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A UNIFIED DIGITAL PLATFORM MODEL AIMED AT INCREASING THE EFFICIENCY OF TRANSPORT RESOURCE UTILIZATION

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Abstract. *This article develops a unified digital platform model aimed at increasing the efficiency of transport resource utilization in the road freight sector of Uzbekistan. The relevance of the study is determined by the rapid growth of freight demand, the dominance of road transport in the national freight structure, the high share of informal activity and the absence of a single electronic environment that brings together carriers, vehicles, transport orders and electronic waybills. The aim of the research is to substantiate the architecture of a unified digital transport platform and to quantitatively assess its potential impact on the utilization of vehicles and fleet capacity. The study employs statistical analysis of official data of the National Statistics Committee for 2015-2024, growth-rate and trend modelling, elasticity estimation, system-structural modelling and scenario analysis based on an integral resource utilization coefficient that combines fleet time utilization, mileage utilization and load capacity utilization. The results show that between 2015 and 2024 road freight turnover grew at an average annual rate of 7.46%, faster than the tonnage carried (4.23%), while the average haul distance increased from 13.5 to 17.8 km. A four-layer platform model is proposed, consisting of a data layer, an integration layer, a market service layer and an analytics and governance layer. Scenario calculations indicate that the platform may raise the integral utilization coefficient by 18.7-63.3% and reduce vehicle-kilometres required per unit of transport work by 11.6-28.6%. The findings can support the Ministry of Transport and logistics operators in designing the national digital freight ecosystem.*

Keywords: *digital platform, transport resources, road freight transport, empty running, freight matching, electronic waybill, resource utilization efficiency, logistics digitalization, Physical Internet, Uzbekistan.*

INTRODUCTION

Freight transport is one of the basic infrastructural sectors of any national economy: it links production with consumption, determines the cost of goods on domestic and foreign markets and directly affects the competitiveness of exporters. In the conditions of the digital economy, the efficiency of the sector increasingly depends not only on the quantity and quality of physical assets - roads, vehicles, terminals - but also on how well information about these assets and about cargo flows is collected, exchanged and used for decision-making. International experience shows that a considerable part of transport resources is consumed unproductively: in the European Union about one fifth of all road freight vehicle-kilometres is performed by empty vehicles [7], and in the United States empty mileage is estimated at 22-25% on a major digital brokerage platform and at about 40% for private fleets [29, 27].

For the Republic of Uzbekistan the problem is particularly relevant. According to the National Statistics Committee, the total volume of freight transported in 2024 reached 1,534.7 million tonnes, of which road transport carried 1,370.1 million tonnes, or 89.3% [19, 18]. The transport sector

contributes nearly 8% of GDP and employs about one million people, and the country has risen from 129th to 88th place in the World Bank Logistics Performance Index between 2014 and 2023 [28]. At the same time, official assessments recognize that more than 42% of the freight transport sector operates in the shadow economy, that there is no unified register of domestic freight vehicles and that no single electronic platform brings together transport orders and services [13]. The information systems of government agencies and private logistics centres are not fully integrated, and the level of digitalization of the sector remains insufficient [23].

State policy sets ambitious targets for the sector. The Strategies "Digital Uzbekistan - 2030" and "Uzbekistan - 2030" identify the digital transformation of the economy and the development of transport and logistics infrastructure as national priorities [6, 5]. A presidential decree adopted in October 2026 envisages increasing the annual capacity of transport and logistics centres to at least 40 million tonnes by 2030 and introduces land and property tax exemptions for eligible centres until 2040 [4]; exports of transport and logistics services are expected to reach USD 3.5 billion and transit cargo traffic 18.5 million tonnes, and logistics centres are to be connected to the Ministry of Transport's E-logistika platform by the end of 2030 [14]. In September 2026 the Ministry of Transport proposed a unified digital transport system including a register of carriers and an aggregator of electronic waybills and transport orders [13]. However, the economic content of such a system, its architecture and its expected effect on resource utilization have not yet been substantiated scientifically.

Thus, the scientific problem lies in the contradiction between the growing demand for freight transport services and the low informational connectivity of the market, which prevents carriers, shippers and the state from using the existing fleet efficiently. As a result, carriers search for loads through informal channels, return trips are often made empty, and the state lacks reliable data for planning infrastructure and regulating the market.

The aim of the study is to develop a model of a unified digital platform for the road freight sector of Uzbekistan and to quantitatively assess its potential effect on the efficiency of transport resource utilization. To achieve this aim, the following *objectives* were set: (1) to systematize theoretical approaches to digital platforms and open logistics networks; (2) to analyse the dynamics and structure of road freight transport in Uzbekistan in 2015-2024; (3) to design the functional architecture of a unified digital transport platform; (4) to estimate the effect of the platform on the integral resource utilization coefficient under alternative scenarios.

