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IMPROVING THE EFFICIENCY OF ROAD TRANSPORT DURING THE CARRIAGE OF AGRICULTURAL GOODS

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ABSTRACT: The purpose of this article is to analyse the possibilities for increasing the efficiency of road transport in the transport of agricultural goods. A prototype of a computer program for the comprehensive calculation of freight carriage tariffs, which currently calculates the cost of transportation expenses in relation to the quality of the road surface, has been considered a promising area of focus. In order to create a quality modern transport logistics system, Kazakhstan needs to ensure transparency of transport tariffs and a mechanism for their control and regulation on a set of details. At the same time, attention should be paid to improving and increasing the efficiency of existing networks and improving its intensity management. Transition to new environmentally friendly fuels, reduction of maintenance and repair costs through consolidation of transport companies, and introduction of technologies and innovations are significant points in this topic.

Keywords: Agriculture, Freight carriage, Economic efficiency, Innovation, Ecology.

1. INTRODUCTION

Between 1960 and 2010, world food production almost tripled and the population almost doubled [1]. This led to an increase in per capita food production of more than 30% [2]. Due to the increase in agricultural production, there is a need to increase the quantitative and qualitative indicators of the transport network. This applies to the creation of new roads and to the improvement of existing ones, and the Republic of Kazakhstan is actively working on this aspect [3, 4]. Increases in the costs of transport services correlate with increases in food prices. Both domestically and internationally, the transport sector plays a crucial role in the distribution of goods in markets, and transport service providers are responsible for moving goods along the supply chain, from raw materials to intermediate processes, through to the subsequent distribution of finished products [5].

The results of the 2015 survey show that the attractiveness of Kazakhstan as a transport and logistics hub will depend on the state of logistics infrastructure, quality of services, and technologies used [6]. One of the key objectives of the “Strategy "Kazakhstan-2050": a new political course of an established state” [7] is formulated as ensuring the competitiveness of the Kazakh transport and communications complex in the world market and increasing trade flows through the country. The purpose of this article is to analyse the possibilities for increasing the efficiency of road transport in the transport of agricultural goods. In order to dive into the subject as much as possible, the following objectives are set: to study the state and prospects of the agricultural road freight carriage industry, to examine selected aspects affecting the economic efficiency of freight carriage in agriculture – variables costs and expenses, possibilities of optimisation, etc. In addition, the need and effectiveness of a prototype computer programme for calculating transport tariffs based on road quality will be analysed.

2. RESEARCH SIGNIFICANCE

Road transport in the field of freight carriage in agriculture is of significant importance since the final value of agricultural products depends on the costs of this aspect. The transport system includes not only roads and vehicles but also services with the selection of optimal consumables and spare parts, storage areas, innovation, and technology, other variable and fixed costs. Each industry is concerned with increasing profits and reducing costs. Also, ensuring that agricultural goods reach their destination on time and in good condition is significant in achieving food security. This research could contribute to broader economic and social development.

3. MATERIALS AND METHODS

The following methods have been used for improving the efficiency of road transport of agricultural goods: a comparative analysis of two

types of freight transport (road and rail) as the largest share in the total volume of freight turnover relative to inland waterway and maritime transport. Both theoretical aspects of advantages and disadvantages and numerical statistics on their development were considered; study of world experience and making analogies on possible ways of increasing the economic efficiency of freight transport in the Republic of Kazakhstan; ascending from abstract perspectives to specific proposals; disclosure of existing computer programme model and theoretical modelling of further possible updates of functionality; study of modern publications on the subject of work, citing of significant aspects.

To justify transport costs and provide the customer with a transparent transport tariff, it is necessary to have a simple algorithm for making calculations, taking into consideration the many indicators included in the database. This will also contribute to improving the efficiency of trucks and optimising road transport by make and type. The developed prototype programme can calculate the cost of transport, including road quality and pavement conditions. Vehicle downtime during repairs and the cost of repairs itself reduces the efficiency of the industry. Based on this, it is objectively justified to propose an increase in cost in correlation with pavement quality.

