Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 126 **2025**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2025.126.13

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Savin, Y., Mytko, M., Antoniuk, O., Tokarchuk, O., Burlaka, S. The impact of fuel costs on the feasibility of cooperation-based operations at auto transport enterprises. *Scientific Journal of Silesian University of Technology. Series Transport*. 2025, **126**, 205-220. ISSN: 0209-3324. DOI: https://doi.org/10.20858/sjsutst.2025.126.13.

Yuri SAVIN[1], Mykola MYTKO[2], Oleh ANTONIUK[3], Oleksii TOKARCHUK[4], Serhii BURLAKA[5]

THE IMPACT OF FUEL COSTS ON THE FEASIBILITY OF COOPERATION-BASED OPERATIONS AT AUTO TRANSPORT ENTERPRISES

Summary. In recent years, significant changes have taken place in Ukraine's automotive transportation sector. Alongside existing transport companies, a large number of relatively small transport and commercial enterprises have been established. As a result, since the mid-1990s, a regional structure for vehicle maintenance and repair has begun to form in Ukraine, based on the principles of concentration, specialization, and cooperation within the region. The transition to a regional infrastructure for vehicle maintenance and repair production allows, in many cases, the abandonment of comprehensive auto transport enterprises (ATEs),

[1] Faculty of Automotive and Mechanical Engineering, The National Transport University, Mykhaila Omelianovycha - Pavlenka 1 Street, 01010 Kyiv, Ukraine. Email: ghsavin@gmail.com. ORCID: https://orcid.org/0000-0003-4329-665X
[2] Faculty of Mechanical Engineering and Transport, The Vinnytsia National Technical University, 95, Khmelnytske Shosse St., Vinnytsia, 21000, Ukraine. Email: mytko_83@ukr.net. ORCID: https://orcid.org/0000-0002-5484-0510
[3] Faculty of Mechanical Engineering and Transport, The Vinnytsia National Technical University, 95, Khmelnytske Shosse St., Vinnytsia, 21000, Ukraine. Email: antonukOP@gmail.com. ORCID: https://orcid.org/0009-0006-5348-4936
[4] Faculty of Engineering and Technology, The Vinnytsia National Agrarian University, 3, Solnyshchaya St., Vinnytsia, 21008, Ukraine. Email: tokarchyk08@ukr.net. ORCID: https://orcid.org/0000-0001-8036-1743
[5] Faculty of Engineering and Technology, The Vinnytsia National Agrarian University, 3, Solnyshchaya St., Vinnytsia, 21008, Ukraine. Email: ipserhiy@gmail.com. ORCID: https://orcid.org/0000-0002-4079-4867

enabling more efficient utilization of existing production potential. This approach creates the necessary conditions to fully meet the needs of vehicle owners for maintenance and repair services. One of the most important factors in organizing cooperative vehicle maintenance and repair operations is the economically feasible distance for transporting vehicles and repair assets to auto-service enterprises or other businesses providing such services. This limitation effectively restricts the potential for cooperation in performing these tasks. However, in recent years, due to the global economic and energy crisis, fuel costs in Ukraine, as well as in most developed countries, have significantly increased. As a result, the recommendations found in scientific literature regarding the feasible distances for transporting vehicles and repair assets to auto-service enterprises are now being questioned and require further research under current conditions. A methodology for determining economically feasible distances for transporting vehicles to auto-service enterprises is presented. Based on the conducted research, the economically viable distances for vehicle maintenance and repair operations at auto-service enterprises in the current stage have been identified. The results take into account the current cost of fuel and lubricants at gas stations (GS) in Ukraine, as well as the hourly labor rates at auto-service enterprises. These findings can be used by companies when organizing cooperative vehicle maintenance and repair services at auto-service enterprises.

Keywords: automobiles, economically feasible transportation distances, production cooperation, automotive transport enterprises, maintenance and repair

1. INTRODUCTION

Automotive transport is the most mobile, efficient, and versatile means of communication, holding a prominent position in the transport sector of Ukraine, as well as in most countries worldwide.

In recent years, significant changes have occurred in Ukraine's automotive transport industry. Alongside the existing auto transport enterprises, a large number of relatively small transport-commercial companies have been established. As a result, since the mid-1990s, a regional structure for vehicle maintenance and repair has begun to form in Ukraine, based on the principles of concentration, specialization, and cooperation of services within the region.

The transition to a regional infrastructure for vehicle maintenance and repair allows, in many cases, the abandonment of comprehensive auto transport enterprises (ATEs). It enables broader application of the principles of concentration, specialization, and cooperation, leading to more efficient use of existing production potential, a significant reduction in capital costs, and the creation of the necessary conditions to fully meet the needs of vehicle owners for production services related to maintenance and repair.

Currently, the maintenance (M) and repair of the fleet of auto transport enterprises or the transport divisions of other companies can be organized in the following ways:

1) all maintenance and repair work on vehicles is performed at the company's own production and technical facilities;
2) all vehicle maintenance and repair work is outsourced to auto-service enterprises under contractual agreements;
3) some of the maintenance and repair work is carried out at the company's own production and technical facilities (primarily routine maintenance and current repairs), while the

other part is performed at auto-service enterprises (mainly diagnostic tasks, as well as minor current repair work, which is minimal but requires specialized, expensive equipment and highly skilled personnel).

The most widespread method of organizing vehicle maintenance and repair is through the company's own production and technical facilities. This approach primarily applies to former state-owned comprehensive auto transport enterprises (ATEs), which is a result of the historical development of automotive transport. Regardless of the number of vehicles in the ATE, and thus the volume of maintenance and repair work, these enterprises established a full range of production departments and equipped them with the necessary technological tools. However, research shows that it is only economically viable for large ATEs to perform all types of maintenance and repair work in-house. In smaller ATEs, production capacities are used inefficiently.

The second method of organizing vehicle maintenance and repair, where all the maintenance and repair work is outsourced to auto-service enterprises under contractual agreements, is commonly used by modern commercial organizations and companies (such as banks, insurance companies, and others). In these cases, the cost of transport maintenance is already factored into the overall cost of services.