The object of the research is the road freight transport system of the Republic of Uzbekistan, including carriers, shippers, freight forwarders, logistics centres and regulatory bodies. *The subject* is the set of organizational and economic relations arising in the use of transport resources through digital platform mechanisms. *The hypothesis* of the study is that the integration of fragmented state and market data into a single platform can increase the integral resource utilization coefficient of the road freight fleet by at least 15% even under conservative assumptions.

The scientific novelty of the research consists in the following: a four-layer model of a unified digital transport platform has been proposed that combines state registers (carriers, vehicles, electronic waybills) with competitive market services (freight matching, backhaul consolidation, multimodal booking); the integral resource utilization coefficient, calculated as the product of fleet time, mileage and load capacity utilization, has been adapted for scenario assessment of platform effects; and the potential reduction in vehicle-kilometres, fuel consumption and emissions for the road freight sector of Uzbekistan has been quantified.

LITERATURE REVIEW

The scientific literature relevant to the topic can be grouped into four thematic streams: the economic theory of digital platforms; the concept of open and interconnected logistics networks (the Physical Internet); research on collaborative transport and digital freight matching; and studies of the digital transformation of logistics, including its institutional and social consequences.

Economic theory of platforms. The foundations of platform economics were laid by J.-C.

Rochet and J. Tirole, who showed that in two-sided markets the volume of transactions depends not only on the overall price level but also on its distribution between the two sides, because each group of users benefits from the participation of the other [24]. G. Parker, M. Van Alstyne and S. Choudary developed this approach for managerial practice, emphasizing that the value of a platform is created by network effects and by the orchestration of interactions between producers and consumers rather than by the ownership of assets [22]. For freight transport, this means that shippers and carriers form the two sides of the market, and a platform creates value to the extent that it reduces search and transaction costs between them. However, these general works do not consider the specific features of transport markets, such as the spatial nature of supply, time windows and the problem of return loads.

The Physical Internet and interoperability. B. Montreuil proposed the concept of the Physical Internet - an open global logistics system in which goods, vehicles and facilities are interconnected through standardized interfaces and protocols, by analogy with the digital Internet [16]. H. Sternberg and A. Norrman, having critically reviewed the literature, concluded that the concept is attractive but that a number of research questions must be resolved before detailed blueprints are developed, in particular regarding business models and governance [26]. S. Pan and co-authors identified digital interoperability - the ability of heterogeneous information systems to exchange and use data - as a key prerequisite for interconnected logistics and showed that current solutions are not yet fully aligned with the Physical Internet paradigm [21]. T. Ambra, A. Caris and C. Macharis combined Physical Internet and synchromodal transport research, arguing that a unified freight transport system requires the joint planning of modes on the basis of real-time information [2]. The most recent work by H. Wu and co-authors proposes a layered "cyber-physical internet" model analogous to the OSI model of computer networks, in which each layer has its own functions and protocols [31]. These studies provide the methodological basis for a layered platform architecture, but they are oriented mainly toward developed markets with high levels of formalization.

Collaborative transport and digital freight matching. M. Gansterer and R. Hartl reviewed the literature on collaborative vehicle routing and distinguished three streams: centralized collaborative planning, decentralized planning without auctions and auction-based decentralized planning; they showed that the exchange of transport requests between carriers enables more efficient and sustainable operations [9]. A. Alnaggar, F. Gzara and J. Bookbinder systematized the business models of crowdsourced delivery platforms and the related optimization problems [1], while S. Mohri and co-authors, in a systematic review of crowdshipping, highlighted both its potential for urban logistics and the lack of empirical evidence on large-scale effects [15]. S. Fazi and J. Fransoo argue that user-centric open booking platforms for end-to-end freight transport ("Freight Mobility as a Service") are a necessary condition for scaling synchromodal transport [8]. Industry data support these conclusions: on the Uber Freight brokerage platform the share of empty miles decreased from 25% in 2023 to 22% in 2024 [29]. At the same time, most of this literature deals with private commercial platforms operating in formalized markets and does not address the role of the state as a provider of basic data infrastructure.

Digital transformation of logistics and its consequences. E. Hofmann and M. Rüsch examined the application of Industry 4.0 technologies in logistics and pointed to the importance of decentralized, real-time data exchange between physical objects and information systems [11]. M. Cichosz, C. Wallenburg and A. Knemeyer identified the barriers to digital transformation of logistics service providers - including the fragmentation of the market, the low digital maturity of small partners and the lack of data standards - as well as success factors such as leadership and step-by-step implementation [3]. V. Helwing, P. Verfürth and M. Franz, studying the German road freight market, showed that business-to-business digital platforms influence the inclusion and exclusion of market actors and may create downward pressure on labour conditions [10]. These works indicate that platform design must take into account not only technical efficiency but also the institutional environment and the distribution of benefits.

