METHODOLOGY FOR ASSESSING THE KEY OPERATIONAL EFFICIENCY INDICATORS FOR REMOVAL AND SHUNTING OPERATIONS OF SHUNTING LOCOMOTIVES

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Resume

The problem dealt with in this article is the methodology of the key performance indicators (KPI) evaluation of shunting locomotives operation when performing hauling and shunting work. The main parameters affecting the efficiency of rolling stock operation are described, including performance, fuel efficiency and locomotive utilization rate. The algorithm of KPI calculation is proposed, based on the analysis of operational data and statistical methods is proposed. According to the analysis of the trend in cargo transportation over the past 3 years, the need to develop a methodology for evaluating the key performance indicators of shunting work is justified. A comparative analysis of various approaches to assessing the operational performance of locomotives is carried out, their advantages and disadvantages are revealed. Practical recommendations for improving the operational performance of rolling stock are described.

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1 Introduction

The railway transport is one of the key elements of the transport system, ensuring efficient logistics of freight and passenger traffic. Shunting locomotives, which perform outbound and shunting operations, play a special role in the functioning of a railway hub. Their operational efficiency has a direct impact on station capacity, freight handling speed and overall operating costs. In this regard, the development of a methodology for assessing the key performance indicators (KPI) for shunting locomotives is an urgent task.

The real conditions of the present show that fuel efficiency of old diesel locomotives does not meet modern requirements and affects the economic performance of the operating depot, so the efficiency of fuel utilization and control of fuel consumption is a priority for the locomotive owning companies [1].

Modern railway transport operating conditions require the introduction of technologies to increase productivity and reduce costs. Traditional methods for assessing the efficiency of shunting locomotives often do not take into account all factors affecting their operation, such as fuel consumption, idle time, capacity utilisation rate and operating costs. Therefore, it is necessary to develop a more accurate KPI evaluation methodology to make informed management decisions.

It is known that about 65-70% of shunting locomotives produced in the 90s of the last century are still in operation on the railways and industrial enterprises of Kazakhstan and the countries of the Commonwealth of Independent States (CIS). These locomotives are not equipped with modern means of remote monitoring of fuel consumption, and the installation of these means requires a large investment. Therefore, for these locomotives, it is necessary to develop a suitable and adapted method for evaluating the operational efficiency of shunting locomotives, taking into account both the technical condition and economic performance.

The issues of shunting locomotives operation efficiency assessment are studied by many researchers. in the works [2-5] were considered approaches to the analysis of fuel efficiency and locomotive utilizations factor. in studies [1, 5-7] mathematical models for shunting operation optimization were proposed. However, most of the existing methodologies focus on individual aspects of efficiency without providing a comprehensive approach to analyzing operational parameters. In this paper a methodology that combines various indicators into a single evaluation system is proposed.

The purpose of the study was to develop a methodology for assessing the key performance indicators of shunting locomotives when performing outbound and shunting work. To achieve this goal, the following objectives were set [5]:

- Analysis of existing methods for assessing the operating efficiency of shunting locomotives;
- Identification of key factors affecting KPIs;
- Development of an algorithm for calculating KPIs taking into account operational data;
- Formulation of recommendations to improve the efficiency of shunting locomotive operation.

The scientific novelty of the study lies in the development of a comprehensive approach to assessing the operational efficiency of shunting locomotives, taking into account both technical and economic indicators. Unlike the existing methods, the proposed approach includes automated analysis of operational data and allows optimizing the operation of the locomotive fleet taking into account various operating conditions. The results obtained can be used by transport companies and railway transport operators to improve the efficiency of shunting locomotives.

2 Materials and methods

Implementation of strategic plans, as well as control over the technological chain of operations, the implementation of which should be achieved in a fairly short period of time and at the lowest costs is a complex and serious process for the organization.

To achieve these goals, the key performance indicators (KPI) are created, which allow to evaluate and analyze the flow of technological processes, to optimize them, to coordinate the actions of personnel and subdivisions [4, 6].

The use of KPIs in managing the production activities of an enterprise makes it possible to [4]:

- improve technological processes;
- quantify all types of activities;
- pay special attention to performance indicators that are necessary to obtain significant operational characteristics.

The use of KPIs makes it possible to consolidate the results of various measurements used in the organization's activities of the so-called key KPIs. Continuous monitoring of the work processes and characteristics assigned to the enterprise complicates the analysis of the results achieved, while the use of KPI indicators is the most effective, their values can be used to analyze the tendency of changes in various

***Figure 1** Diagram of a balanced scorecard*

production units within the enterprise with different sets of KPI indicators that can be used together for continuous monitoring of the business goals assigned to the enterprise [5]. The implementation and use of the KPIs is a tool that enables an organization to evaluate its business processes, as well as strategy implementation. A diagram of a balanced scorecard is shown in Figure 1.