The third method of organizing vehicle maintenance and repair (a mixed approach), where part of the work is done in-house and the rest is outsourced to auto-service enterprises, is used by modern small transport-commercial enterprises. For these companies, fully establishing their own production and technical facilities is, first, economically unfeasible and, second, practically impossible.

The above-mentioned methods of organizing vehicle maintenance and repair, currently implemented in Ukraine, are also common in developed countries around the world.

One of the most important factors in organizing cooperative vehicle maintenance and repair operations is the economically feasible distances for transporting vehicles and repair assets to auto-service enterprises or other businesses providing these services. These distances effectively limit the potential for cooperative work.

2. LITERATURE REVIEW

The issues of improving organizational forms for vehicle maintenance and repair production, as well as the development of automotive transport infrastructure, have been addressed in the works [16, 17]. An analysis of the completed research indicates that the implementation of modern organizational forms for vehicle maintenance and repair remains a relevant issue and requires further resolution.

The feasibility of performing cooperative work is limited by the economically viable distances for transporting vehicles and repair assets to auto-service enterprises.

The distances considered appropriate in literature sources [1, 3, 17-19] are as follows: 10-15 km for TM-1, 20-45 km for TM-2, and 40-80 km for current repairs (CR).

However, these transportation distances were determined back in the 1970s and 1980s and do not reflect current conditions. At that time, the appropriate distances were calculated for auto transport enterprises (ATEs) with a fleet size of 100 to 300 vehicles, which accounted for 63.4% of the total number of ATEs in the 1970s-1990s. Today, the number of ATEs in Ukraine with over 100 vehicles is less than 1%. The majority of auto transport enterprises (approximately

64%) now operate with a fleet of 10 or fewer vehicles. This shift necessitates an increase in the economically viable distances for vehicle transportation.

On the other hand, during this period, the cost of fuel has increased almost tenfold in euro terms (from €0.10-0.20 per liter in the 1970s-1980s to €1.3-1.8 per liter today). The proportion of fuel and lubricant costs in the total cost of transporting vehicles and repair assets to auto-service enterprises now exceeds 50%. This has led to an increase in transportation costs and, consequently, a reduction in the economically feasible distances for performing cooperative TM and vehicle repair at auto-service enterprises.

The most relevant economically feasible distances for transporting vehicles and repair assets to auto-service enterprises under modern conditions are presented in the dissertation by Mytko M.V. [18, 19]. First, these studies account for the structural changes in Ukraine's auto transport enterprises, and second, they also consider the changes in fuel and lubricant costs during that time (2017-2019). The economically feasible transportation distances for cooperative TM and repair work, obtained in studies [18, 19], differ significantly from those previously cited in academic literature. The distances for transporting vehicles to auto-service enterprises for TM-2 and current repair (CR) tasks have decreased, while the distances for transporting components and assemblies for specialized CR tasks have substantially increased.

However, in recent years, due to the global economic and energy crisis (2020-2022) and the state of war in Ukraine (2022-2023), fuel prices have almost doubled. Currently, in Ukraine, A-95 gasoline costs €1.18-1.43 at various gas stations, while diesel fuel is priced at €1.24-1.48. Additionally, the devaluation of the Ukrainian hryvnia has significantly increased the cost of services at auto-service enterprises. As a result, the recommendations provided in studies [18, 19] regarding the economically feasible distances for transporting vehicles and repair assets to auto-service enterprises are now questionable and require further research under current conditions.

This issue applies not only to Ukraine but also to most developed countries worldwide. Over the past four years, the price of A-95 gasoline has risen significantly. In the United States, it increased by almost 57% (from €0.71 in 2019 to €1.12 in 2023) [20, 22]; in Australia, by 56% (from €0.74 in 2019 to €1.16 in 2023) [20, 24]; in Spain, by 28% (from €1.29 in 2019 to €1.65 in 2023) [20, 21, 23]; in Germany, by 36% (from €1.29 in 2019 to €1.80 in 2023) [20, 21, 23]; in France, by 25% (from €1.50 in 2019 to €1.88 in 2023) [20, 21, 23]; in the United Kingdom, by 23% (from €1.41 in 2019 to €1.73 in 2023) [20, 21]; and in the Czech Republic, by 31% (from €1.24 in 2019 to €1.62 in 2023) [20, 21].

The aim of this article is to determine the economically feasible transportation distances for technical maintenance and vehicle repair through cooperation under current conditions at auto-service enterprises.

3. MATERIALS AND METHODS

The feasibility of performing maintenance (TM) and repair of vehicles from a transport or other enterprise through cooperation with auto-service enterprises depends on the scope of the work and the costs required to carry out the work directly at the enterprise. Therefore, to determine the feasibility of performing vehicle maintenance and repair through cooperation with auto-service enterprises, the criterion used is the maximum volume of work for which performing a specific type of maintenance and repair becomes economically unviable at the transport enterprise.

The objective function for determining the feasibility of performing the *k-th* type of vehicle maintenance and repair work at a transport enterprise through cooperation with auto-service enterprises is as follows:

$$C_{k,\,ATE,\,i} \geq C_{k,\,CSP,\,j} \tag{1}$$

where: $C_{k,\,ATE,\,i}$ – *i* is the cost per man-hour for performing the *k-th* type of work at the *i-th* transport enterprise (in EUR per man-hour); $C_{k,\,CSP,\,j}$ – is the cost per man-hour for performing the *k-th* type of work at the *j-th* auto-service enterprise (in EUR per man-hour).

The use of this criterion is justified by the fact that, currently, the cost of services at auto-service enterprises and other specialized vehicle maintenance and repair facilities is determined based on the cost of one man-hour for the specified type of work, i.e., the specific labor costs per man-hour. Therefore, performing the *k-th* type of maintenance and repair work at the *i-th* ATE is deemed economically unfeasible if the cost per man-hour for carrying out this work at the transport enterprise exceeds the cost per man-hour for the *k-th* type of work at the *j-th* Centralized Specialized Production (CSP) facility (see Fig. 1).