A computer programme has been developed to calculate the cost of freight transportation depending on the type and capacity of the vehicle and the quality of roads. The reference values are vehicle and fuel costs, depreciation rates, driver's wages, availability and cost of trailers, etc. These figures are entered into the database and can be updated as they change. The data is local to each company, vehicle data is entered, the distance and type of pavement to be transported are specified, and the data is then sent to the operator, who calculates the cost of transporting the goods.

The estimated cost of freight transportation services per kilometer was determined according to the methodology of the Ministry of Transport and Communications of the Republic of Kazakhstan [8]. The calculation of the cost is the final goal of the programme and is done according to the methodology of the Ministry of Transport and Communications of the Republic of Kazakhstan after filling in the necessary data in the “Handbooks” section.

4. RESULTS AND DISCUSSION

4.1. State and prospects of agricultural road freight carriage

The total length of the road network of the Republic of Kazakhstan is 96000 km, including the length of the republican network is 25000 km, with the share of roads in normative condition – 89%; the length of the local network is 71000 km, including the share of roads in normative condition – 75% (Fig. 1). In addition, 15000 km of local roads have been repaired. Decree of the Government of the Republic of Kazakhstan No. 1055 “On approval of the State Program for Infrastructure Development "Nurly Zhol" for 2020-2025” [9] was adopted, according to which it is planned to build and reconstruct 12000 km of roads in the next 6 years, and to carry out major and medium repairs of 11000 km of national network roads (Table 1).

Table 1 Effects of the “Nurly Zhol” programme

Effect	2014	2019	Increase
Income	180 bln. tenge	782.4 bln. tenge	4.3 times
Cargo	1.3 mln. tonnes	1.8 mln. tonnes	1.5 times

In 2019, Decree of the President of the Republic of Kazakhstan No. 1030 “On approval of the State Program for Infrastructure Development "Nurly Zhol" for 2015-2019” [10] was completed, under which 3000 km of roads of national importance were built and reconstructed, about 7000 km of roads were repaired [1]. The new programme for the period from 2020 to 2025 also notes plans to continue work in this area. From 2016 to 2019, the mass of cargo transported by road in Kazakhstan increased by 11.6%: from 3.18 to 3.55 billion tonnes. The growth in road freight carriage in the state was driven by the development of the road network as part of government infrastructure projects. In general, when comparing the volume of freight transportation in Kazakhstan by all modes of transport, from 2012 to 2016 it can be saw the greatest growth in road transport (Table 2) [11].

Considering the evolution of the volume of freight transport by road between 2016 and 2020 (Table 3-4), a significant drop in volumes during the pandemic can be noted [12].

From January to March 2020, the volume of freight carriage by all types of transport in the Republic of Kazakhstan amounted to 843.9 million tonnes, of which 80%, or 675.3 million tonnes, were transported by road freight transport. Compared to the same period last year, the volume of freight transported by all types of transport during the pandemic expectedly decreased – by 3.4% and by 5% for road freight transport. In 2020, quarantine measures taken by the Kazakh government to prevent the spread of coronavirus infection resulted in a 7.4% reduction in road freight transport to 3.29 billion tonnes [12]. Sufficient investment and government support for transport are needed to maintain the productivity of the various modes of transport of agricultural products, particularly grain [4].