Thus, the KPI system is linked to the strategic goals of the organization. The KPI system is most relevant in business process management. To develop and use KPIs in an organization, it is necessary to define a list of goals that it wants to achieve.

Shunting locomotives play an important role in ensuring the efficient functioning of railway transport, carrying out work on sorting wagons, transporting goods and forming trains. One of the key factors of their operation is the analysis of the tendency of traffic volumes and fuel consumption, which makes it possible to optimize costs and increase the efficiency of railway junctions [7].

The analysis of the volume of transportation by shunting locomotives includes an assessment of the number of wagons handled, the volume of goods transported and the intensity of shunting work. In recent years, there have been trends towards an increase or decrease in traffic volumes, due to a number of factors [6]:

- Changing the structure of cargo flows;
- Optimizing the operation of railway stations;
- Seasonal fluctuations in freight traffic.

The statistical methods of data analysis are used to assess the development of transportation, which make it possible to identify the key trends and predict the further development of shunting operations.

The results of the analysis of the ratio between the traffic volumes and fuel consumption make it possible to evaluate the efficiency of using shunting locomotives. It is important to take into account the efficiency of the locomotive, which shows how efficiently the fuel is used when performing shunting work. Optimization of operating modes and routing can help to reduce specific fuel consumption while increasing traffic volumes.

On non-public railway access roads [8]:

- train work is performed by 3 pairs of TEM2 diesel locomotives, where each pair consists of 3 interconnected locomotives;
- the removal work is performed by 1 coupling of 2 coupled TEM2 diesel locomotives.

Shunting operations are performed by 8 single TEM18 diesel locomotives.

The total number of diesel locomotives involved in all types of work is 19 TEM2 and TEM18.

Figure 2 shows the histogram of traffic volume changes for 2022-2024 performed by the non-public railway stations.

The train operation is carried out by 3 interconnected diesel locomotives (spark), with a weight of 126 tons per locomotive, the total weight of 3 is 378 tons. This is an additional mass to the weight of the train, therefore, the values of traffic volumes by year are shown both without taking into account the weight of diesel locomotives and with taking into account the same [4, 8].

The results of the analysis of traffic tendency in the period 2022-2024 show that in [9]:

- 2023 traffic volumes decreased by 4.4% compared to 2022;
- traffic volume amounted to 12,132,543 tons, and exceeded the indicator of 2023 (9,606,583 t) by 26.3%.

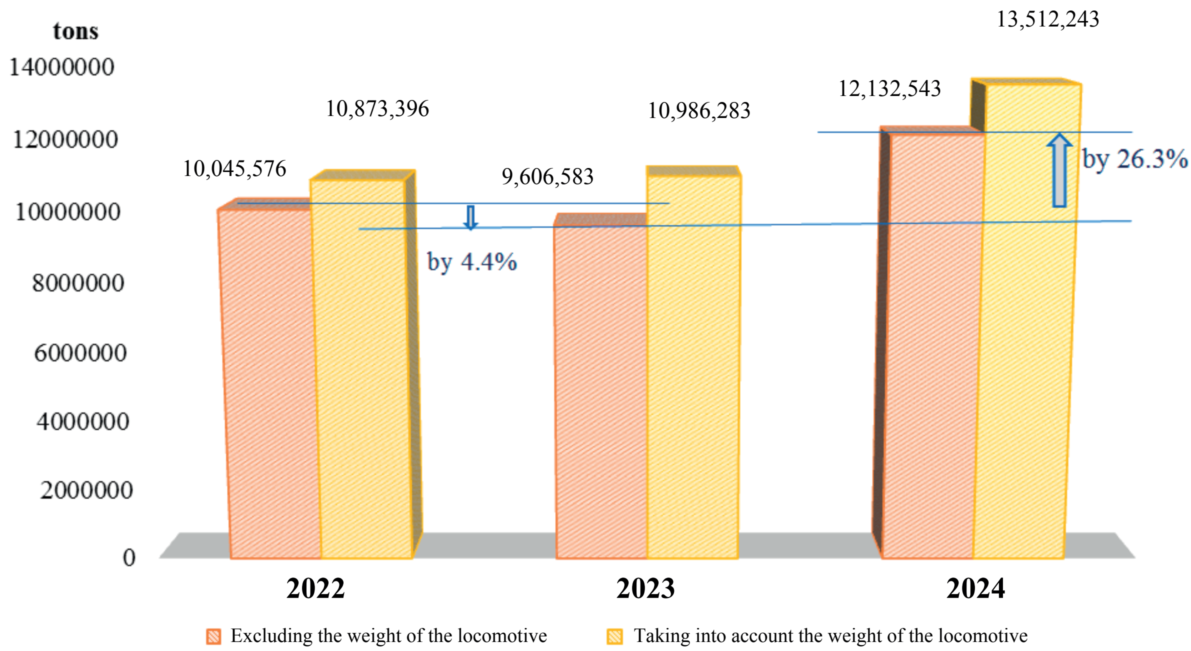


***Figure 2** Histogram of traffic volume changes for 2022-2024*

The main factors contributing to the decline in traffic volumes in 2023 relative to 2022 are the post-crisis state of the economy.