However, this function does not account for the costs associated with transporting vehicles or repair assets to the maintenance and repair facility.

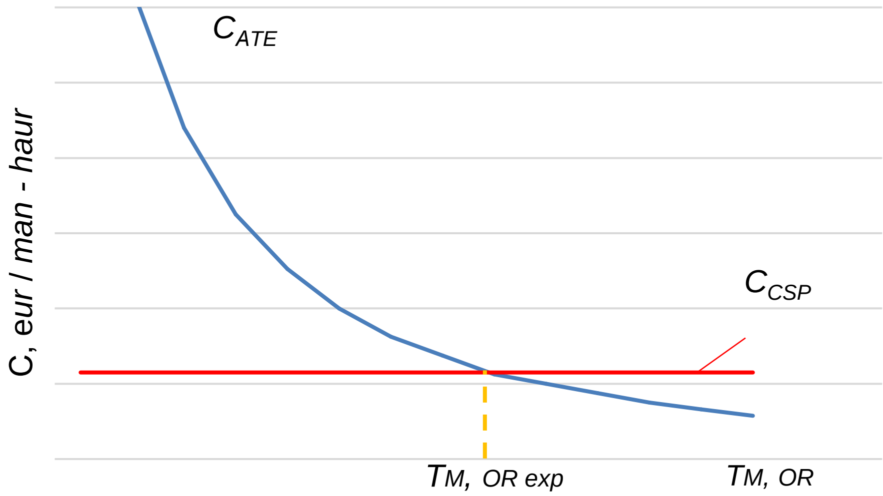

Fig. 1. Determining the feasibility of performing the *k-th* type of technical maintenance and vehicle repair work at an ATE through cooperation with auto-service enterprises

Taking transportation costs into account, the function is as follows:

$$C_{k,\,ATE,\,i} \geq C_{k,\,CSP,\,j} + C_{k,\,del,\,j} \tag{2}$$

where: $C_{k,\,del,\,j}$ – represents the cost of vehicle delivery or repair assets for performing the *k-th* type of work at the *j-th* CSP facility, allocated per man-hour of labor, in EUR per man-hour.

The performance of the *k-th* type of maintenance and repair work at the *i-th* transport enterprise is deemed economically unfeasible if the cost per man-hour of performing the work at the transport enterprise exceeds the cost per man-hour for the *k*-th type of work at the *j-th*

CSP, taking into account the costs associated with transporting vehicles or repair assets to the CSP for maintenance and repair (see Fig. 2).

As shown in Fig. 2, with an increase in the distance for transporting vehicles or repair assets to the CSP, the maximum volume of TM and repair work for which performing a specific type of work is economically unfeasible at the transport enterprise gradually decreases.

The cost per man-hour for performing the *k-th* type of work at the *i-th* ATE is determined by:

$$C_{k,\,ATE,\,i} = C_{LC,\,k,\,i} + C_{eq,\,k,\,i} + C_{fac,\,k,\,i} \tag{3}$$

where: $C_{LC,\,k,\,i}$ – represents the unit labor cost for repair workers, including overheads, performing the *k-th* type of work at the *i-th* ATE, allocated per man-hour of labor, in EUR per man-hour; $C_{eq,\,k,\,i}$ – denotes the unit cost of equipment required for performing the *k-th* type of work, allocated per man-hour of labor, in EUR per man-hour. This unit cost includes not only the cost of the equipment itself but also depreciation charges, installation costs, and energy consumption. $C_{fac,\,k,\,i}$ – refers to the unit cost of facilities used for performing the *k-th* type of work, allocated per man-hour of labor, in EUR per man-hour. This cost includes depreciation on the facility, as well as heating and lighting expenses.

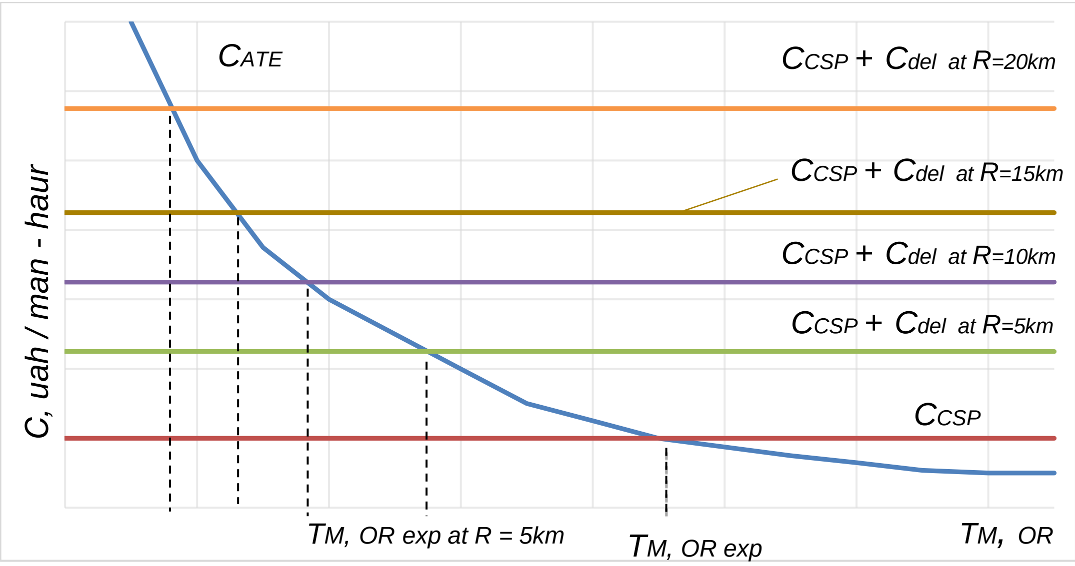

Fig. 2. Determining the feasibility of performing type *k-th* maintenance and repair work on vehicles of an ATE in cooperation with service enterprises, taking into account delivery costs

In accordance with the certification regulations for enterprises performing technical maintenance and repair of vehicles, a company must be equipped with all the necessary technological equipment to perform type *k-th* work. Therefore, it is assumed that both the ATE and the CSP are equipped with identical technological equipment for performing type *k-th* work. This allows the quality of work performed in both the ATE and CSP to be considered equal.

