increasingly important in today's global logistics landscape.

The cost-benefit analysis of implementing smart highway technologies presents a compelling investment case. With a positive net present value, such initiatives promise not only to enhance the safety and efficiency of freight transportation but also to offer substantial economic benefits in the long run.

Kazakhstan's efforts to develop digital ecosystems for its transportation and logistics services are both timely and necessary. The challenges identified, coupled with the outlined recommendations, provide a clear roadmap for leveraging technology to achieve greater efficiency, sustainability, and safety in freight transportation. By continuing to focus on digitalization, infrastructure modernization, and international collaboration, Kazakhstan can enhance its logistic sector's competitiveness, contributing significantly to its economic growth and the well-being of its population. The journey towards transforming Kazakhstan into a leading logistics hub is complex and requires concerted efforts across all levels of government, industry, and society. Yet, the potential rewards justify the investments and initiatives, promising a future where Kazakhstan's transport and logistics sector is not only more efficient and sustainable but also a key driver of regional and global trade.

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ЦИФРЛЫҚ КӨЛІК ЖӘНЕ ЛОГИСТИКАЛЫҚ ЭКОЖҮЙЕЛЕР АРҚЫЛЫ ЖҮК КӨЛІКТЕРІН БАСҚАРУДЫ ЖЕТІЛДІРУ

Аңдатпа. Қазақстан тұрақты экономикалық өсу мен азаматтардың өмір сапасын арттырудың стратегиялық бағыты ретінде көлік-логистика секторын цифрландыруға басымдық береді. Қазақстан Президентінің жарлықтары мен жолдауларын басшылыққа ала отырып, ұлт өзінің транзиттік әлеуетін дамытуға және көлік-логистикалық процестерді оңтайландыру үшін заманауи технологияларды енгізуге ден қойған. Көлік қызметінің тиімділігін арттыруға, транзиттік және мультимодальды әлеуетті дамытуға, сондай-ақ көліктік коммуникациялардың қауіпсіздігі мен тұрақтылығын қамтамасыз етуге басты назар аударылады. Бұл бастама көлік-логистика секторының ішкі жалпы өнімге үлесін арттыруға және Қазақстанның аймақтағы орталық транзиттік хаб ретіндегі ұстанымын нығайтуға бағытталған.

Сандық экожүйедегі соңғы жетістіктер, соның ішінде заттар интернеті (IoT), жасанды интеллект (AI) және блокчейн сияқты технологиялар жүк тасымалдау индустриясында төңкеріс жасауға дайын. Бұл технологиялар тиімділікті арттыруды, жеткізу тізбегінің көрінуін жақсартуды және қоршаған ортаға әсерді азайтуды уәде етеді. Қазақстанның көлік-логистикалық кешенін цифрландыру бойынша күш-жігері, оның ішінде цифрлық көлік дәліздерін енгізу және интеграцияланған ақпараттық-логистикалық платформаны дамыту бойынша ұсыныстар осы артықшылықтарды жүзеге асыру жолындағы маңызды қадамды көрсетеді. Бұл тәсіл басқару процестерінің ашықтығы мен тиімділігін арттырып қана қоймайды, сонымен қатар елдің экономикалық өсуі мен өңірлік интеграцияға елеулі үлес қоса отырып, шығындарды азайтып, түпкілікті пайдаланушыларға көрсетілетін қызметтердің сапасын арттырады.

Түйінді сөздер. Көліктегі цифрландыру, логистика секторындағы инновация, жүк тасымалдаудағы тиімділікті арттыру.

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СОВЕРШЕНСТВОВАНИЕ УПРАВЛЕНИЯ АВТОМОБИЛЬНЫМИ ПЕРЕВОЗКАМИ С ПОМОЩЬЮ ЦИФРОВЫХ ТРАНСПОРТНЫХ И ЛОГИСТИЧЕСКИХ ЭКОСИСТЕМ

Аннотация. Казахстан отдает приоритет цифровизации своего транспортного и логистического сектора как стратегическому направлению устойчивого экономического роста и повышения качества жизни своих граждан. Под руководством указов и посланий

Президента Казахстана, нация сосредоточена на развитии своего транзитного потенциала и внедрении современных технологий для оптимизации процессов транспорта и логистики. Основное внимание уделяется повышению эффективности транспортной деятельности, развитию транзитного и мультимодального потенциала, а также обеспечению безопасности и стабильности транспортной связи. Эта инициатива направлена на увеличение вклада транспортного и логистического сектора в ВВП и укрепление позиций Казахстана как центрального транзитного узла в регионе.

Недавние достижения в области цифровых экосистем, включая технологии, такие как Интернет вещей (IoT), искусственный интеллект (AI) и блокчейн, готовы революционизировать индустрию грузоперевозок на грузовиках. Эти технологии обещают повышение эффективности, улучшение видимости цепочек поставок и снижение воздействия на окружающую среду. Усилия Казахстана по цифровизации его транспортно-логистического комплекса, включая рекомендации по внедрению цифровых транспортных коридоров и разработке интегрированной информационно-логистической платформы, означают важный шаг к реализации этих преимуществ. Такой подход не только повысит прозрачность и эффективность управленческих процессов, но и сократит затраты и улучшит качество услуг для конечных пользователей, внося значительный вклад в экономический рост страны и региональную интеграцию.

Ключевые слова. Цифровизация в транспорте, инновации в логистическом секторе, повышение эффективности в грузоперевозках.