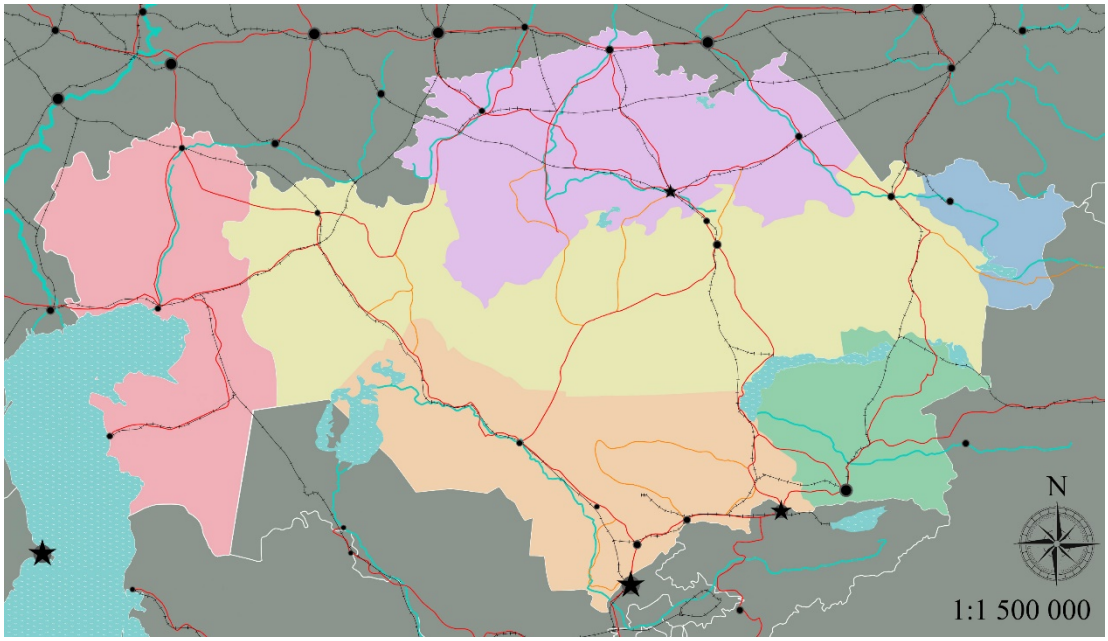

Fig.1 Road map and administrative regions of Kazakhstan

Table 2 Volume of freight transportation of the Republic of Kazakhstan by types of transport (2012-2016)

	2012	2013	2014	2015	2016	2016/2012
Total cargo, million tonnes	3231.8	3508.0	3749.8	3733.8	3729.2	+15.4%
Including:	-	-	-	-	-	-
By rail	294.8	293.7	390.7	341.4	338.9	+15%
By road	2718.4	2983.4	3129.1	3174.0	3180.7	+17%
By inland water	1.3	1.1	1.3	1.2	1.2	-7.9%
By the sea	4.0	4.0	3.6	2.5	2.6	-36.6%

Table 3. Dynamics of road freight carriage volumes in Kazakhstan from 2016 to 2020

Parameter/Year	2016	2017	2018	2019	2020
Volume of goods transported by road, billion tonnes	3.18	3.32	3.42	3.55	3.29
Dynamics, %	0.2 (from 2015)	4.5	3.0	3.7	-7.4

Table 4. Length of public roads, Kazakhstan, 2016-2020 (thousand km)

Index	2016	2017	2018	2019	2020
The length of automobile public roads, thousand km	96.4	95.4	96.2	95.6	97.9
% to the previous year	-	-1.0	0.9	-0.6	2.4

The development of logistics infrastructure in Kazakhstan is possible on the basis of customs warehouses, in particular, at the existing freight terminals of “Kedentransservice” JSC (joint-stock company) in Kazakhstan [6]. The formation and creation of the transport company on the basis of customs warehouses of temporary storage “Kedentransservice”. Road transport offers the advantage of door-to-door transport so that consignors can move goods from consignor to consignee in the same mode, and the ease and completeness of these connections between consignor and consignee cannot be matched by any other alternatives [13]. Transport services should include any operations that are not part of the transportation process but related to its preparation and implementation, such as wrapping and loading/unloading of cargo, packing and marking, intermediate storage, etc. In modern conditions, this list of services has to be complemented by marketing, commercial, information, insurance services, etc. [5].