The cost of spare parts and consumables used during work in the CSP is accounted for separately. It is assumed that identical spare parts and consumables are used for performing specific types of work in both the ATE and CSP. Therefore, costs for spare parts and operating materials are not considered.

The cost of one man-hour of maintenance and repair work in the *k*-th production unit of the ATE is determined as follows [1]:

$$C_{1\ m.\text{-}h.} = (SA_{a.w.} + C_{de.\ pr.} + C_{de.\ eq.} + C_{ut.}) / L_{TMR} \tag{4}$$

where: $SA_{a.w.}$ – the annual salary of a maintenance worker, EUR; $C_{de.\ pr}$ – annual depreciation costs for premises, EUR; $C_{de.\ eq.}$ – annual depreciation costs for equipment, EUR; $C_{ut.}$ – annual costs for utilities (energy supply, water, heating, etc.), EUR; L_{TMR} – annual labor for technical maintenance and repair work, man-hours.

$$\begin{aligned} C_{1\ m.\text{-}h.} = (12 \times SA_{m.w.} \times A_{sa.} \times P + S_p \times C^p{}_{1\ m^2} \times R^p{}_{(de)} \times x_w + \\ +1{,}22 \times C_{(eq)} \times R^{eq}{}_{de} \times x_w + 12 \times S_p \times C_{1\ m^2 utility} \times x_w) / L_{TMR} \end{aligned} \tag{5}$$

where: $SA_{m.w.}$ – monthly salary of a maintenance worker, EUR; $A_{sa.}$ – salary accruals, in %; P – number of workers, persons; S_p – space of the premises, in m²; $Cp_{1\ m^2}$ – cost per square meter of production area, EUR; $Rp_{(de)}$ – depreciation rate for the building, in %; $C_{(eq)}$ – cost of the equipment, EUR; Req_{de} – depreciation rate for the equipment, in %; *1.22* – coefficient accounting for installation costs and engineering communications; $C_{1\ m^2 utility}$ – specific utility costs per square meter of the premises per month, EUR; x_w – number of workstations; L_{TMR} – annual labor for technical maintenance and repair work, man-hours.

The cost of delivering vehicles or repair stock to the CSP per 1 man-hour of labor intensity is determined as follows [1]:

$$C_{p\text{-}1\ km} = (C_{ve} + SA_d + E_{fuel} + E_{tmr}) / l_{tmr} \tag{6}$$

where: C_{ve} – cost of hiring a vehicle for transport services, EUR; SA_d – driver's salary, EUR; E_{fuel} – fuel expenses, EUR; E_{tmr} – expenses for technical maintenance and vehicle repair, EUR; l_{tmr} – labor of work for technical maintenance and vehicle repair, in man-hours.

$$\begin{aligned} C_{p\text{-}1\ km} = (2 \times (C_{ve} \times R^{ve}{}_{de} \times D_d) / (D_y \times h_w \times O_s) + 2 \times (SA_{(m.d.)} \times A_{sa} \times D_d) / \\ / (H_{m.d.} \times O_s) + 4 \times (R_f \times C_{1l} \times D_d) / 100) / t_{TMR} = 2 \times D_d \times ((C_{ve} \times R^{ve}{}_{de}) / \\ / (D_y \times th_w \times O_s) + (SA_{(m.d.)} \times A_{sa}) / (H_{m.d.} \times O_s) + 2 \times (R_f \times C_{1l}) / 100) / t_{TMR} \end{aligned} \tag{7}$$

where: $R^{ve}{}_{de}$ – depreciation rate for the vehicle used in transport, in %; D_y – number of working days per year; h_w – working hours, in hours; D_d – delivery distance, in kilometers; O_s – average operating speed, in km/h; $SA_{(m.d.)}$ – average monthly salary of the driver, EUR; $A_{sa.}$ – salary accruals, in %; $H_{m.d.}$ – monthly working hours fund for the driver, in hours; R_f – fuel consumption rate, in liters per 100 km; C_{1l} – cost per liter of fuel, EUR.

The economically feasible delivery distance of vehicles and repair stock for performing type *i-th* TM and repair work at automotive service enterprises is determined by the formula:

$$R_i = \frac{(C_{ATE,10,i} - C_{CSP,i})}{C_{p-1\ km,\ i}} \tag{8}$$

where: $C_{ATE,10,i}$ – cost of performing the *i-th* type of works at the ATE, which includes 10 vehicles, EUR /man-hour; $C_{CSP,i}$ – cost of one norm-hour of performing the *i-th* type of works at the CSP, EUR /man-hour; $C_{p\text{-}1\ km,\ i}$ – cost of transporting vehicles to the CSP per kilometer, per 1 man-hour, EUR /man-hour * km.

The methodology for determining the economically feasible delivery distances of vehicles to automotive service enterprises includes the following stages:

Stage I – perform a technological calculation for a transport enterprise with 10 vehicles, determining the annual volume of TM and repair work, the number of production personnel, the number of TM and repair posts, and the size of production premises.

Stage II – determine the cost per 1 man-hour for each type of technical maintenance and repair work at the transport company.

Stage III – assess the feasibility of performing technical maintenance and repair work at the ATE and identify the economically feasible delivery distances of vehicles.

Initially, the cost of performing each type of TM and repair work at the transport company is compared with the cost of performing these works at other enterprises (service stations, ATE, CSP) located near the ATE (as per equation 1), and a preliminary decision is made regarding the feasibility of outsourcing the work to an automotive service enterprise.