Changes in the tendency of transportation volumes contributed to a similar change in fuel consumption development (Figure 3).

Thus, in train operation, the fuel consumption by train locomotives in 2023 decreased by 6.6% compared to 2022, while in 2024 it increased by 30.2% compared to 2023.

At the same time, the total fuel consumption for all types of work (train, export and shunting) in 2024 increased by 22.5% compared to 2023.

Figure 4 shows the tendency of changes in the specific fuel consumption of diesel locomotives during the transportation process.

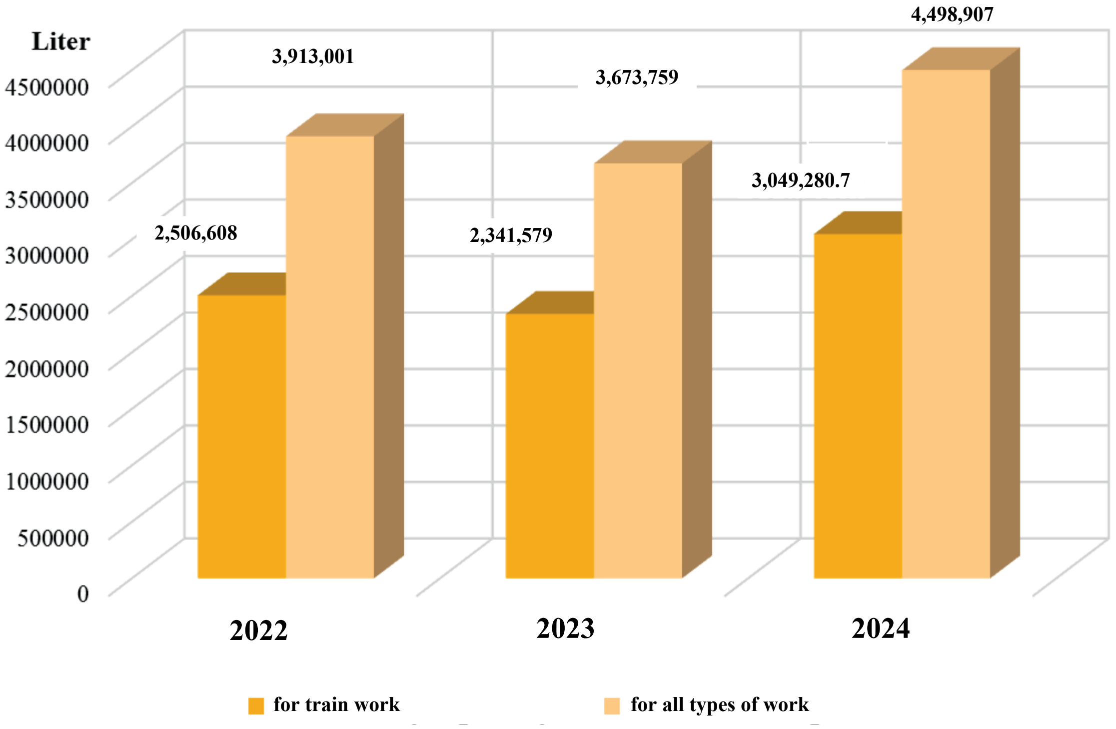


Figure 3 *Tendency of changes in fuel consumption by diesel locomotives in 2022-2024*

