Improving use of shunting locomotives based on changes in infrastructure of railway station

Shinpolat Suyunbayev, *Utkir* Khusenov, *Sakijan* Khudayberganov, *Sherzod* Jumayev*, and *Shokhrukh* Kayumov

Tashkent State Transport University, 100167, Tashkent, Uzbekistan

Abstract. It is known that one of the main factors reducing the shortage of shunting locomotives at railway stations and leading to a reduction in their employment time due to increased labor productivity is the state of equipment of the railway station infrastructure with SCB devices. This article presents a way to attract low-mobility shunting locomotives by reducing the duration of employment of shunting locomotives allocated for the daily amount of work performed at the station when equipping them with devices by changing the infrastructure of an electric decentralized railway station. A comparative analysis of the time spent by the shunting locomotive in motion during the day when performing each technological operation for the maintenance of cargo facilities, as well as the amount of time spent on additional actions, is carried out.

1 Introduction

Railway transport in the Republic of Uzbekistan is important for the development of a diversified economy, the transportation of a large number of goods and passengers, as well as for the implementation of socially significant transport services. Railway stations are one of the main elements of the railway infrastructure and one of the main links that meet the needs of the state and the population in transportation.

The basis of local work carried out at the station is loading and unloading, distribution of loaded and empty wagons, provision of the station with empty wagons for loading, and removal of loaded and unloaded wagons from stations.

Several scientific results have been achieved in the course of the research conducted in the world to improve the technologies of transport processes in the organization of shunting operations; in particular, fuel injection systems of shunting locomotives have been modernized, systems have been improved to increase the processing capacity of mainline and industrial railways, locomobiles have been introduced to deliver wagons to cargo facilities, traction units have been developed to push wagons to a warehouse or conveyor belt during loading and unloading operations, solar energy use systems have been created to reduce the energy consumption of shunting locomotives [1-13].

All actions of rolling stock on railway transport are divided into train and shunting

* Corresponding author: shbjumayev_92@mail.ru

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types. The movement of a moving train, a group of wagons, or a separate wagon and locomotive along station tracks to work with trains and wagons, provide loading and unloading operations and perform other operations is called shunting movement [14-17].

The main part of shunting work is performed by specialized shunting locomotives that ensure the performance of other actions, such as transfer, assembly, rearrangement of wagons to transshipment points, distribution of trains, and formation of new trains, transfer, and assembly of wagons for repair [17].

One of the main problems at railway stations is the shortage of shunting locomotives. The main reasons leading to the shortage of shunting locomotives are the obsolescence of the technical means of railway stations and the inconsistency of the technical equipment and infrastructure of the station with the shunting process. The need for shunting locomotives is increasing due to the relatively heavy workload of shunting locomotives during shunting operations at railway stations.

The main directions of economic and social development of the Republic of Uzbekistan for 2022-2025 include the need to further improve train safety and increase railways' capacity and carrying capacity. In the coming years, automation and telemechanics devices will be introduced at mainline and industrial railway stations.

Tasks for the further development of railway transport in Uzbekistan as one of the priority tasks of increasing the level of technical equipment of the railways of JSC "UTY", the issue of complex equipment of stations with modern automation and telemechanics devices to increase the capacity not only of individual stages and stations but also of all main roads, improving the performance of the main sections.

The research object is the mainline and industrial railway stations where shunting operations with locomotives are carried out. The subject of the research is the methods of effective organization of shunting work using electric centralization of the railway station, reducing the duration of employment of shunting locomotives and increasing the productivity of shunting locomotives. The research aims to minimize the shortage of shunting locomotives based on the development of the railway station infrastructure and the improvement of the technology of transport processes for the organization of shunting operations. The research objectives are to reduce the duration of shunting work at a railway station and improve methods for determining the optimal number of shunting locomotives.

2 Materials and Methods

In our republic, it is important to increase independence from imported products, coding in the railway automation and telemechanics, and developing switch control devices based on energy- and resource-saving technologies. Uzbekistan Temir Yullari JSC still uses manually operated switches at several mainline railway stations (see Figure 1). This, in turn, causes many shunting locomotives at these stations, the time spent on shunting work, fuel, and the number of workers working at the station [15, 23].