Social distancing for the COVID-19 pandemic has had a significant impact on the behaviour and movement of people, which has affected consumer demand for goods. Safety regulations and travel restrictions reduced the efficiency of businesses and increased the cost of production. The flexibility of the road transport industry was vital for emergency response and the distribution of needed supplies [14]. Recent studies have shown that the quality of transport services provided to enterprises and

organisations in the agricultural and industrial complex does not meet modern requirements: transportation deadlines are not met, and there are losses and damage to goods during transportation. The most rational and promising direction to improve the road is to improve the centralised system of managing the operation of vehicles [5]. The efficiency of road freight transport consists of the organisation of the transportation process and the technical and operational indicators of the rolling stock. Efficiency can be evaluated by the volume and quality of the work performed [15].

The competitiveness of road transport has declined due to the rapid correlation of transport costs with fuel prices or exchange rates. Recent studies have found that a factor for using railways is distancing greater than 600 km, as in this case the economic benefits of the logistics system are higher. At the same time, for distances less than 600 km, road transport is the better choice. However, if the recipient has rail access, then rail transport is preferable at distances of 900 km and more. The economic return to the system, in this case, is 6% higher than for road transport [16]. Many kilometres of railway lines have been abandoned, while short railway lines have been developed. At the same time, mergers between Class I railways were taking place, which, according to some reports, led to the loss of rail connections for the purpose of freight carriage [4]. The development of transit road freight carriage will be facilitated by the economic growth of China and Southeast Asian countries and their interest in increasing the volume of cargo shipments to Western Europe overland through the territory of Kazakhstan (Table 5) [12].

In 2015, Kazakhstan, Russia, and Belarus jointly established a unified transport and logistics company to reduce the transport time in the East-West direction. The presence in such Chinese hubs as Urumqi, Chongqing, and Lianyungang will provide an opportunity to influence the formation of the cargo base and conduct a direct dialogue with shippers, promoting the advantages of overland routes through Kazakhstan (Fig. 2) [6].

4.2. Interface and functionality of the developed programme

The transport system should be as economical and efficient as possible [1]. With the help of the described developed programme, it will be possible to calculate direct and indirect costs and to determine the economic efficiency of transport. After entering the initial data (described in the Materials and methods section), the program, by clicking on the “Calculate freight tariffs” button at the bottom of the window, will automatically calculate the cost of freight transportation for the consumer, reduced to one kilometer. The “Handbook” command contains technical and economic characteristics of some trucks (brand, payload, fuel consumption, price, manufacturer). One can use the “Settings” command to additionally update the database of vehicles with their technical specifications. The “Help” command is used to get acquainted with the program and to learn the sequence of user actions during work.

The fare calculation is the ultimate goal of the programme and is carried out by the methodology of the Ministry of Transport and Communications of the Republic of Kazakhstan after filling in the necessary data in the “Handbook” section [8]. After that, pressing the “Calculate fare” button opens a window where the car brand from the drop-down list, the number of drivers and trailers, and the percentage of road quality are entered into the empty cells. The sum of percentages of individual road segments must be 100%. If this condition is not met, an appropriate message appears.