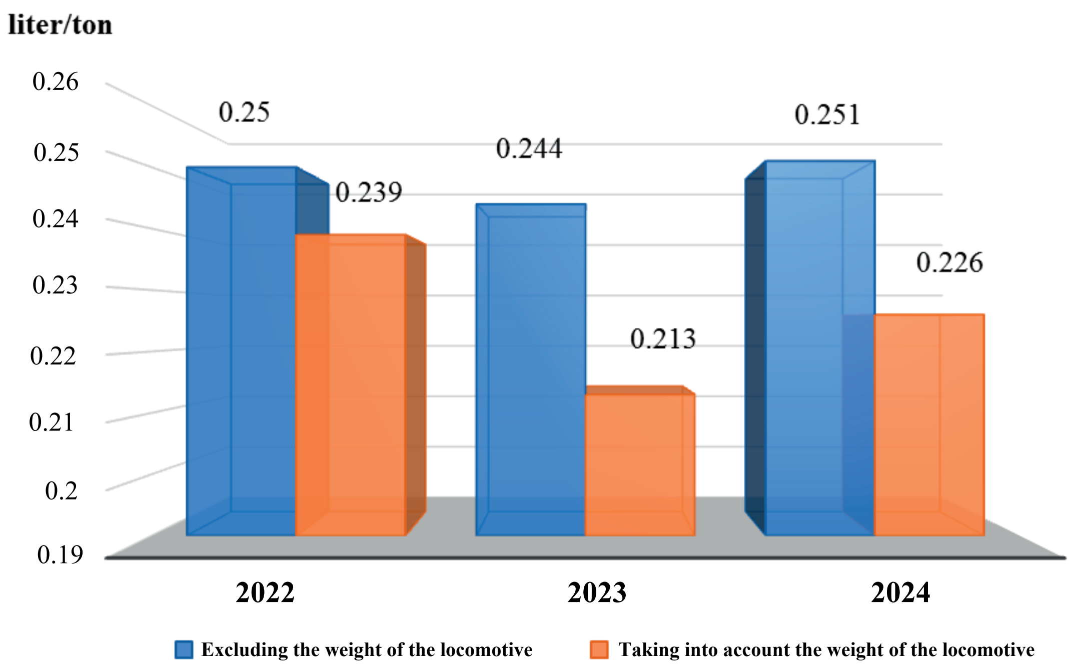


Figure 4 *Tendency of changes in the specific fuel consumption of diesel locomotives for the transportation process*

The specific fuel consumption of diesel locomotives for all types of work: train, export, shunting, in 2024 amounted to 0.371 liters /ton, which is 2.9% better than the value of the specific consumption in 2023 (0.382 liters / ton).

The amount of fuel savings is (0.382 - 0.371) = 0.011 liters/ton • 12,132,543 tons = 133,458 liters, i.e., it has a positive trend.

The specific fuel consumption of train locomotives in 2024 was 0.251 liters/ton, which is 2.9% worse than the value of the specific consumption in 2023 (0.244 liters/ton). The amount of fuel overspending is: (0.244 - 0.251) = - 0.007 l/t • 12,132,543 t = 84,928 liters - negative tendency.

For example, train operation of non-public railway sidings is carried out on sections of station A - station B is 95 km long. Freight trains are exchanged between the non-public railway sidings and mainline networks at the stations adjacent to station B. An analysis of the operation of railway sidings over 10 years shows that the average number of 4-6 pairs of trains per day. Moreover, the average mass of odd-numbered trains departing from station A is (4000-6000) tons, and the average mass of even-numbered trains receiving railway sidings is (1500-3000) tons. This is due to the specifics of the operation of railway sidings, arriving trains are mainly empty wagons for loading the goods of the owner [1, 7].

The purpose of the timing observations is to obtain the initial data for the development and establishment of time standards for a full turn of the locomotive at the station A - station B.

The procedure for conducting time-lapse observations, filling out time-lapse records and analyzing the results was carried out in accordance with specially developed requirements.

The photochronometric observations included taking photographs and recording every second the operating time of the diesel generator set of the locomotive at a certain position of the driver's controller (the driver's handle) used by the train driver.

The development of time standards was carried out by an analytical and research method, according to which the standards were established based on the analysis of the results of observation (timekeeping) of the normalized operation performance. Control trips were carried out on technically serviceable diesel locomotives with the involvement of experienced drivers [10].

The time limit was set by the analytical and research method based on the analysis of data obtained as a result of direct observation of the operating time of diesel locomotives at specific positions of the driver's controller in specific conditions.

According to the technical condition, the railway tracks allow trains weighing 6,000 tons and above to operate at an acceptable speed of 70 km/h.

The main factor affecting the fuel consumption is the speed of the train.

During experimental trips, the possibility of reaching speeds within the permissible limits on this section was checked.

Thus, as a result of time-lapse observations, the total travel time of diesel locomotives with a train on the site was determined [10].

The driver did not use the 8th position of the driver's controller practically, due to the danger of failure of diesel locomotives. The average net speed of the train along the section was 32 km/h. Fuel consumption was determined based on the design data of diesel locomotives. The conformity check was carried out on rheostat tests of diesel locomotives. The traction characteristics and fuel consumption according to the positions of the driver's controller are shown in Figure 5 and in Table 1.