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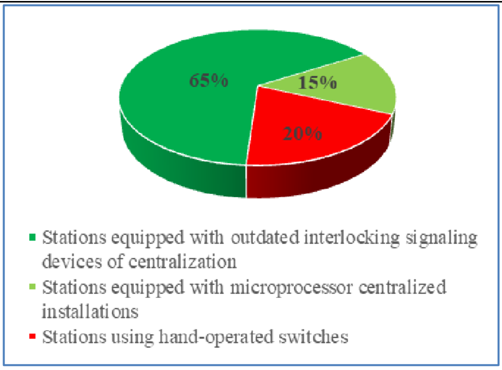

Regional railway junction	Number of stations	Number of stations using manually operated strelted conductors
Tashkent	57	6 (11%)
Kokand	39	21(53%)
Bukhara	69	10 (14%)
Kngrad	51	9 (18%)
Karshi	31	5 (16%)
Termiz	25	2 (8%)
Total	272	53 (20%)

Fig. 1. The number of stations using manually operated switchgear and their share according to "Uzbekistan temir yullari" JSC

Figure 1 shows the number and proportion of stations using manually operated switches operated by Uzbekistan Temir Yullari JSC. Based on the data in Figure 1, a total of 477 switchmen work at stations using manually operated switches owned by Uzbekistan Temir Yullari JSC. On average, 11.448 billion soums are spent annually on these switchmen (Table 1).

Table 1. Approximate costs for a manual control station with a kurbel

Namber of stations	Number of switchmen, people	The average monthly financial amount allocated for 1 employee, sum	Total financial resources allocated monthly to employees of "Uzbekistan Temir Yullari" JSC, sum	Total financial resources allocated to employees of "Uzbekistan Temir Yullari" JSC per year, sum
53	477	2 million	954 million	11.448 billion

The gradual systematic equipping of stations with an electrical centralization system will be the main solution to eliminate such problems at stations. By improving the technology of transport processes, and the organization of shunting work based on the development of the infrastructure of the railway station, it is possible to achieve prompt execution of shunting work performed at the station and thereby achieve a relative reduction in the shortage of shunting locomotives.

Several scientific papers have been carried out to determine the number and duration of employment of shunting locomotives assigned for shunting work performed at mainline and industrial railway stations [18-20]. Still, the procedure for reducing the employment and shortage of shunting locomotives based on the development of railway infrastructure has not been described in detail.

Most shunting locomotives operated at railway stations have a large capacity and consume excess fuel and energy resources to perform small amounts of shunting work indicates the need to provide shunting locomotives following the volume of work at railway stations. As a result, the task is to improve the performance of shunting locomotives and minimize fuel consumption by reducing the time spent by shunting locomotives on shunting cars at railway stations that are inextricably linked with the freight facilities of the station.

As a result of the development of the infrastructure of the station "Z", which is not equipped with an electric centralization system under the management of JSC "Uzbekistan Temir Yullari", shown in Figure 2, and equipping it with an electric centralization system, shunting works are carried out. with a group of train cars that arrived from the station "M" during the day, we will consider the procedure for reducing the number of shunting locomotives allocated to perform shunting work at the station based on the reduction in the duration of shunting locomotives.