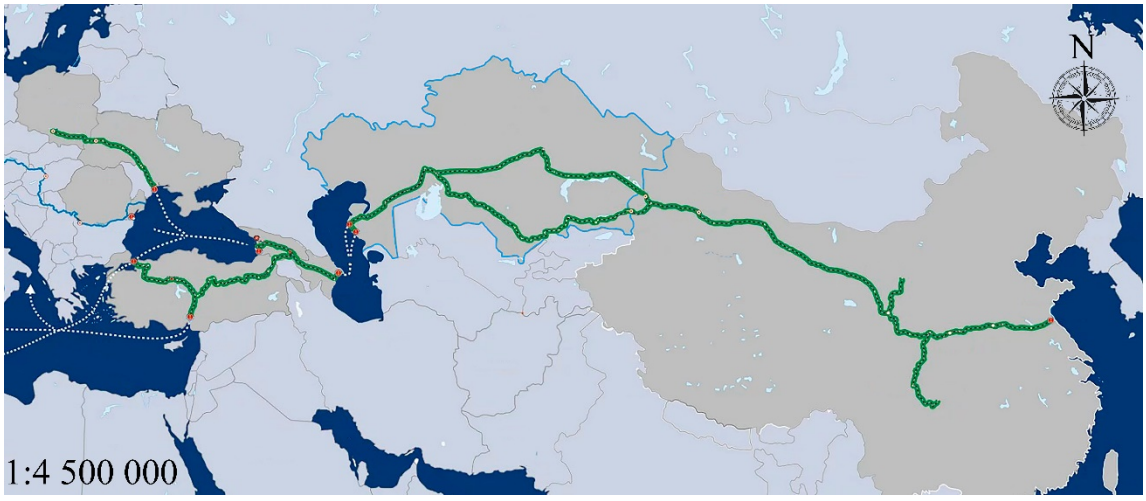

Fig. 2 Kazakhstan as a transport and logistics hub

Table 5 International Road corridors in Kazakhstan

Corridor name	Direction	Area in Kazakhstan
Northern corridor of the Trans-Asian Railway	Western Europe-China, Korea, Japan through Russia and Kazakhstan	Dostyk-Astana-Petropavlovsk
Southern corridor of the Trans-Asian Railway	South-Eastern Europe-China-South-East Asia through Turkey, Iran, Central Asian countries and Kazakhstan	Dostyk-Saryagash
Central Asian corridor	Central Asia - Russia and EU countries	Saryagash-Arys -Kandagach-Ozinki
corridor “North-South”	Northern Europe - countries - the Persian Gulf through Russia and Iran	Aktau seaport section - the regions of the Urals and Aktau - Atyrau
TRACECA	Eastern Europe - South Caucasus - Caspian Sea - Central Asia	Central Asia

After this, the operational cost of the transport is automatically displayed in the remaining cells, and the cost per kilometer is displayed in the cell “Cost per truck kilometer”. Multiplying this value by the transport distance will calculate the total cost of transport. In the price list of companies providing cargo transportation services, the cost of 1 km of transportation is from 150 tenge. A comparison of tariffs for trucking services and the estimated rates under the proposed programme shows that they are overstated by a factor of 2 or more. This is due to the underdevelopment of transport logistics, the desire of transport service providers to maximise profits, and poorly developed competition among carriers. There are recommendations to include measures to ensure transparency in freight cost regulation [18], which is what this Programme implies. Anticipation of new technologies will of course also be an important aspect in the future of freight transport [19].

4.3. Study of the aspects affecting the economic efficiency of freight transport in agriculture

Among the most important variable costs are fuel and labour (Table 6). Nevertheless, the global experience and developments offer even more environmentally friendly options, with higher economic efficiency for the production owners [19; 20]. Switching to gas and diesel fuel is one such solution. The technical solutions presented in the Russian market [21; 22] provide a gas/diesel ratio in the normal operation of 75/25% to 85/15%, which is insufficient in the conditions of the tasks set by the project. In the USA, models with a gas/diesel ratio of 95/5% have been presented and successfully implemented [23].

Table 6. Most significant variable costs in many industries [12]

Variable costs	%
Fuel	39
Labor	24
Other	37

At the moment, the Eurasian Economic Community countries have not managed to repeat the foreign success. The technological solutions are not only in the field of software; they are more likely to be a complex task. All actuators of the fuel mixture formation system are involved in the formation of the gas/diesel flow ratio: intake manifold paths, combustion chambers of the internal combustion engine (ICE) and the related combustion process of the fuel mixture in the combustion chamber. An attempt to reverse-engineer imported systems was unsuccessful. Some specialised research institutes in the Russian Federation and the Republic of Kazakhstan can form a theoretical basis for fuel mixture combustion processes in the voiced ratio (gas/diesel = 95/5%) with the preparation of a technology demonstrator.