The experience of large emerging markets is particularly instructive for Uzbekistan. In China,

where the road freight market is also dominated by fragmented self-employed truckers, a survey by the China Federation of Logistics & Purchasing found that nearly 60% of truck drivers rely on digital freight platforms to find cargo and that the share of platform-sourced cargo is steadily increasing [30]. This shows that, once a critical mass of users is reached, platforms can become the main channel of market coordination even in an informal environment. At the same time, the Chinese experience confirms the concerns raised by V. Helwing and co-authors: platforms increase the number of jobs available to self-employed drivers, but not necessarily their quality, which requires attention from regulators.

In the national scientific literature, the problems of transport and logistics in Uzbekistan are studied mainly from the standpoint of infrastructure and the organization of logistics services. G. Samatov and co-authors analysed international freight transport, freight turnover and economic indicators and substantiated the importance of logistics activities and transport and logistics centres for the modernization of the national economy [25]. S. Ilkhomov examined the development of digital platforms for the services of transport and logistics providers, focusing on the functions of dispatching and information support in freight logistics [12]. These works confirm the relevance of digitalization for the national transport sector, but they consider platforms primarily at the level of an individual company or logistics centre and do not offer a sector-wide model linking state registers with market mechanisms or a quantitative assessment of the effect on fleet utilization.

Measurement of resource utilization. In classical transport economics, the efficiency of fleet use is measured by a system of partial indicators - fleet time utilization, mileage utilization and load capacity utilization - whose product characterizes the share of the potential productivity of the fleet that is actually realized. International statistics apply a similar logic: Eurostat regularly publishes the share of vehicle-kilometres performed empty and average loads by type of operation [7]. In contrast, studies and industry reports on digital freight platforms usually focus on a single indicator - most often the share of empty miles [29, 27] - and do not consider the simultaneous effect of platforms on load factors and the time utilization of vehicles. This narrows the assessment of the economic effect of platforms and makes the results of different studies difficult to compare.

Governance of freight platforms. The literature also differs in its view of who should own and operate the platform. Commercial models assume that the platform is created by a private intermediary that captures part of the value of transactions [1, 22]. The Physical Internet literature and S. Fazi and J. Fransoo emphasize openness and neutrality, arguing that end-to-end coordination requires common standards and open access rather than a single dominant intermediary [21, 8]. Analysts of the Asian Development Bank, considering Uzbekistan, see the role of the state as that of an orchestrator that creates a connected, data-driven environment for all market participants [20]. These positions are not mutually exclusive: the state can provide the basic data infrastructure, while private companies compete in providing services on top of it. However, such a hybrid model has not yet been formalized in the literature.

A comparative summary of the main theoretical approaches and their limitations with respect to the conditions of Uzbekistan is presented in Table 1.

Table 1

Comparison of theoretical approaches to the digital coordination of freight transport

Approach	Key authors	Main contribution	Limitation for the conditions of Uzbekistan
Theory of two-sided platforms	Rochet, Tirole [24]; Parker et al. [22]	Network effects; pricing between market sides; orchestration instead of asset ownership	Does not consider spatial supply, time windows, return loads
Physical Internet and interoperability	Montreuil [16]; Sternberg, Norrman [26]; Pan et al. [21]; Wu et al. [31]	Open, interconnected logistics networks; layered architecture; data standards	Oriented to formalized markets with mature information systems
Collaborative	Gansterer, Hartl [9];	Exchange of requests	Private platforms; role of

transport and freight matching	Alnaggar et al. [1]; Mohri et al. [15]; Fazi, Fransoo [8]	between carriers; matching algorithms; open booking platforms	the state as data provider not addressed
Digital transformation and social effects	Hofmann, Rüsch [11]; Cichosz et al. [3]; Helwing et al. [10]	Barriers and success factors; effects on labour and market inclusion	No quantitative model of fleet utilization effects
National studies	Samatov et al. [25]; Ilkhomov [12]	Role of logistics and digital services for the national economy	Company-level focus; no sector-wide platform model

With regard to Uzbekistan, analytical materials of international organizations note that the country has implemented individual digital projects in transport, while the transition to a connected, data-driven sector - from the role of "operator" to that of "orchestrator" - remains unfinished [20]. Government assessments confirm the absence of a unified carrier register and a single electronic platform for transport orders [13, 23].

Thus, the analysis of the literature reveals a research gap: existing studies either describe platforms and open logistics networks in general terms for developed markets, or address individual optimization problems, while there is no integrated model that combines state data infrastructure with competitive market services and quantifies its effect on resource utilization in a transition economy with a high share of informal road freight activity. The present study aims to fill this gap.