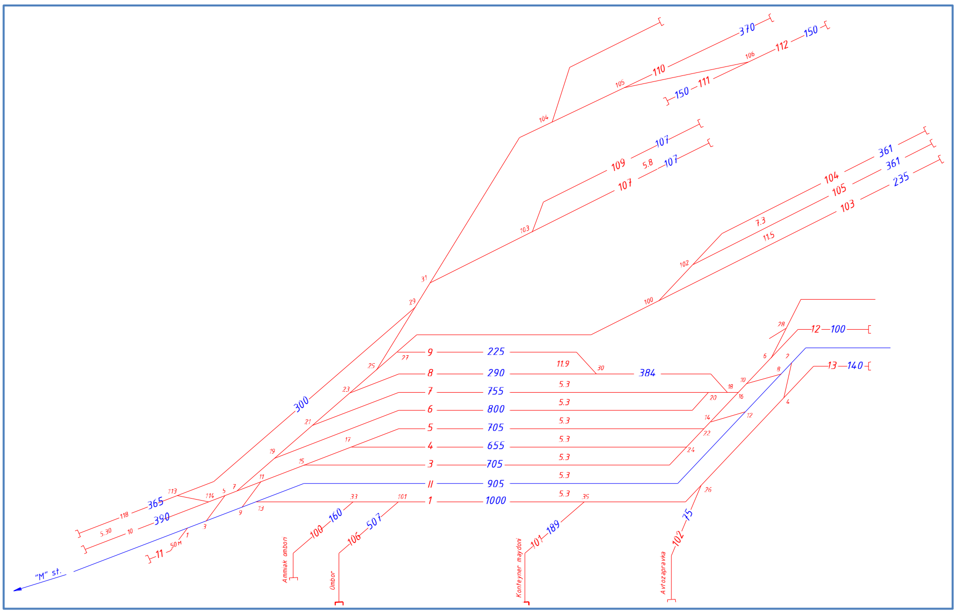

Fig. 2. Station scheme "Z"

Road II of station "Z" as shown in figure 2 is the main road for trains that are accepted and shipped from station "M"; road 1 is to road 100 of the cargo object, road 6 is to road 104 of the cargo object, road 5 is to road 105 of the cargo object, road 7 is to road 103 of the cargo object, road 8 is a separate empty (runaway) road for locomotives to cycle. In contrast, road 9 is specialized for washing wagons that require cleaning. All wagons removed from cargo facilities, in preparation for shipment, are assembled on the 3rd track of the station "Z", specialized for the wagons being sent. The maneuverability of the shunting locomotive was determined based on the specialization of the track of the station "Z".

The composition of trains taken to the station "Z" consists of a tank with increased sulfuric acid, a tank with increased ammonia acid, a mineral hopper with an increased concentration of phosphorus, a group of closed, semi-open type cars with an increased concentration of potassium chloride. From the cargo facilities of the station "Z", the export of exported goods is carried out on closed, semi-open, and Hopper mineral carriers with mineral fertilizers.

5 trains consisting of 45 groups of wagons with various loads will be received from the station "M" to the II main track of the station "Z" during the day, as indicated in Table 1 of the scientific work [17].

The duration of the daily employment of the shunting locomotive consists of the sum of the time spent on the implementation of the main 6 sequential processes shown in Fig.3.

The time intervals spent on the execution of processes in this sequence are also determined by dividing them alternately into two parts:

– the time of employment of the shunting locomotive during movement;

– the time spent on performing additional technological operations performed with a maneuverable train.

The driving time of a shunting locomotive with a group of wagons or separately, depending on its mileage and the requirements of regulatory documents, is determined by the following formula [2, 7-11].

$$T_{yur} = (0.0407 + 0.0017 \cdot m_w) \cdot \frac{v}{2} + \frac{0.06 l_{mov}}{v}, \text{ minutes} \qquad (1)$$

Here respectively, m_w is the number of wagons the shunting locomotive is pulling, wag;

v is the specified walking speed of the shunting locomotive, km/h;

l_{mov} is the distance of movement of the shunting locomotive, m.

If the shunting locomotive moves alone, then the number of cars given in Formula (1) is assumed to be 0, and as a result, the travel time takes the form.

$$T_{yur} = \frac{0.0407 v}{2} + \frac{0.06 l_{mov}}{v}, \text{minutes} \qquad (2)$$