If it is feasible to perform the work at the service enterprise, the cost of delivering the vehicles or repair stock to the service station is calculated per 1 man-hour of labor intensity (equation 7), and the economically feasible delivery distances for transporting the vehicle or its individual components from the ATE to the service enterprises are determined (equation 8).

To obtain general results and conclusions regarding the economically feasible distances for delivering vehicles to automotive service enterprises for technical maintenance and repair under cooperation, calculations were carried out under the following reference conditions, which are characteristic of most ATEs in Ukraine at the present stage:

- the transport enterprises have a fleet of 10 vehicles;
- the vehicles operate under the third category of operating conditions;
- the average daily mileage of the vehicles is 200 km;
- storage conditions for the fleet: open parking without heating;
- calculations were performed for the following standard vehicle models used by transport enterprises:
  - For taxi ATE:
    - Small-class vehicles – Chevrolet Aveo;
    - Medium-class vehicles – GAZ-31105.
  - For freight ATE:
    - Small payload trucks – GAZ-33021 "Gazelle";
    - Heavy payload trucks – KAMAZ-53215.
  - For bus ATE:
    - Medium-capacity buses – Mercedes-Benz "Vario" TYP A407;
    - High-capacity buses – LAZ A-183 D1 "City".

The calculations were performed using a program developed as part of the dissertation by M.V. Mytka [18].

In the current conditions, the cost of fuel and lubricants significantly affects the cost of delivering vehicles and repair assets when performing TM and repair work through cooperation with specialized service enterprises. Currently, at gas stations, the price of A-95 gasoline ranges from €1.15 to €1.38 per l (for calculations, €1.15/l is used), and the price of diesel fuel ranges from €1.20 to €1.43 per l (for calculations, €1.20/l is used).

The cost of delivering vehicles and repair assets to service enterprises per kilometer, which is allocated to 1 man-hour of labor intensity for TM and repair works, is shown in Tab. 1.

Tab. 1

The cost of delivering vehicles and repair assets from transport enterprises to service enterprises per kilometer, allocated to one man-hour of labor intensity for maintenance and repair works

Name of maintenance and repair works	Cost of delivery per 1-kilometer distance to the automotive service enterprises, EUR / man-hour					
	Taxi ATE		Cargo ATE		Bus ATE	
	small class vehicles (Chevrolet Aveo)	medium class vehicles (GAZ-31105)	vehicles with small cargo capacity (GAZ-33021 «Gazelle")	vehicles with large cargo capacity (KAMAZ-53215)	medium capacity buses (Mercedes-Benz "Vario" Type A407)	large capacity buses (LAZ A-183 D1 «City")
Cleaning and Washing	0,69	0,90	1,04	1,04	1,11	0,86
General diagnostics (D-1)	0,69	0,90	1,04	1,65	1,11	1,73
In-depth diagnostics (D-2)	0,46	0,60	0,69	0,82	0,74	0,86
Fastening, adjustment, lubrication works (TM-1)	0,34	0,36	0,42	0,21	0,15	0,19
Fastening, adjustment, lubrication works (TM-2)	0,076	0,082	0,087	0,053	0,037	0,048
Adjustment and assembly-disassembly works (CR)	0,34	0,45	0,52	0,27	0,37	0,43
Painting	0,69	0,90	1,04	0,82	0,55	0,69
Unit Repairs	0,14	0,18	0,21	0,27	0,22	0,29
Locksmith-mechanical work	0,14	0,18	0,21	0,27	0,22	0,29
Electrotechnical work	0,23	0,30	0,35	0,33	0,28	0,35
Battery repairs	0,34	0,45	0,52	0,55	0,55	0,58
Fuel system instrument repairs	0,23	0,30	0,35	0,33	0,28	0,35
Tire mounting and vulcanization	0,34	0,45	0,52	0,41	0,37	0,43

Blacksmith-spring work	0,34	0,45	0,52	0,33	0,37	0,35
Copper work	0,34	0,45	0,52	0,41	0,37	0,43
Upholstery	0,23	0,30	0,35	0,33	0,28	0,35
Taxi companies	0,34	0,45	–	–	–	–
Welding, tinsmith, and bodywork	0,23	0,30	0,35	0,41	0,28	0,43

The share of fuel and lubricant costs in the overall cost of delivering vehicles and repair assets to service enterprises currently ranges from 37% to 53%, depending on the type of vehicle. This increase in delivery costs leads to a corresponding reduction in the economically viable distances for vehicle deliveries when performing TM and repair work through cooperation with service enterprises.

The economically viable distances for delivering vehicles, components, and assemblies for TM and repair under current conditions through cooperation with specialized service enterprises are shown in Tab. 2. It is assumed that when performing station-based maintenance and repair tasks (such as routine maintenance (RM), TM - 1, TM - 2, diagnostic tasks, post-repair tasks CR, painting CR, welding, bodywork, and armature work CR), the vehicle itself is delivered to the service enterprise. For section-based repair tasks CR (e.g., unit repairs, electrical work, and other tasks), the delivery of repair assets is performed using a light-duty truck (GAZ-33021 "Gazelle").

The modern economically viable delivery distances for TM and repair tasks are significantly different from those presented in academic literature and the dissertation research [18].

According to Tab. 2, for taxi ATE, the economically viable delivery distance for RM is up to 2 km; for freight ATE, it is 2-3 km, and for bus ATE, it is 1-3 km. These distances are almost 1.5 to 2 times shorter than those recommended in the study [18].

For taxi ATE, the economically viable delivery distances for performing TM - 1, TM - 2 under current conditions are close to the recommendations found in literature sources [17]. However, for freight and bus ATEs, the corresponding delivery distances are significantly shorter. The same applies to the delivery distances for post-repair tasks CR (adjustment and assembly-disassembly work CR) to service enterprises. The distances presented in Tab. 2 significantly limit the feasibility of performing these tasks through cooperation with service enterprises.