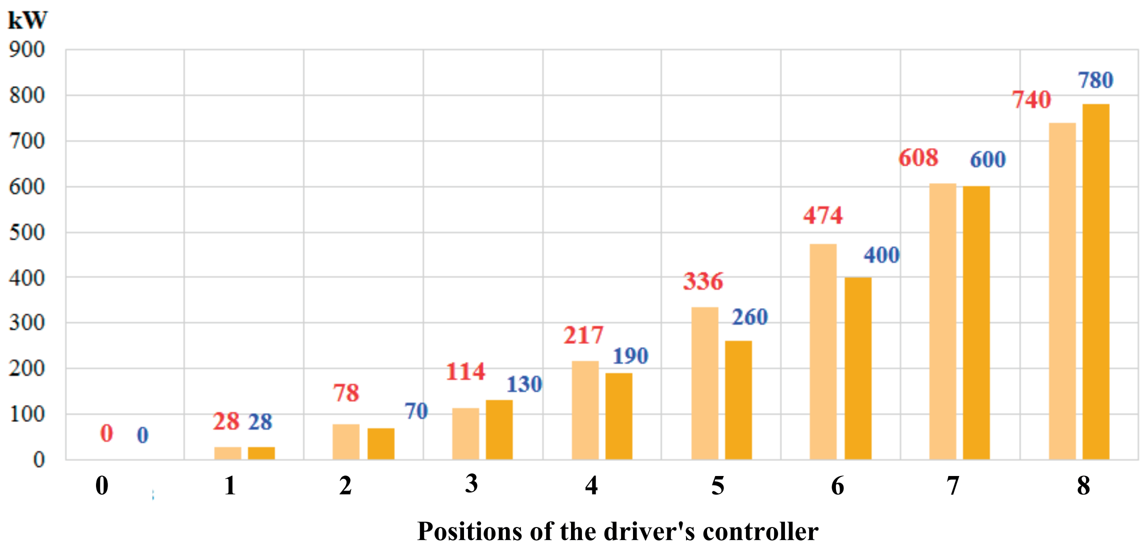
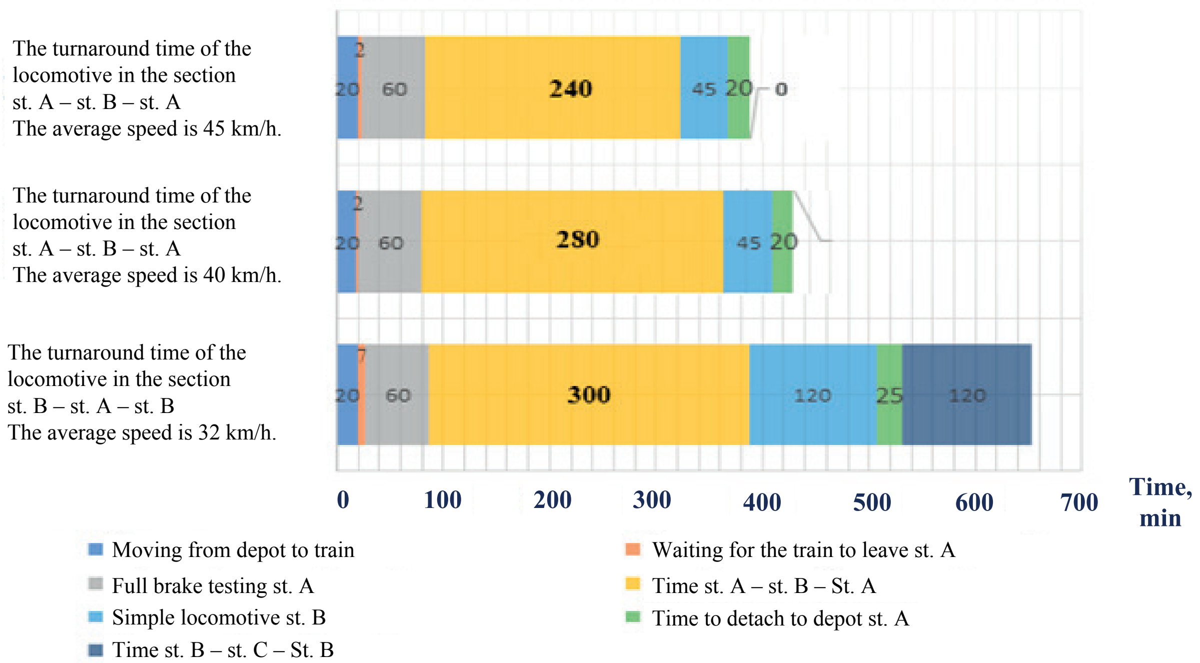


Figure 5 *Traction characteristics of the TEM2 (TEM18) diesel locomotive*

***Table 1** Fuel consumption by the positions of the locomotive driver TEM2 (TEM18) controller*

Number of the position of the driver's controller	Fuel consumption (rheostatic)	Power	
		Rheostatic	Passport information
	kg/min	kW	
0 (idling)	0.16	-	-
1	0.19	28	28
2	0.27	78	70
3	0.52	114	130
4	0.76	217	190
5	1.04	336	260
6	1.6	474	400
7	2.4	608	600
8	3.4	740	780



Designations: Station A - Almaty-1 station and Station B - Aksengir Station, Station C - Chemolgan Station

***Figure 6** Duration of required regulatory operations.*

Figure 6 shows the effect of the average speed of movement on the time of full rotation of diesel locomotives with trains in a given section of circulation.

3 Results and discussions

Currently, there are over 600 non-public railway access roads in Kazakhstan [8], owned by enterprises and organizations of various forms of ownership in metallurgy, mining, coal, oil production and processing, machine-building and other sectors of the economy.