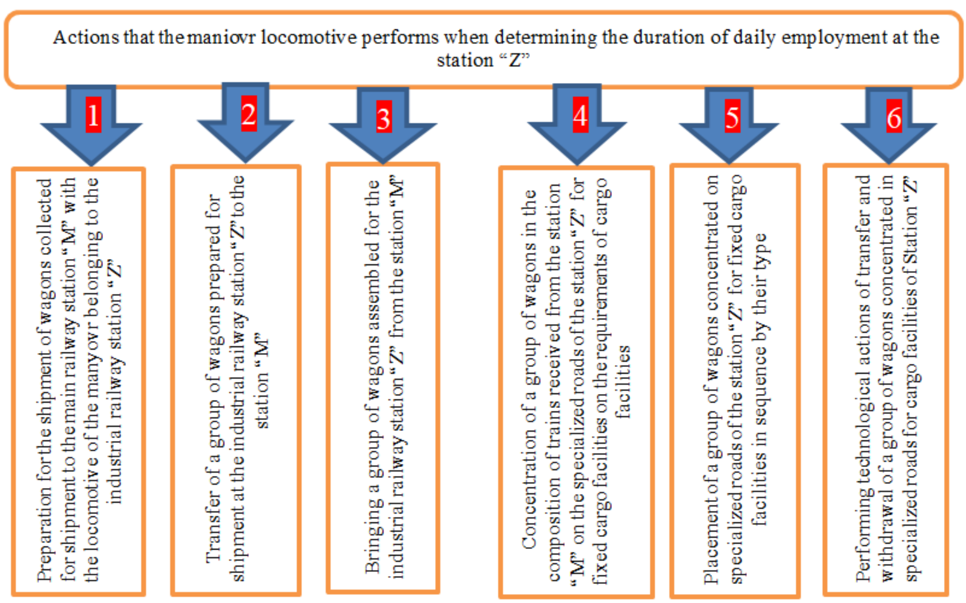

Fig. 3. Actions that a shunting locomotive assigned to the industrial railway station "Z" must perform per day

In a shunting locomotive, certain additional time is spent on performing several operations, such as preparing a group of wagons for transportation, removal to cargo facilities, preparing for shipment to a neighboring station and preparing a route, putting brake shoes, receiving instructions to start shunting work, reporting on shunting work, connecting the shunting locomotive to the train and disconnecting. The basis of additional actions leading to the employment of the shunting locomotive is the actions shown in Figures 4a and 4b for connecting and disconnecting the shunting locomotive from the train and along the course of the shunting locomotive. It consists of the sum of time spent by a shunting locomotive to perform various additional technological operations, the procedure for determining each of which is given, respectively, in scientific papers [15, 17-19, 23].