METHODOLOGY

The research was designed as a mixed applied study combining quantitative analysis of secondary statistical data with system-structural modelling and scenario analysis. This design was chosen because the absence of a functioning national platform did not allow its effects to be measured directly; therefore, the current state of the sector was established empirically, and the potential effects of the platform were assessed by means of a transparent parametric model.

Data. The empirical base consisted of annual official data of the National Statistics Committee of the Republic of Uzbekistan for 2015-2024 obtained from the SIAT open data portal: the volume of cargo transported by road (million tonnes), the total volume of cargo transported by all modes (million tonnes) and road freight turnover (million tonne-kilometres) [18, 19, 17]. Information on the institutional state of the sector was taken from official publications of the President of the Republic of Uzbekistan, the Ministry of Transport and regulatory acts [23, 13, 6]. International benchmarks of empty running were taken from Eurostat and industry sources [7, 29, 27]. Railway data were not included in the time-series analysis because the 2024 figure published in the annual series differed markedly from previous years, indicating a change in coverage.

Statistical analysis. For each year, the share of road transport in total freight and the average haul distance were calculated:

$$\bar{L}_t = P_t / Q_t , \quad (1)$$

where $\bar{L}_t$ is the average haul distance, km; P_t is road freight turnover, t-km; Q_t is the volume of road freight, t. Average annual growth rates were calculated as compound annual growth rates:

$$CAGR = (X_T / X_0)^{1/T} - 1 , \quad (2)$$

where X_0 and X_T are the values of the indicator in the initial (2015) and final (2024) years and $T = 9$. Linear trends of the form $P_t = a + b \cdot t$ were estimated by the ordinary least squares method, and the elasticity of freight turnover with respect to the tonnage carried was estimated using the log-linear model:

$$\ln P_t = c + \varepsilon \cdot \ln Q_t + u_t , \quad (3)$$

where ε is the elasticity coefficient; an elasticity greater than one indicates that transport work grows faster than the tonnage, i.e. that haul distances are increasing.

System-structural modelling. The platform architecture was designed by functional decomposition: the information needs of each group of participants (shippers, carriers, forwarders, logistics centres and state bodies) were identified, grouped into functional modules and arranged in

layers according to the principle used in the Physical Internet and cyber-physical internet literature, where each layer provides services to the layer above it [21, 31]. The core of the market layer was formalized as an assignment problem of matching available vehicles i with loads j:

$$max\ \Sigma_i\ \Sigma_j\ (r_{ij} - c_{ij}^{d}) \cdot x_{ij}\ , \quad (4)$$

subject to $\Sigma_j\ x_{ij} \leq 1$ for each vehicle, $\Sigma_i\ x_{ij} \leq 1$ for each load, $w_j \cdot x_{ij} \leq q_i$ (load weight does not exceed vehicle capacity), compatibility of time windows, and $x_{ij} \in \{0; 1\}$, where r_{ij} is the freight revenue, c_{ij}^{d} is the cost of the empty (deadhead) run from the current location of vehicle i to the loading point of load j. The explicit inclusion of the deadhead cost in the objective function is what distinguishes a resource-oriented platform from a simple bulletin board of offers.

Scenario analysis. The efficiency of transport resource utilization was measured by the integral coefficient traditionally used in transport economics:

$$K = \alpha \cdot \beta \cdot \gamma\ , \quad (5)$$

where α is the fleet time utilization coefficient (share of calendar time in which vehicles are in productive operation); β is the mileage utilization coefficient (share of loaded kilometres in total kilometres, $\beta = 1 - e$, where e is the share of empty running); γ is the load capacity utilization coefficient (ratio of actual load to rated capacity). For a given volume of transport work, the required vehicle-kilometres are:

$$V = P / (\bar{q} \cdot \gamma \cdot \beta)\ , \quad (6)$$

where $\bar{q}$ is the average rated capacity of a vehicle, t. Because Uzbekistan does not publish official statistics on empty running and load factors, baseline parameters were set on the basis of international benchmarks adjusted for the short average haul distance and high fragmentation of the national market: empirical evidence shows that empty journeys are more prevalent in domestic short-distance transport [7]. Three platform scenarios were compared with the baseline: conservative (S1), moderate (S2) and target (S3), where S3 corresponds to the empty running level observed in the EU (about 22%). The baseline fleet time utilization coefficient of 0.60 corresponds to about 219 working days per vehicle per year; the baseline load capacity utilization of 0.60 reflects the mixed structure of the fleet, in which small and medium trucks frequently operate with partial loads. The step between scenarios was set so that the reduction of empty running in S1 (five percentage points) corresponds to roughly two years of the improvement observed on a large digital brokerage platform, where empty mileage fell by three percentage points in one year [29]. For the illustrative absolute estimate, an average capacity of 10 t, fuel consumption of 25 l per 100 vehicle-km and an emission factor of 2.68 kg CO_2 per litre of diesel fuel were assumed. To test the robustness of the absolute estimates, a sensitivity analysis was carried out for average capacities of 8, 10 and 12 t. The research was carried out in four consecutive stages: collection and verification of statistical data; calculation of descriptive indicators and estimation of trend and elasticity models; design of the platform architecture; and scenario and sensitivity calculations. All calculations were performed in Python 3 using the NumPy and Matplotlib libraries.