The infrastructure, complexes of structures, devices and technical means of many non-public railway access roads allow them to provide all types of transportation process.

The transportation activities of the railway access roads of Kazakhstan are carried out by means of diesel traction, consisting mainly of old shunting locomotives TEM2, TEM18.

On railway sidings, diesel locomotives are used in shunting operations related to performing a wide range of different operations for sorting wagons, forming and disbanding trains, feeding and cleaning wagons to cargo loading and unloading fronts, and other shunting operations in accordance with the technological process of the sidings.

The specifics of the operation of shunting locomotives are very different from the operation of diesel locomotives operating in the mainline mode. There are many more factors that combine to make it difficult to determine the actual fuel consumption of a particular locomotive [9].

The system of accounting for the operation of diesel locomotives when using them for shunting operations allows to set the time periods during which a particular locomotive was in motion or standing. However, this is not enough to understand the usefulness and effectiveness of its use [11].

The parking of a diesel locomotive can be caused by various reasons or form part of its shunting operation.

A locomotive can move with a full-fledged train, with several cars, or travel in reserve. In all the cases, it is impossible to determine how efficiently a locomotive is being used based on such a formal feature.

Consequently, the indicators, successfully used to account for and determine the efficiency of diesel locomotives in train operation, are not informative enough when assessing its effectiveness in shunting.

On railway access roads, the movement pattern of diesel locomotives during the shunting operations is almost the same, but the time spent on performing these operations and the power used for the corresponding positions of the locomotive driver's controller may be different. The power depends on the adjustment of the diesel generator set of a particular locomotive, the experience of the driver, etc. Various operational and climatic factors also have a significant impact.

To assess the efficiency of using a particular diesel locomotive, it is important to know the fuel consumption at the positions of the driver's controller used during shunting operations.

Knowing the costs of each individual maneuver and the number of movements (half-trips) during a shift, it is not difficult to determine the total fuel costs for performing shunting work by a diesel locomotive.

Therefore, the main criteria for the efficiency of using a diesel locomotive to perform the shunting work are: time to perform operations and fuel consumption [12].

The TEM2 and TEM18 locomotives are of old construction, they are not equipped with built-in technical means of accounting for fuel consumption, therefore, the amount of fuel in the tank of the locomotive is monitored visually by the driver according to the measuring glass on the fuel tank or fuel rail with a scale of division equal to 250 liters. Accounting for fuel consumption per shift of locomotive operation is carried out by the difference in the amount of fuel in the tank of the locomotive at the beginning and end of the shift.

It should be noted that currently there are many companies that offer the installation of automatic fuel consumption monitoring and metering systems on diesel locomotives. At the same time, the main motive for installing flow meters on old diesel locomotives is to prevent unauthorized fuel discharge by railway workers.

Basically, these systems came from motor transport, differing in measurement principles and, consequently, costs, they poorly take into account large volumes of fuel tanks, the profile of the path, warming up, seasonality of work - determining consumption rates, etc.

In addition, the installation of fuel consumption monitoring and metering systems on old diesel locomotives may face significant problems, depending on the technical characteristics and structure of a particular locomotive model.

The main problems that may arise are [10]:

1) Lack of compatibility - old diesel locomotives have outdated control systems that are sometimes incompatible with modern types of fuel flow meters. Therefore, their installation will require modernization or replacement of control systems;
2) Unavailability or lack of spare parts - factories that produced old diesel locomotives could stop producing or supporting spare parts. This makes it difficult to obtain the necessary components for installing flow meters;
3) Technical limitations during installation - the structures of old diesel locomotives have limited space for installing new equipment, and this will create difficulties in integrating flow meters.
4) Required changes to the locomotive - the installation of new equipment may require changes to the design of the locomotive, for example, the addition of additional cables, sensors, etc. This may require careful design and engineering work;
5) The need for certifications - in some cases, the installation of new equipment may require review and certification by regulatory authorities. This may include compliance with safety standards and environmental regulations.

In general, the actual fuel consumption of a diesel locomotive per shift can be represented as the sum of fuel consumption over periods of operation in load mode and at idle [4]:

$$G_{act.shift} = \sum(G_j \cdot \Delta\tau_j + gi \cdot \Delta\tau_i), \quad (1)$$

where: G_j - fuel consumption at the j-th position of the driver's controller, kg/min;

$\Delta\tau_j$ - operating time of the locomotive at the j-th position, min;

g_i - fuel consumption of a diesel locomotive at idle, kg/min;

$\Delta\tau_i$ - diesel engine idling time, min.

As can be seen from Equation (1), the amount of fuel consumption depends on the operating time of the locomotive at the *j*-th position of the driver's controller and idling, therefore, the main indicator to be normalized is the duration of shunting operations.

The time standards for preparatory and final operations, which determine the duration of maneuvering operations for a certain time, are obtained analytically, regulated and introduced into regulatory and reference documents [12].