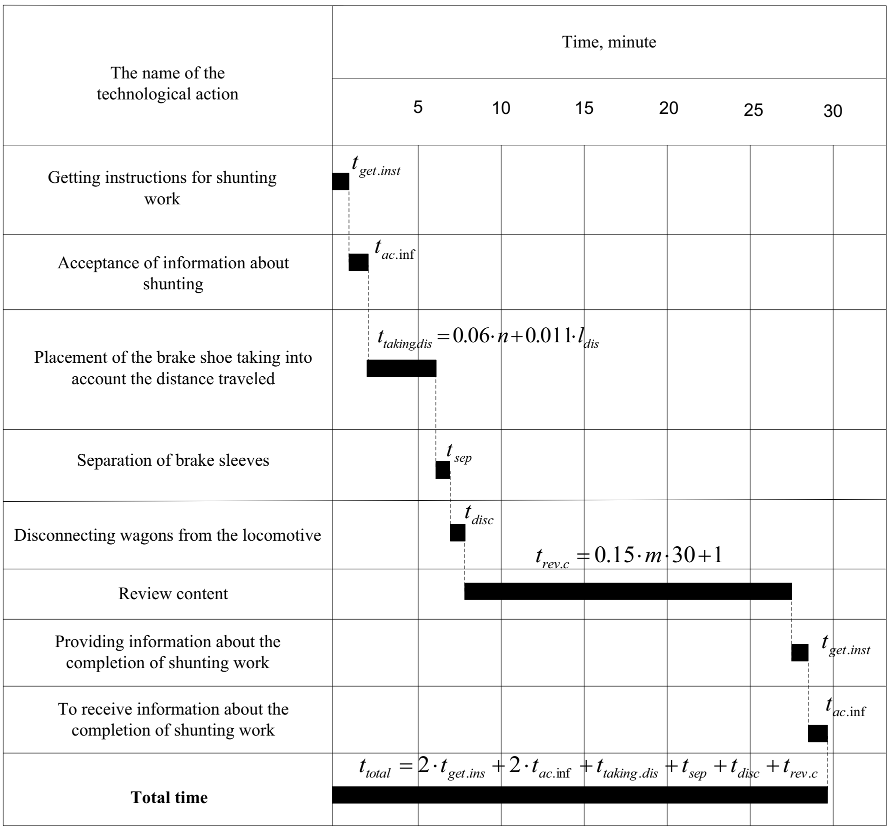

Fig. 4a. Technological graph of shunting work performed when disconnecting the locomotive from the structure

The first three shown in Figure 3 refer to the industrial railway station "Z" with a shunting locomotive for the preparation of wagons assembled for shipment to the mainline railway station "M", for the delivery of a group of wagons prepared for shipment to the station "M", for the delivery of a group of wagons assembled for delivery from the station "M" to the station "Z", to perform technological operations, such as one cycle of the action execution process is shown in Figure 5. At the station "Z" during the day, the cycle consisting of these three technological actions is performed 5 times.

The cycle duration, which includes the first three actions in Figure 3, is shown in Figure 5. It is established that after equipping the station "Z" with an electric centralization system, it takes 193 minutes. Of these, the preparation of a group of wagons consisting of 45 wagons for shipment took 34 minutes, delivery to the station "M" - 70 minutes, and delivery to the station "M" of a group of wagons consisting of 45 wagons - 89 minutes.

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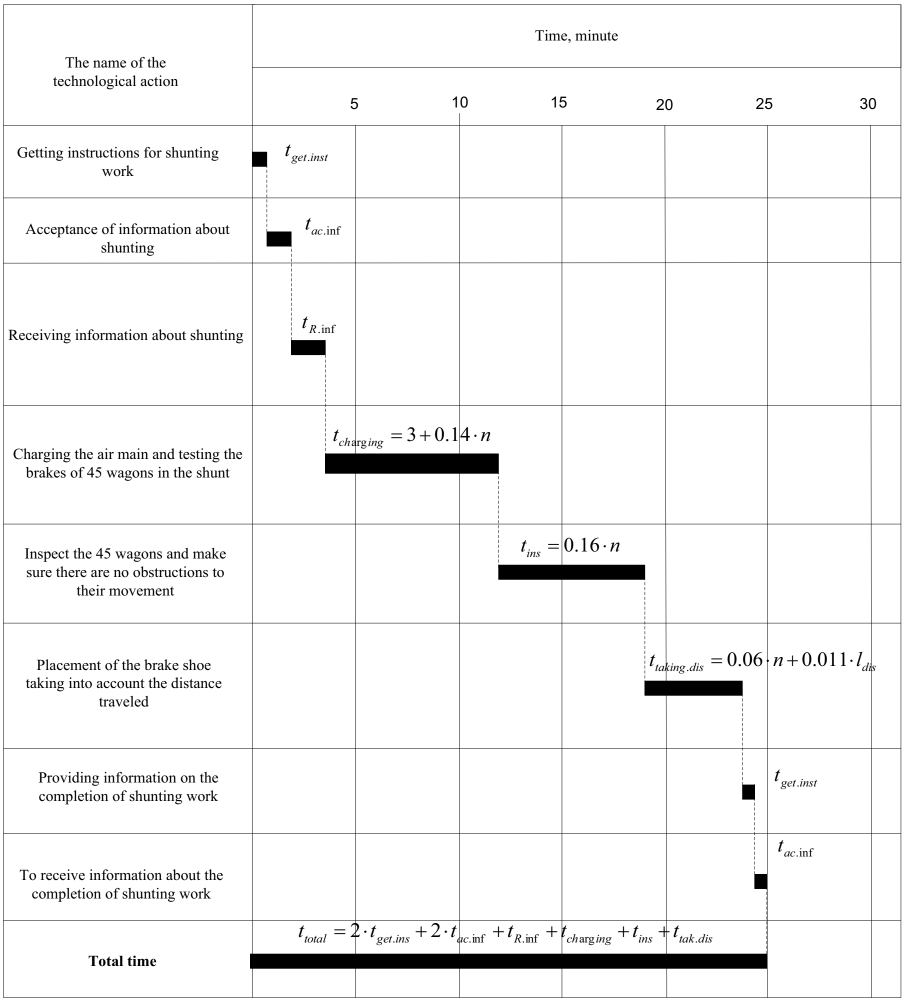