For taxi ATE with only 10 vehicles, performing post-repair tasks CR through cooperation with service enterprises is already economically unviable. This also applies to freight ATE, where performing post-repair tasks CR through cooperation with only 10 heavy-duty trucks is economically impractical. Thus, for scheduled TM - 1, TM - 2 and post-repair tasks CR at small freight or bus ATEs with up to 10 vehicles, it becomes viable to have 1-2 universal workstations to perform these tasks on-site.

This is explained, firstly, by the sufficient volume of TM and CR work, which allows for organizing these tasks directly at the transport enterprise, and secondly, by the significant cost of delivering vehicles to service enterprises. This is particularly true for large-capacity trucks and buses with high passenger capacity.

As for performing diagnostic works D-1 and D-2, as well section-based current repair tasks, the obtained economically viable delivery distances to service enterprises significantly exceed the recommendations provided in educational and scientific literature [17-19]. This is due to the limited scope of these works in small enterprises and the high cost of performing these works directly at the ATE. Primarily, this is attributed to the high cost of technological equipment, especially diagnostic stations and areas for painting works. However, the modern economically viable delivery distances for vehicles, components, and assemblies, as presented in Tab. 2, are 10-35 km shorter for diagnostic works and 25-265 km shorter for unit repairs compared to the recommendations in study [18]. This discrepancy is explained by the significant increase in fuel costs in recent years.

Thus, the economically viable delivery distances for general diagnostics D-1 are as follows: for taxi ATE - up to 80-135 km, for freight ATE - up to 35-115 km, and for bus ATE - up to 40-80 km, depending on the type of vehicle. According to the recommendations of Mytko M.V., these distances are, respectively, up to 110-170 km for taxi ATE, up to 40-100 km for freight ATE, and up to 55-100 km for bus ATE.

Tab. 2

Economically viable delivery distances for vehicles, components, and assemblies for TM and repair work through collaboration at specialized automotive service enterprises

Name of maintenance and repair works	Economically feasible delivery distances, km					
	Taxi ATE		Cargo ATE		Bus ATE	
	small class vehicles (Chevrolet Aveo)	medium class vehicles (GAZ-31105)	vehicles with small cargo capacity (GAZ-33021 «Gazelle")	vehicles with large cargo capacity (KAMAZ-53215)	medium capacity buses (Mercedes-Benz "Vario" Type A407)	large capacity buses (LAZ A-183 D1 «City")
Cleaning and Washing	up to 8	up to 5	up to 6	up to 4	up to 2	up to 1
General diagnostics (D-1)	up to 130	up to 80	up to 115	up to 35	up to 69	up to 42
In-depth diagnostics (D-2)	up to 145	up to 90	up to 165	up to 60	up to 101	up to 80
Fastening, adjustment, lubrication works (TM-1)	up to 20	up to 15	up to 12	0	0	up to 4
Fastening, adjustment, lubrication works (TM-2)	up to 30	up to 25	up to 35	0	0	0
Adjustment and assembly-disassembly works (CR)	up to 6	up to 5	up to 10	up to 10	up to 7	up to 10
Painting	up to 105	up to 50	up to 100	up to 60	up to 81	up to 70
Unit Repairs	up to 60					
Locksmith-mechanical work	up to 90					
Electrotechnical wok	up to 110					

Battery repairs	up to 230					
Fuel system instrument repairs	up to 215					
Tire mounting and vulcanization	up to 180					
Blacksmith-spring work	up to 205					
Copper work	up to 280					
Upholstery	up to 510					
Taxi companies	up to 280	up to 190	–	–	–	–
Welding, tinsmith, and bodywork	up to 80	up to 65	up to 115	up to 40	up to 44	up to 40

For in-depth diagnostics D-2, the current economically viable delivery distances are as follows: for taxi ATE - up to 90-145 km, for freight ATE - up to 60-160 km, and for bus ATE - up to 80-101 km. The economically viable delivery distances for painting works are up to 50-105 km for taxi ATE, up to 60-100 km for freight ATE, and up to 70-85 km for bus ATE, depending on the type of vehicle.

The economically viable delivery distances for performing current repair works in specialized service enterprises range from 60 to 300 km, depending on the type of work.

It is important to note that Tab. 2 presents the maximum possible economically viable delivery distances, which are calculated for small enterprises with up to 10 vehicles. As the number of vehicles at the enterprise increases, the economically viable delivery distances decrease. This is due to the increase in the volume of TM and repair works, which subsequently reduces the cost of performing these tasks at the enterprise. As an example, Fig. 3 illustrates the change in the cost of cleaning and washing works RM in a taxi ATE, depending on the volume of these works.

Furthermore, the economically feasible transportation distances presented in Tab. 2 for conducting TM and repair of vehicles through cooperation are approximate. This is particularly relevant for the transport of parts and assemblies for repair, as their delivery cost largely depends on how transportation to the service enterprises is organized. Therefore, in each specific case, the feasibility of performing TM and vehicle repairs through cooperation should be determined based on corresponding calculations.

The obtained economically feasible transportation distances align with the trend in TM and vehicle repair organization observed in developed countries across Europe and the United States. In these regions, transport companies, not only small but also medium and large-scale enterprises, typically carry out only station-based TM and repair tasks at their own facilities, while most specialized current repair tasks are performed through cooperation with specialized service enterprises.

4. CONCLUSIONS

One of the most important factors in organizing the TM and repair of vehicles through cooperation is the economically feasible transportation distances for delivering vehicles and repair assets to service enterprises or other facilities providing relevant services.