This is followed by the creation of technical documentation and its subsequent transfer to production. The enterprise responsible for the project can apply to the federal or regional government for special-purpose financing. The likelihood of targeted funding is high, as the investment in the development of the technology is aimed at involving domestic scientific institutions. In addition, the end result of the research (the Technology) is significant for the economy in terms of reducing the costs of fuel and lubricants for trucks, road, municipal, and construction machinery in the field of agriculture. Renewable technologies, such as electrification and hydrogen, are being tested for all modes and can conceptually eliminate most emissions problems, but they are more difficult to implement options [17]. Indirectly, environmental and ecological issues are also influenced by the ground pressure aspect of machinery. The trend towards improved traction and driveability of wheeled machines through the improved drivetrain and engine power also includes a significant factor, such as wheel and tyre designs that enable a significant expansion in the use of wheeled machines, both in industry and agriculture. Pneumatic tyres and wheels are a very important and costly part of the machine, directly affecting the dynamics and smooth running, traction properties, permeability, braking properties, etc.

Different tyre types have been developed for industrial and agricultural machinery operating under different conditions. For example, tyres with a universal tread pattern are excellent for driving on asphalt or dry dirt roads. In soft ground conditions, tyres with a universal tread pattern become “soiled” – clogged with soil, and their effectiveness is

reduced to a minimum. The vehicle stops moving at all or experiences relatively low speed because of heavy sliding. The most effective improvement of the permeability of the car in difficult road conditions, when driving on soft and viscous soils, is achieved with the use of special tyres of new designs: tyres with adjustable internal pressure, strong tyres. Another type of tyre, in particular the arch tyres, are produced without cameras. Arch tyres exhibit high radial deflections in operation, which very often result in half-axle damage and high shock loads in the vehicle powertrain. Run-flat tyres are designed to continually run off-road and on country roads but must also withstand travelling on asphalt. However, they are completely ineffective on roads with high load-bearing capacity due to rapid wear.

The relevance of the logistic approach to solving the problems of organisation of production and interaction of production enterprises, processing of agricultural products and their delivery to the country's population is determined by the transition from the seller's market to the consumer market, which requires a flexible response of production and trade systems to the rapidly changing priorities of consumers [5]. The choice of optimal cargo flows is restricted by the availability of vehicles, the specified location, and the technical and logistical characteristics of the respective production facilities. Significant economic effect in solving this problem can be achieved if new links are added to the system of agricultural cargo delivery to consumers. Production units (facilities) are established at locations where agricultural products are classified, and consignments are formed, primary processing is carried out, if necessary, etc. Those carriers, which are overwhelmingly small businesses, have access to a limited customer base and find it difficult to invest in technology and human resources. Thus, those market players with only limited working capital may face problems in maintaining solvency, and therefore, there is a constant flow of businesses leaving the market. In contrast, medium and large-sized players tend to be much more competitive and have a better bargaining position in the market [15].

Competition between different types of transport requires ensuring that perishable goods can be delivered to consumers in the shortest possible time without loss or deterioration in quality. Inefficient transport distribution networks reduce profit margins for businesses and increase the cost of goods to the public. The use of inefficient methods of cargo preservation leads to a deterioration in the consumer properties of goods, increased fuel consumption, and an increase in the number of harmful exhaust emissions from vehicles. This increases the negative impact of transport on the environment, especially in large cities, which makes the issue of cargo security and transport efficiency an urgent one. Transport costs have an important impact on the selling price of a product. Thus, transport losses must be kept to a minimum. But in addition to this loss in quantity, there is a loss in quality when the product undergoes changes during carriage [1]. Therefore, in recent years, carriers have paid increasing attention to automating the control of perishable goods during transport. When evaluating the performance of refrigerated vehicles, it is important to consider the weather and operating conditions of the transport. The traditional solution to the problem of temperature control in transport is primarily the use of autonomous electronic recorders. However, the use of these devices as monitors of temperature and other parameters of the isothermal space of the vehicle implies the need to select the optimal placement of recorders or so-called control points, which requires further research [24].