ANALYSIS AND RESULTS

The main indicators of road freight transport in Uzbekistan for 2015-2024 are presented in Table 2.

Table 2

Main indicators of road freight transport in the Republic of Uzbekistan, 2015-2024

Year	Road freight, mln t	Total freight, mln t	Share of road, %	Road freight turnover, mln t-km	Average haul distance, km	Growth of turnover, %
2015	943.3	1,070.5	88.1	12,752.6	13.5	-
2016	1,002.8	1,132.5	88.5	13,297.8	13.3	4.3
2017	1,013.1	1,146.2	88.4	13,607.7	13.4	2.3
2018	1,102.2	1,243.0	88.7	14,640.8	13.3	7.6
2019	1,177.7	1,319.8	89.2	15,879.3	13.5	8.5
2020	1,238.2	1,366.7	90.6	16,233.4	13.1	2.2

2021	1,282.0	1,420.2	90.3	19,062.3	14.9	17.4
2022	1,284.1	1,420.9	90.4	20,509.8	16.0	7.6
2023	1,322.0	1,455.7	90.8	22,290.7	16.9	8.7
2024	1,370.1	1,534.7	89.3	24,364.0	17.8	9.3
CAGR, %	4.23	4.08	-	7.46	3.09	-

Over the period, the volume of road freight increased by 45.2%, from 943.3 to 1,370.1 million tonnes, while road freight turnover increased by 91.1%, from 12.75 to 24.36 billion t-km. The share of road transport in total freight remained in the range of 88.1-90.8%. The average haul distance was stable at 13.1-13.5 km in 2015-2020 and increased to 17.8 km by 2024; the largest single-year growth in freight turnover (17.4%) was recorded in 2021 (Figure 1).



Figure 1. Road freight volume, freight turnover and average haul distance (labels) in Uzbekistan, 2015-2024

The estimated linear trend of road freight turnover is $P_t = 10{,}077.8 + 1{,}306.6 \cdot t$ ($R^2 = 0.947$), that is, transport work increased on average by about 1.3 billion t-km per year; the trend of road freight volume is $Q_t = 905.9 + 48.7 \cdot t$ ($R^2 = 0.968$). The elasticity of freight turnover with respect to the tonnage carried, estimated by model (3), was $\varepsilon = 1.65$ ($R^2 = 0.893$): a 1% increase in tonnage was associated with a 1.65% increase in transport work.

Based on functional decomposition, a four-layer model of the unified digital transport platform (UDTP) was developed (Figure 2). The lower layer forms reliable data about the participants and resources of the market; the integration layer connects the platform with state and corporate information systems through standardized application programming interfaces (API); the service layer implements market mechanisms of resource allocation; the upper layer provides analytics and governance.

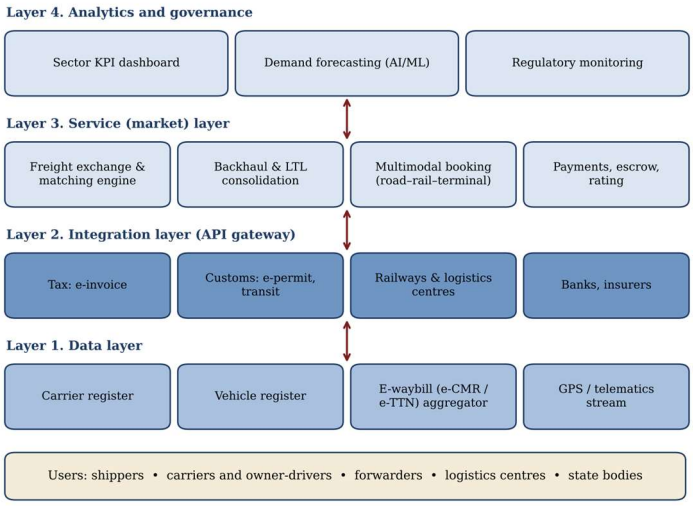

Figure 2. Architecture of the unified digital transport platform (UDTP)

The functional modules of the platform and the components of the resource utilization coefficient that each module affects are summarized in Table 3.