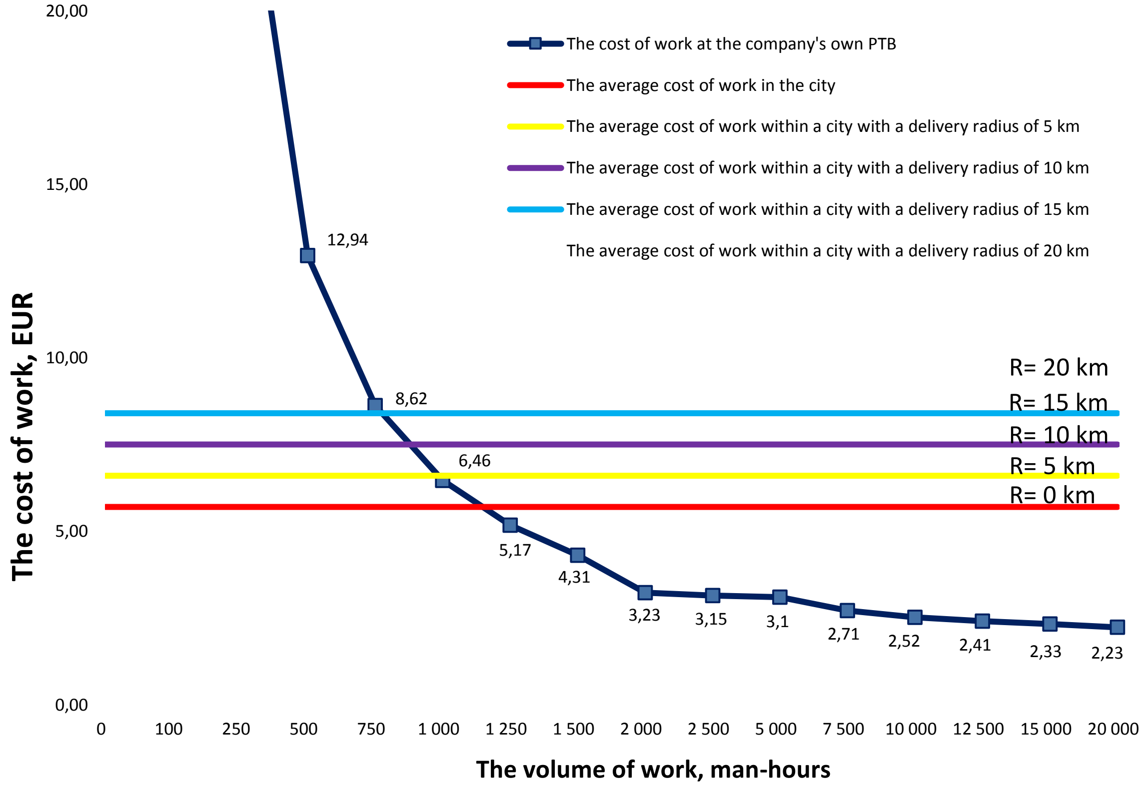

Fig. 3. Dependence of the cost of cleaning and washing operations RM in a taxi ATE

Existing recommendations in academic and scientific literature regarding optimal transportation distances either fail to account for the changing structure of automotive transport enterprises in Ukraine or overlook the rising costs of fuel and TM and repair services in the current context.

A methodology for determining economically feasible transportation distances for delivering vehicles to service enterprises has been developed. Based on the conducted research, economically viable distances for performing technical maintenance and vehicle repair at service enterprises have been identified. These calculations take into account the current fuel and lubricant prices at gas stations in Ukraine, as well as the labor rates at service enterprises.

It is worth noting that the developed methodology for determining feasible transportation distances for cooperative maintenance and repair work, along with the obtained results, could be of interest not only for Ukraine but also for many countries worldwide, where fuel prices have nearly doubled in recent years.

References

1. Савін Ю.Х., М.В. Митко. 2019. „Визначення економічно доцільних відстаней доставки автомобілів на підприємства автосервісу". *Вісник Вінницького політехнічного інституту. Науковий журнал* 2(143): 99-104. [In Ukrainian: Savin Y.Kh., M.V. Mytko. 2019. „ Determination of economic advisable distances of automobile delivery on autoservice enterprise". *Visnyk of Vinnitsa Polytechnic Institute. Scientific journal* 2 (143): 99-104]. ISSN: 1997-9266. DOI: https://doi.org/10.31649/1997-9266-2019-143-2-99-104.
2. Mytko Mykola. 2020. „Methodological bases for improving the structure of production subdivisions of motor transport enterprises". *Technology, energy, transport of agricultural industry* 2(109): 64-70. ISSN 2520-6168. DOI: https://doi.org/10.37128/2520-6168-2020-2-7.
3. Savin Yuriy, Mykola Mytko. 2013. „ Determining the feasibility of creating production units for servicing and repairing cars at motor transport enterprises". *Systems and means of motor transport. Selected problems. Series: TRANSPORT* 4: 533-540. Monograph. Rzeszów. ISBN: 978-83-7199-878-3.
4. Polievoda Y., I. Kupchuk, Y. Hontaruk, I. Furman, M. Mytko. 2022. „Method for determining homogeneity of fine dispersed mixtures based on the software analysis of photo cross-cut of the sample". *Przeglad Elektrotechniczny* 11(98): 109-113. ISSN: 0033-2097. DOI: https://doi.org/10.15199/48.2022.11.20.
5. Smyrnov Y., D. Borysiuk, T. Volobuyeva, T. Plakhtii, M. Nasterenko. 2023. „Model for devising and defining technical development projects of motor transport enterprises". *Eastern-European Journal of Enterprise Technologies* 5(3): 125. DOI: https://doi.org/10.15587/1729-4061.2023.289004.
6. Sakxno, V., V. Poliakov, V. Bilichenko, I. Murovany, A. Kotyra, G. Duskazaev, D. Baitussupov. 2021. „Selection and reasoning of the bus rapid transit component scheme of huge capacity". *Mechatronic Systems 1: Applications in Transport, Logistics, Diagnostics, and Control* 1: 233-242. DOI: https://doi.org/10.1201/9781003224136-20.
7. Dykha A., V. Svidersky, I. Danilenko, V. Bilichenko, Y. Kukurudzyak, L. Kirichenko. 2020. „Design and study of nanomodified composite fluoropolymer materials for tribotechnical purposes". *Eastern-European Journal of Enterprise Technologies* 5(12): 107. DOI: https://doi.org/10.15587/1729-4061.2020.214533.
8. Zaspa Y., A. Dykha, D. Marchenko, S. Matiukh, Y. Kukurudzyak. 2020. „Exchange interaction and models of contact generation of disturbances in tribosystems". *Eastern-European Journal of Enterprise Technologies* 4(5): 106. DOI: https://doi.org/10.15587/1729-4061.2020.209927.
9. Leontiev D., O. Voronkov, I. Nikitchenko, V. Korohodskyi, L. Ryzhykh, N. Rudenko, T. Makarova. 2021. „Feasibility of Heating the Air in a Hybrid Pneumatic Engine for a Compact Vehicle". *SAE Technical Paper*. 1(1246): 1-10. ISSN: 0148-7191. DOI: https://doi.org/10.4271/2021-01-1246.
10. Shuklynov S., M. Kholodov, V. Verbitskiy, V. Makarov. 2020. „Simulation of the Combined Braking Control System for Hybrid Electric Vehicles". *SAE Technical Paper* 1(0217): 1-7. ISSN: 0148-7191. DOI: https://doi.org/10.4271/2020-01-0217.
11. Smieszek M., V. Mateichyk, M. Dobrzanska, P. Dobrzanski, G. Weigang. 2021. „The impact of the pandemic on vehicle traffic and roadside environmental pollution". *Rzeszow city as a case study*. *Energies* 14(14): 4299. ISSN 1996-1073. DOI: https://doi.org/10.3390/en14144299.