It should be noted that in many ways, the time standards for shunting operations used in railway transport were established in the 50-70 years of the 20th century and do not correspond to modern operating conditions of railway rolling stock and modern train handling technologies.

It should also be noted that the analytical methods for calculating the time for maneuvering operations described in different sources have both common features and differences.

For example, in [13] it was proposed to set the time limit for sorting the composition by the expression:

$$\tau_c = A \cdot q + B \cdot n, \quad (2)$$

From Equation (2):

$$\tau_c = 1.2(A \cdot q \cdot k_q + B \cdot n \cdot k_n)\, k_{cur} + \tau_{set}, \quad (3)$$

where: A and B - constant coefficients, depending on the method of maneuvering, min/uncoupling;
q, n - the number of uncoupling and wagons in the train, respectively;
k_q, k_n - coefficients of repeated sorting of uncouples and wagons;
k_{cur} - a coefficient that takes into account the increase in sorting time when the exhaust track is located in curves with a small radius of repeated sorting of uncouples and wagons;
τ_{set} - time to settle the wagons, min.

The equation, used to determine the duration of maneuver operations, reads:

$$\tau_{det} = 0.06 \cdot L_{tr}/v_{tr}, \quad (4)$$

where: L_{tr} - travel route length, km;
v_{tr} - travel speed, km/h.

The above expressions represent linear dependences for determining the time for sorting Equation (2) and Equation (3), and the time for performing shunting operations in Equation (4) on the number of detaches and wagons in the train, the length of the route and the speed of movement of the locomotive.

However, for the same conditions, they can give different values of the time norms, and to establish a constant average value of the norm, it is necessary to conduct long-term field and computational studies.

The working conditions of the non-public access roads differ from those of the main railway transport networks, both in terms of technical equipment and staff, as well as in operating technology.

Since the main activity of non-public access roads is the performance of the same type of cargo operations, the establishment of time standards for shunting operations based on time-lapse observations is much easier. It allows to obtain average technological standards for shunting work that take into account the actual features and conditions inherent in specific access roads and specific types of diesel locomotives used.

The value of the standard operating time of a locomotive per shift is established experimentally based on the timing of shunting operations by a serviceable locomotive under the control of a qualified engineer [11]:

$$\tau_{st.shift} = 12 - (\tau_{shift\ ch.} + \tau_{lunch} + \tau_{wait.time}), \quad (5)$$

where: *12* - total shift time, h;
τ_{lunch} - lunch time, 1 h;
$\tau_{shift\ ch.}$ - the time of acceptance and delivery of diesel locomotives by locomotive crews is 0.5 h;
$\tau_{wait.time}$ - the waiting time for work is set experimentally based on the rhythm of the access roads, h.

The operating time of the locomotive at the appropriate positions of the driver's controller, indicating this position and idling mode, is taken from the timing data of observations of shunting operations.

The value of the fuel consumption rate per shift [11]:

$$G_{cons.rate\ shift} = G_{act.fuel\ cons.} / \tau_{act.time.shift} \cdot \tau_{st.shift}, \quad (6)$$

where: $\tau_{act.time.shift}$ and $G_{act.fuel\ cons.}$ - respectively, the actual operating time of the locomotive and the actual fuel consumption per shift.
$\tau_{st.shift}$ - the standard operating time of a diesel locomotive per shift, established based on the timing studies.

Total actual fuel consumption per shift $G_{act.fuel\ cons.}$ consists of their fuel consumption at the positions of the driver's controller, which were used by the driver when performing shunting work and idling when the locomotive was waiting for work and the designated parking areas of the locomotive (lunch, shifts of locomotive crews). To determine the consumption of diesel fuel at the appropriate positions of the driver's controller, the fuel consumption per kilowatt (1 kW) of diesel power is determined during the rheostatic tests of the locomotive. This figure is then multiplied by the locomotive's power at the driver's controller position and the operating time at that position.

The amount of fuel overspending (burnout) - $\Delta G_{fuel\ over.}$:

$$\Delta G_{fuel\ over.} = G_{act.shift} - G_{cons.rate.shift}. \quad (7)$$

The amount of downtime:

$$\Delta\tau_{dt} = \tau_{stand.m.} - \tau_{act.m.}, \quad (8)$$

$$\sum G_{cons.m.} = \sum G_{cons.shift} \;/\; \sum \tau_{act.time} \cdot \tau_{st.shift}, \quad (9)$$

where: $\sum G_{cons.shift}$ - fuel consumption by locomotives per shift, l;
$\sum \tau_{act.time}$ - actual working time per shift, h;
$\tau_{stand.m.}$ - the established standard of the locomotive's working hours per shift (month);
$\tau_{act.m.}$ - the actual working time of the locomotive per shift (month).