Table 3

Functional modules of the UDTP and their link to resource utilization indicators

Layer	Module	Main function	Indicator affected
1. Data	Carrier and vehicle registers	Unique identification of carriers and vehicles, capacity, body type, permits	α, γ (visibility of available capacity)
1. Data	E-waybill aggregator	Single record of each trip; legal and tax confirmation of the transport service	β, γ (measurement); formalization
1. Data	GPS / telematics stream	Real-time position and status of vehicles	α, β
2. Integration	API gateway	Data exchange with tax, customs, railway, logistics centre, bank and insurance systems	α (fewer delays and idle time)
3. Service	Freight exchange and matching engine	Assignment of loads to vehicles with explicit deadhead cost, model (4)	β, γ
3. Service	Backhaul and LTL consolidation	Search for return loads; combining partial loads in one vehicle	β, γ
3. Service	Multimodal booking	Booking of road-rail-terminal chains through logistics centres	α, γ (long-haul shift)
3. Service	Payments, escrow, rating	Guaranteed settlement; reputation of participants	α (trust, faster turnover)
4. Analytics	KPI dashboard, forecasting	Monitoring of α, β, γ by region and corridor; demand forecasting	All indicators (management)

The parameters of the scenarios and the results of the calculations by formulas (5) and (6) are given in Table 4.

Table 4

Scenario assessment of the effect of the UDTP on transport resource utilization

Indicator	Baseline	S1 Conservative	S2 Moderate	S3 Target
Fleet time utilization, α	0.60	0.63	0.66	0.70
Share of empty running, e	0.35	0.30	0.27	0.22
Mileage utilization, β = 1 − e	0.65	0.70	0.73	0.78
Load capacity utilization, γ	0.60	0.63	0.66	0.70
Integral coefficient K = α·β·γ	0.234	0.278	0.318	0.382
Change in K vs baseline, %	-	+18.7	+35.9	+63.3
Change in vehicle-km per unit of transport work, %	-	−11.6	−19.1	−28.6
Change in required fleet (vehicle-days), %	-	−15.8	−26.4	−38.8
Vehicle-km for 2024 transport work*, bln	6.25	5.52	5.06	4.46
Vehicle-km saved*, bln	-	0.72	1.19	1.78
Fuel saved*, mln l	-	180.6	297.6	446.2
CO_2 emissions avoided*, mln t	-	0.48	0.80	1.20

In the conservative scenario, the integral coefficient increased from 0.234 to 0.278 (+18.7%), and in the target scenario to 0.382 (+63.3%). The vehicle-kilometres required to perform the 2024

volume of transport work decreased from 6.25 billion to 5.52-4.46 billion, depending on the scenario. The largest contribution to the reduction of vehicle-kilometres came from the mileage utilization coefficient β: in scenario S3 its increase from 0.65 to 0.78 alone reduced the required vehicle-kilometres by 16.7%.

Because the absolute estimates depend on the assumed average vehicle capacity, they were recalculated for capacities of 8, 10 and 12 t (Table 5). The relative indicators in Table 4 do not depend on this parameter.

Table 5

Sensitivity of vehicle-km and fuel savings to the average vehicle capacity

Average capacity $\bar{q}$, t	S1 Conservative	S2 Moderate	S3 Target
Vehicle-km saved, bln:			
$\bar{q}$ = 8 t	0.90	1.49	2.23
$\bar{q}$ = 10 t	0.72	1.19	1.78
$\bar{q}$ = 12 t	0.60	0.99	1.49
Fuel saved, mln l:			
$\bar{q}$ = 8 t	225.8	372.0	557.8
$\bar{q}$ = 10 t	180.6	297.6	446.2
$\bar{q}$ = 12 t	150.5	248.0	371.9

Across the range of capacities considered, the savings in the conservative scenario amounted to 0.60-0.90 billion vehicle-km and 150.5-225.8 million litres of fuel per year, and in the target scenario to 1.49-2.23 billion vehicle-km and 371.9-557.8 million litres.

DISCUSSION

The results allow us to answer the research questions formulated in the introduction. First, the statistical analysis showed that the demand for transport resources in Uzbekistan is growing faster than the physical volume of freight: an elasticity of 1.65 and a near doubling of freight turnover in nine years mean that the same tonnage requires increasingly more vehicle-kilometres. If the efficiency of the fleet remains unchanged, this growth must be met by an almost proportional increase in the number of vehicles, fuel consumption and road load. This makes the question of resource utilization not only microeconomic but also macroeconomic.