Fig. 4b. Technological graph of shunting operations performed when connecting the locomotive to the structure

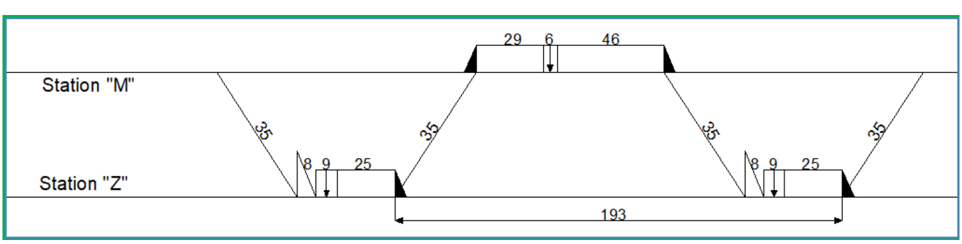

Fig.5. The cycle of the duration of employment of the shunting locomotive between the centralized electric stations "M" and "Z"

The result of determining one cycle of the duration of concentration of a group of wagons in the composition of trains received from the station "M", according to the requirements of cargo facilities on specialized tracks of the station "Z" for installed cargo facilities, is 54.8 minutes. The cycle consisting of this action is also carried out 5 times a day.

In conditions of a shortage of tracks at a railway station, wagons transferred to different tracks of a certain cargo object are summed up on a certain track of the station in a mixed form. Before transferring a group of wagons to designated cargo facilities, their sequential placement by types of wagons is required. The sequence of the arrangement of the group of wagons transferred to the freight facilities of the 6th track of the station "Z" was determined by a coordinated random selection based on the laws of combinatorics. As a result, the arrangement of groups of wagons grouped following the requirements for cargo facilities on the 6th track is shown in Figure 6, and each wagon is indicated by the number of the cargo facility for which the transfer is provided. The result obtained when determining the group of wagons on this route, based on the time of arrangement of wagons in sequence by their types [15, 17-18], is 62.1 minutes. The cycle consisting of this action is carried out 9 times a day.

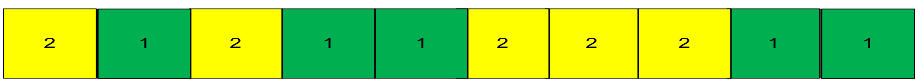

Fig. 6. The order of the concentrated wagons on the 6th track of the station "Z"

The procedure for performing technological operations for the transfer and export to cargo facilities of a group of wagons concentrated on specialized tracks of the station to cargo facilities for the electro-centralized and electro-centralized states of the station "Z" is given in scientific work [17, 19].

The number of shunting locomotives required at the station can be determined graphically based on the analytical calculation and the schedule of the station's daily operation. With the analytical method of calculation, the daily locomotive-minute consumption for the station's total volume of shunting work is determined first of all. Shunting locomotive-minute consumption is defined as the sum of the number of shunting processes performed (sorting, compilation, transfer, export, etc.). At the same time, the norms of specific technological processes spent on each process are also determined.

The required number of maneuver locomotives, either by station or by each maneuver region separately, can be determined using the following formula [15]:

$$M_{shunt} = \frac{K_u^{sh} \cdot \Sigma Mt}{\alpha_{as} \cdot 1440 - \left(T_{sb} + T_{ek} + T_{tp}\right)}, locomotive \qquad (3)$$

Here respectively, ΣMt is represents the sum of time spent on all shunting operations performed at the station and is determined by table 2, loc-min;

T_{add} is additional time for the employment of a shunting locomotive (the norm of the time for changing crews, crews). We take this time as 90 minutes;

K_u^{sh} is coefficient of the unevenness of the daily volume of shunting work $K_u^{sh} \in (1.1-1.3)$;

α_{as} is a coefficient that considers stops due to certain interfering routes when using a traction tract ($\alpha_{as} = 0.95$).