In recent studies, it has been empirically established that at ambient temperatures of up to +10°C, refrigerated trucks with gas-fuelled compressor-type refrigeration units are more appropriate for transporting frozen products by road. At air temperatures above +10°C, the optimum transport volume and route length must be determined to ensure the preservation of goods that can be delivered to the consignee without spoilage. If it is not possible to ensure cargo safety by optimising the route and transport volume, it is advisable to replace the compressor-type refrigerator with a refrigerator of the eutectic type. The developed methodologies make it possible to calculate the optimal load of a refrigerated vehicle and the characteristics of the delivery route and to determine the objective fuel consumption rate of a refrigerated vehicle [25]. These developments can be used to further develop the functionality of the Programme for Improving the Economic Efficiency of Freight Carriage developed by the authors of the article.

The service station is the main vehicle maintenance facility in the automotive service system for the maintenance and repair of vehicles owned by the public. Modern service stations are multifunctional facilities that, depending on their capacity and purpose, carry out various operations. Larger service stations have specialised sections for overhauling parts and assemblies. Flow lines can be used for diagnostics and maintenance [26]. As a possible development of the functionality of the Programme, it is possible to implement maintenance data sheets in the interface, with reminders of the necessary machine condition checks. The development of logistics infrastructure at the beginning includes, firstly, the management of storage and packaging facilities, transport and handling equipment; secondly, the development of

material and financial flow management information systems to manage and optimise stocks, etc. There is now a worldwide trend to outsource many transport and logistics functions to logistics enterprises, thus reducing logistics costs. Firstly, it is usually much cheaper to pay a fee to a firm than to pay salaries, taxes, insurance, and other costs associated with maintaining your own transport department. The level of expertise is often higher with a firm specialising in transport logistics. They may have relationships with transport companies throughout the country and be able to negotiate better deals for the shipment. Thus, the Programme developed has the prospect of being hosted on a large platform where customers will be able to choose from a variety of options. Linking this aspect to the transition to a green economy, the most cost-effective measures to decarbonise road transport are obtained by improving (densification) of vehicle loads through optimisation and cooperation (overloading) [27-28].

5. CONCLUSION

In order for transit cargo flows to move to Kazakhstan's transport system, domestic transport and logistics complexes and its infrastructure need to be created, transparency of transport tariffs and the mechanism of their control and regulation need to be ensured. At the same time, attention should be paid not to indicators of increasing physical elements of transport infrastructure, as it is often claimed when justifying the decision to invest in transport infrastructure, but primarily to improving and increasing the efficiency of existing networks, improving the management of its intensity of use. The volume of agricultural production will tend to increase, especially for broad consumer products, correlating with population growth. In the authors' view, road transport operators will therefore see a steady but relatively slow growth in demand for transport services across all market segments. However, tougher competition and rising costs (for labour and fuel) will tend to restrain turnover, especially for smaller operators or those who are not part of wider commercial networks.

Poor road conditions affect the cost of transporting agricultural products, which in turn affects the income of producers. The computer programme developed is needed to deliver agricultural cargo quickly, safely, and economically anywhere in the world. Reduction of tariffs for cargo transportation, especially for agricultural products, will allow increasing profits of commodity producers. Possible aspects for extending the functionality and implementing a more comprehensive tariff calculation, and the cost reduction opportunities, have been discussed in this paper. This includes the organisation of large logistics complexes and specialised workshops to reduce maintenance, repair, and storage costs, etc. Controlling the speed of transport and maintaining the quality of the product by ensuring the necessary transport conditions will reduce losses and indirectly influence the cost of the product. It is also important to switch to a more economical fuel – a combination of gas and diesel at a 95/5% ratio can pay back the equipment in 2-3 years, and subsequently save on fuel and reduce the concentration of emissions in the atmosphere. In addition, the use of correctly selected tyres has an impact on improving the environmental condition and increasing the efficiency of agricultural machinery use.

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