Second, the very short average haul distance (13-18 km) indicates that the national road freight market consists largely of local and intra-regional trips performed by many small operators. Eurostat data show that empty journeys are particularly frequent in exactly this type of domestic short-distance transport [7]. This supports the assumption that the baseline level of empty running in Uzbekistan is higher than the EU average and that the potential for its reduction is significant.

Third, the proposed model differs from the purely commercial platforms described in the literature [1, 29]. In formalized markets, private freight exchanges can rely on existing registers, contracts and electronic documents. In Uzbekistan, where more than 42% of freight transport operates informally and there is no unified register of vehicles [13], a market platform alone would not be able to see a significant part of the available capacity. Therefore, the data layer - the register of carriers and vehicles and the e-waybill aggregator - plays the role of public digital infrastructure, while competition between private operators should take place at the service layer through open APIs. This hybrid arrangement is consistent with the principles of openness and interoperability of the Physical Internet [16, 21] and with the idea of open booking platforms proposed by S. Fazi and J. Fransoo [8]. It also corresponds to the transition from the state as an "operator" to the state as an "orchestrator" of the sector [20]. In practical terms, the E-logistika platform, to which logistics centres are to be connected by 2030 [14], can serve as the nucleus of the integration layer of the UDTP.

Fourth, the scenario results are comparable with empirical evidence. The conservative scenario assumes a five-percentage-point reduction in empty running; on the Uber Freight platform a three-point reduction was achieved within one year [29], so scenario S1 can be considered

achievable in the medium term. Scenario S3 corresponds to the current EU level of about 22% [7] and should be viewed as a long-term benchmark. The gain in the integral coefficient in the conservative scenario (18.7%) exceeds the threshold of 15% set in the hypothesis; therefore, the hypothesis is confirmed within the assumptions of the model. These results are in line with the conclusions of M. Gansterer and R. Hartl that the exchange of transport requests between carriers yields efficiency gains [9].

At the same time, the findings of V. Helwing and co-authors warn that digital platforms may increase price pressure on small carriers and owner-drivers [10]. Since the majority of Uzbek road carriers are small operators, the governance layer of the UDTP should include transparent rating rules, limits on intermediary commissions and guaranteed payment mechanisms. The barriers identified by M. Cichosz and co-authors - low digital maturity of small partners and lack of data standards [3] - also suggest that the platform should be implemented step by step, starting with simple mobile interfaces and mandatory e-waybills for selected cargo categories.

The proposed model also has an important institutional effect that is not captured by the efficiency indicators. The Ministry of Transport explicitly links the unified digital transport system with bringing informal activity into the formal economy and increasing transparency across the sector [13]. Since every trip registered through an electronic waybill becomes visible to the tax and statistical authorities, the platform simultaneously reduces the information asymmetry between market participants and between the market and the state. In a sector where more than 42% of activity is estimated to be informal [13], this creates the preconditions for a wider tax base, fairer competition between formal and informal carriers and more reliable transport statistics, including the indicators of empty running that are currently not available.

The environmental dimension of the results deserves attention as well. The avoided emissions of 0.48-1.20 million tonnes of CO_2 per year obtained in the scenarios are achieved without new infrastructure or fleet renewal, solely by using existing vehicles more intensively. This is consistent with the conclusion of the Physical Internet literature that the interconnection of logistics networks is a means of improving both economic efficiency and sustainability [16, 31].

The growth of the average haul distance and the elasticity of freight turnover above one also have implications for the modal structure of transport. As trips become longer, a growing share of them reaches distances at which combined road-rail transport through logistics centres becomes competitive. The multimodal booking module of the UDTP, connected to railway and logistics centre systems, can therefore support the development of synchromodal transport chains, as suggested by T. Ambra and co-authors and by S. Fazi and J. Fransoo [2, 8].

At the same time, the implementation of the UDTP involves risks that must be addressed in its design. The concentration of data on all freight flows in one system raises issues of data protection and commercial confidentiality; therefore, access rights at the integration layer must be strictly differentiated, and private operators should receive only the data necessary for their services. There is also a risk that one private operator will dominate the service layer and use its position to raise commissions; open APIs and equal access conditions for all certified exchanges reduce this risk.

The results also shed light on the economic mechanism by which a platform of this type should be launched. Platform theory shows that two-sided markets face the problem of the "cold start": shippers do not join a platform without carriers, and carriers do not join without loads [24, 22]. In the Uzbek case, this problem can be solved institutionally rather than through subsidies: if electronic waybills and registration in the carrier register become mandatory, information about vehicles and trips will enter the data layer regardless of whether participants use market services. The platform thus starts with complete coverage of supply, and private freight exchanges connected through open APIs compete for the quality of matching. This distinguishes the proposed model from purely market-based exchanges and explains why, unlike in China, where platforms grew spontaneously [30], a state-supported data layer is required in a market with a high share of informal activity.