12. Smieszek M., N. Kostian, V. Mateichyk, J. Mosciszewski, L. Taranduchka. 2021. „Estimation of the Public Transport Operating Performance: Example of a Selected City Bus Route”. *Communications - Scientific Letters of the University of Zilina* 23 (2): 75-82. ISSN: 1335-4205. DOI: https://doi.org/10.26552/com.C.2021.2.
13. Borysiuk D., A. Spirin, I. Kupchuk, I. Tverdohlib, V. Zelinskyi, Y. Smyrnov, V. Ognevyy. 2021. „The methodology of determining the place of installation of accelerometers during vibrodiagnostic of controlled axes of wheeled tractors”. *Przeglad Elektrotechniczny* 10(97): 44-48. ISSN: 0033-2097. DOI: https://doi.org/10.15199/48.2021.10.09.
14. Kupchuk I., V. Yaropud, V. Hraniak, J. Poberezhets, O. Tokarchuk, V. Hontar, A. Didyk. 2021. „Multicriteria compromise optimization of feed grain grinding process”. *Przeglad Elektrotechniczny* 11(97): 179-183. ISSN: 0033-2097. DOI: https://doi.org/10.15199/48.2021.11.33.
15. Kupchuk I., S. Burlaka, O. Galushchak, T. Yemchyk, D. Galushchak, Y. Prysiazhniuk. 2022. „Research of autonomous generator indicators with the dynamically changing component of a two-fuel mixture”. *Polityka Energetyczna – Energy Policy Journal* 25(2): 147-162. ISSN: 1429-6675. DOI: https://doi.org/10.33223/epj/150746.
16. Бідняк М.Н., В.В. Біліченко. 2006. *Виробничі системи на транспорті: теорія і практика : монографія*. Вінницький національний технічний ун-т. Вінниця: УНІВЕРСУМ-Вінниця. [In Ukrainian: Bidniak M.N., V.V. Bilichenko. 2006. *„Production systems in Transport: theory and practice: monograph”.* Vinnytsia national technical university. Vinnytsia: UNIVERSUM-Vinnytsia: Textbook]. ISBN: 966-641-200-4.
17. Канарчук В.Є., І.П. Курніков. 1997. *Виробничі системи на транспорті*. Київ.: Вища школа. [In Ukrainian: Kanarchuk V.Y., I.P. Kurnikov. 1997. „*Production systems in transportation*”. Kiev, K.: Higher school: Textbook]. ISBN: 5-11-004580-1.
18. Митко М.В. 2019. „Підвищення ефективності роботи автотранспортних підприємств удосконаленням структури виробничих підрозділів”. *PhD thesis*, Київ, Україна: Національний транспортний університет. [In Ukrainian: Mytko M.V. 2019. „Improving the efficiency of work at motor transport enterprises by enhancing the structure of production units”. *PhD thesis*, Kyiv, Ukraine: National Transport University]. Available at: http://diser.ntu.edu.ua/Mytko_dis.pdf.
19. Митко М.В. 2019. „Підвищення ефективності роботи автотранспортних підприємств удосконаленням структури виробничих підрозділів”. *Abstract PhD* thesis, Київ, Україна: Національний транспортний університет. [In Ukrainian: Mytko M.V. 2019. „Improving the efficiency of work at motor transport enterprises by enhancing the structure of production units”. *Abstract PhD thesis*, Kyiv, Ukraine: National Transport University]. Available at: http://diser.ntu.edu.ua/Mytko_aref.pdf.
20. Economic pravda. 2019. „*A full tank: how much gasoline can residents of different countries buy for their salary*”. Available at: https://www.epravda.com.ua/news/2019/07/5/649403/.
21. Auto travels. „*Fuel in Europe*”. Available at: https://autotravels.com.ua/en/petrol-europe.
22. Segodnyasegodnya. „Fuel prices in the USA - how much can you buy gasoline and diesel for”. Available at: https://economics.segodnya.ua/ua/economics/avto/ceny-na-toplivo-v-ssha-za-skolko-mozhno-kupit-benzin-i-dizel-1615957.html.

23. Telegraf. 2023. „Comparison of prices for gasoline, diesel and autogas in Europe and Ukraine as of March 1”. Available at: https://www.telegraf.in.ua/kremenchug/10115589-porivnjannja-cin-na-benzin-dizelne-palne-ta-avtogaz-u-yevropi-ta-v-ukrajini-stanom-na-1-bereznja.html.
24. Take-profit.org. The price of gasoline in Australia. Available at: https://take-profit.org/statistics/gasoline-prices/australia/.

Received 14.09.2024; accepted in revised form 23.11.2024