The actual specific fuel consumption is:

$$KPI = \tau_{act.} \;/\; \tau_{stand.} \quad (10)$$

Thus, the assessment of key performance indicators (KPIs) for the removal and shunting operation of shunting locomotives is an important tool for operational efficiency management. To form a KPI system, the following parameters must be taken into account [13-15]:

- Locomotive performance - the number of wagons handled per shift;
- Fuel efficiency - specific fuel consumption per unit of work performed (ton-km or wagon-hour);
- Locomotive utilization factor - the ratio of operating time under load to the total operating time;
- The average speed of shunting work is an indicator that affects the throughput of nodes;
- Locomotive downtime - waiting time without performing useful work;
- The volume of cargo transported is the total weight of cargo moved as part of shunting operations.

To create a KPI, it is recommended to use the developed monitoring methodology, which allows to collect and analyze data in real time [16-17]. This makes it possible to quickly identify bottlenecks in the operation of shunting locomotives and make informed decisions to optimize their operation. Examples of KPIs for export and shunting operations are given in Tables 2 and 3.

Regular data monitoring, the use of modern analysis methods and the introduction of a continuous monitoring system can not only reduce fuel costs but increase the productivity of the shunting locomotive fleet, as well.

***Table 2** Examples of KPIs for export and shunting work*

Estimated performance of locomotives			Values Norms	Units of measurement
Operating hours of shunting and hauling locomotives	Shift change (delivery and acceptance of the locomotive) - $\tau_{st.shift}$		1	h
	Lunch – τ_{lunch}		1	
	Waiting for work – $\tau_{wait.time}$		2 (acceptable)	
	per shift	$\tau_{st.shift} = 12 - (\tau_{shift.ch.} + \tau_{lunch} + \tau_{wait.time})$	10 - 8	
	per day	$\tau_{day} = 2 \cdot \tau_{st.shift}$	20 - 16	
	per month	$\sum \tau_{stand.m.} = 30.4 \cdot \tau_{day}$	$\sum \tau_{stand.m.} = 486.4 \div 600.8$	
The amount of downtime	$\Delta\tau_{dt} = \tau_{stand.m.} - \tau_{act.m.}$		$\Delta\tau_{dt}$	
Fuel consumption of shunting and hauling locomotives	$\sum G_{cons.m.} = \sum G_{act.m.} / \sum \tau_{act.time} \cdot \sum \tau_{act.m.}$ where: $\sum G_{act.m.}$ - fuel consumption by locomotives per month,; $\sum \tau_{act.m.}$ - the actual working hours per month, h.		$\sum G_{cons.m.}$	l
The amount of fuel overspending	$\Delta G_{fuel.over} = \sum G_{act.m.} - \sum G_{cons.m.}$		$\Delta G_{fuel.over}$	

***Table 3** Standard and actual time values for shunting and removal work*

Estimated indicator	Designation of the indicator	Units of measurement	Established norms, indicators	Measurement limit of the indicator value		
REMOVAL AND SHUNTING WORK						
The degree of underworking of the locomotives' time	$KPI = \tau_{act.m.} \;/\; \tau_{stand.m.}$	-	$\tau_{stand.m.}$ - the established standard of the locomotive's working hours per shift (month);	1 ÷ 0.8	0.8 ÷ 0.75	< 0.75
The amount of downtime	$\Delta\tau_{dt}$	h	$\tau_{act.m.}$ - the actual working time of the locomotive per shift (month);	$\Delta\tau_m = \tau_{stand.m.} - \tau_{act.m.}$		
The amount of inefficient fuel consumption	$\Delta G_{fuel.over}$	l	G_{idle} = 0.18 kg/min - fuel consumption at idle.	$\Delta G_{fuel.over} = \Delta\tau_m \cdot G_{idle}$		

4 Conclusions

The KPI value eliminates the problem of fuel losses, which are often associated with inappropriate spending and unauthorized fuel discharge.

Efficient use of fuel helps to reduce operating costs and environmental impact.

As a result of this study, the following conclusions were obtained:

- The development and implementation of a key performance indicators (KPIs) system requires careful planning, integration of appropriate tools and resources, as well as continuous monitoring and updating. If implemented correctly, such a system can significantly increase the efficiency of using locomotives and ensure the optimal functioning of railway sidings.
- The expediency of developing and applying this technique lies in its economic efficiency, that is, there is no need to install a fuel flow meter with the appropriate financial costs for their purchase, installation and debugging, eliminating the problems of structural incompatibilities of old diesel locomotives and fuel consumption monitoring and accounting systems.
- Based on the data of timing studies, it is possible to develop more efficient plans and schedules for the movement of shunting locomotives. This helps to reduce fuel costs, reduce time delays and increase overall productivity
- The development of accounting methods based on time - based research contributes to the introduction of new technologies and methods, which can make the company more competitive and attractive to investors.

Thus, increasing efficiency and reducing costs will contribute to improving the financial performance of the company and its overall stability in the market.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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