The sensitivity analysis showed that the absolute savings vary by about ±25% depending on the assumed vehicle capacity, but even in the least favourable combination (conservative scenario,

12 t) the annual saving of 0.60 billion vehicle-km and about 150 million litres of fuel remains economically significant. The relative effect on the integral coefficient does not depend on this assumption, which strengthens the conclusion about the direction and order of magnitude of the platform effect. It should also be emphasized that the scenarios differ not in the technology used but in the depth of its adoption: the same platform architecture yields the conservative or the target effect depending on the share of trips registered on it, the quality of data and the number of private services connected. Consequently, the main managerial task is not the creation of the software itself but ensuring the participation of carriers and shippers, which again underlines the importance of mandatory registration and of incentives for the use of platform services.

Compared with the national studies, the results extend the company-level view of digital logistics platforms [12] and the infrastructure-oriented view of logistics development [25] to the level of the entire road freight sector. They show that the effect of the planned logistics hubs and the E-logistika platform will depend largely on whether these facilities are connected to a common data layer: logistics centres increase capacity, but only information integration ensures that this capacity is used by fully loaded vehicles.

The human factor should not be underestimated either. A considerable part of road freight in Uzbekistan is performed by owner-drivers and small firms that have limited experience with digital services. For them, the platform must be available through a simple mobile application in Uzbek and Russian, with minimal data entry, automatic generation of electronic waybills and fast settlement of payments. Experience of digital transformation of logistics providers shows that the low digital maturity of small partners is one of the main barriers to the success of digital projects [3]; therefore, training programmes and support services should be planned as an integral part of the platform rather than as an optional addition.

Based on the results, a three-stage implementation of the UDTP can be justified. At the first stage, the data layer is created: the carrier and vehicle registers and the e-waybill aggregator are launched, initially for selected cargo categories and for carriers serving state procurement. At the second stage, the integration layer and open APIs are introduced, and private freight exchanges, logistics centres and the railway are connected. At the third stage, the analytics layer is developed, and indicators α, β and γ are monitored by region and corridor to manage the sector on the basis of data.

The study has several limitations. Official statistics on empty running, load factors and fleet time utilization are not published in Uzbekistan, so the baseline and scenario parameters are based on international benchmarks and expert assumptions; the absolute estimates of vehicle-kilometres, fuel and emissions are illustrative and sensitive to the assumed average vehicle capacity. The time series covers only ten years and was analysed with simple trend models. The costs of creating and operating the platform were not assessed, and the effects of possible rebound demand were not taken into account.

CONCLUSION

The study substantiated a model of a unified digital platform aimed at increasing the efficiency of transport resource utilization in the road freight sector of Uzbekistan. It was established that in 2015-2024 road freight turnover grew at an average annual rate of 7.46%, faster than the tonnage carried (4.23%), with an elasticity of 1.65, which increases the pressure on the fleet. A four-layer platform model comprising data, integration, service and analytics layers was proposed, in which state registers and electronic waybills serve as public digital infrastructure and market services compete on an open basis. Scenario calculations showed that the platform can raise the integral resource utilization coefficient by 18.7-63.3% and reduce the vehicle-kilometres required per unit of transport work by 11.6-28.6%; the research hypothesis was confirmed. Thus, the answer to the main research question is positive: a unified digital platform that combines state data infrastructure with open market services is an effective instrument for increasing the efficiency of transport resource utilization, and its effect is achieved mainly through the reduction of empty running and better use of

vehicle capacity, rather than through additional investment in the fleet.

The practical significance of the study lies in the following recommendations for the Ministry of Transport and other stakeholders: to launch the data layer first - a mandatory register of carriers and vehicles and an e-waybill aggregator; to adopt an open API standard that allows private freight exchanges and logistics centres to connect to the platform; to include indicators of empty running, load factor and fleet utilization in national transport statistics; to link tax and other incentives to trips registered on the platform; and to pilot the platform on high-density corridors served by the planned logistics hubs. Implementation should proceed in three stages - data layer, integration layer and analytics layer - so that each stage produces measurable results and creates the conditions for the next one.

The implementation of these recommendations will make it possible to reduce transport costs for shippers, increase the income of carriers through higher vehicle productivity, bring a significant part of informal freight activity into the formal economy and reduce the environmental burden of road freight transport without additional investment in the fleet.

The contribution of the study to economic science lies in combining the theory of two-sided platforms, the concept of open logistics networks and the classical indicators of transport resource utilization in a single analytical framework that can be applied to transition economies with a high share of informal activity.

Future research should focus on field surveys to measure empty running and load factors in Uzbekistan, cost-benefit analysis of the platform and agent-based simulation of the behaviour of carriers and shippers under different platform pricing rules.

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