The number of shunting locomotives required at the station can be determined graphically based on the analytical calculation and the schedule of the station's daily operation. With the analytical method of calculation, the daily locomotive-minute consumption for the station's total volume of shunting work is determined first of all. Shunting locomotive-minute consumption is defined as the sum of the number of shunting processes performed (sorting, compilation, transfer, export, etc.). At the same time, the norms of specific technological processes spent on each process are also determined.

The required number of shunting locomotives, by stations or separately for each shunting area, can be determined by the formula [15]:

$$\eta_{shunt} = \frac{M_{shunt}^{acc}}{M_{shunt}^{accep}} \cdot 100\% \qquad (4)$$

Here respectively,

M_{shunt}^{acc} is account number of shunting locomotives, locomotives;

M_{shunt}^{accep} is accepted number of shunting locomotives, locomotives.

3 Results and Discussion

The duration of the daily employment of the shunting locomotive for each of the actions shown in figure 3 is shown in Table 2, based on the above.

Table 2. The duration of operation of the shunting locomotive at the station "Z" during the day

Station "Z"	Duration of actions, minutes						Total
	1	2	3	4	5	6	
Without electrical centralization	300	620	280	486	993	4139	6818
Electrical centralization n	170	350	445	274	559	2329	4127

According to Table 2, the maneuver locomotive Station "Z" is occupied by 6818 minutes in the case of electric decentralization and 4127 minutes in the case of electric centralization.

Based on the above formula (3) and the data in Table 2, we clarify the number of maneuver locomotives required for the station as follows.

For the current state without electrical centralization of the station "Z"

$$M_{shunt} = \frac{1.1 \cdot 6818}{0.95 \cdot 1440 - (30 + 60 + 50)} = 6.1 \approx 7 \; locomotive$$

The load indicator of the shunting locomotive, according to the formula (4), takes the form:

$$\eta_{shunt} = \frac{6.1}{7} \cdot 100 = 87.1\ \%$$

Since the performance of the shunting locomotive is more than 85%, 8 shunting locomotives will be accepted and brought to 76%.

For the electric centralization of e due to the development of the infrastructure of the station "Z"

$$M_{shunt} = \frac{1.1 \cdot 4127}{0.95 \cdot 1440 - (30 + 60 + 50)} = 3.69 \approx 4\ \textit{locomotive}$$

The load indicator of the shunting locomotive according to the formula (2)

$$\eta_{shunt} = \frac{3.69}{4} \cdot 100 = 92.2\ \%$$

Since the performance of the shunting locomotive is more than 85%, 5 shunting locomotives will be accepted and brought to 73.8%.

According to the calculations, the number of shunting locomotives is taken as an integer. Therefore, it is necessary to provide for their use in various shunting areas, the redistribution of work between these areas, their unification with increased use of locomotives, and other measures.

Therefore, in the current electric decentralized state of the" Z" station, 8 shunting locomotives are required for shunting work performed at the station. In the case of centralized power supply, the development of the station " z " infrastructure requires 5 shunting locomotives.

4 Conclusion

1. Thanks to the development of the industrial railway station "Z" infrastructure, it was possible to reduce the duration of daily employment of shunting locomotives operating at this station from 6818 minutes to 4127 minutes, reducing it by 2691 minutes.
2. As a result of developing the infrastructure of the industrial railway station "Z" and equipping it with an electric centralization system, the possibility of implementing 5 maneuver locomotives instead of 8 maneuver locomotives was achieved to fulfill the schedule of the daily work plan to be carried out at the station.
3. At the stations not equipped with the electrical centralization system under the JSC" Railways of Uzbekistan", the estimated annual expenditure for streamers was determined. By equipping the stations with an electrical centralization system, it was clarified that such spending could reduce costs and increase the productivity of maneuver locomotives.

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