Normalization of Time Losses in Sorting Station Operations Using a Python-Based Instrumental Tool

Dilmurod Butunov[1,2], Shakhriyor Daminov[1,2] and Choriyor Jonuzoqov[1,2]
[1]*Tashkent State Transport University, 100167 Tashkent, Uzbekistan*
[2]*University of Diyala, 32009 Baqubah, Diyala, Iraq*
dilmurodpgups@mail.ru, daminovshakhriyor@gmail.com

Keywords: Sorting Station, Python, Instrumental Tool, Unproductive Time Loss, Wagon Flow, Receiving Park.

Abstract: The study aims to reduce unproductive time losses in wagon flow processing at railway sorting stations using a Python-based software tool. The work employed mathematical and graphical modeling, structural analysis, flowcharting, algorithm theory methods, and the Python programming language. The problems caused by unproductive time losses in sorting station operations were identified. Based on the flowcharting method, a systematic analysis of the operation of the sorting station's receiving park was carried out, revealing that time losses are caused by human factors during waiting periods between technological operations. The values of unproductive time losses were determined for each element of the receiving park's operation. Consequently, it was concluded that the current graphical modeling method is inefficient and that a new mechanism for reasonably standardizing the value of each element needs to be developed. An instrumental tool was created using the algorithm theory method and the Python programming language to standardize time losses at the sorting station. This mechanism enables rational regulation of the value of each element in the operation of the receiving park and allows online monitoring of station employees' activities.

1 INTRODUCTION

There is a strong competition among modes of transport in the world to solve the problem of minimizing unproductive time losses in transporting goods and passengers to their destinations in the shortest possible time. In this, the role of railway transport, which occupies a leading position in the implementation of large-scale transportation, is of great importance [1]-[5].

When delivering cargo to its destination by railway, the rhythm of transportation is determined by sorting stations [3], [6], [7].

The main task of sorting stations in the transportation process is to process train and wagon flows in minimal time intervals [3], [6]. In this case, one of the main problems is to minimize unproductive time losses in technological operations and inter-operational work performed with transit and local wagons [3], [6], [8]-[10].

The standing time of transit processing wagons at the sorting station consists of the following parameters [3], [6], [9].

Here (Fig. 1) setting technical standard values for each parameter and monitoring their implementation in practice determines the efficiency of the transportation process [1], [3], [8]. However, various factors negatively affect the actual implementation of the station wagon standing time standards during the production process [3], [6], [7], [10], resulting in unproductive time losses during the transportation process. Such time losses cause the following problems for railway transport: exceeding the norm of shipping deadlines; to decrease or loss of customer confidence in shipping; to the decline in its position in the transport market; a sharp decline in the sector's economic revenues; the emergence of economic problems in the future development of the industry, etc.

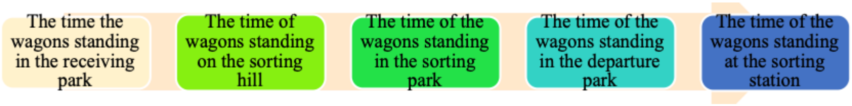

Figure 1: Parameters of the standing time of wagons at the sorting station.

From the above, it can be concluded that the human factor is mainly responsible for the emergence of such problems. In this regard, it is necessary to develop a mechanism for reasonably regulating the value of each parameter of the waiting time of wagons at sorting stations, which determine the rhythm of the transportation process, and to control them in practice.

2 METHODS

Many scientists have conducted scientific research over the years on the development of technologies for organizing and managing wagon flows at sorting stations, including the development and improvement of methods for determining, standardizing, monitoring, and analyzing the standing times of wagons at the station and in each of its parks [1], [2], [4], [6], [9].

Special attention is paid to the analysis, evaluation, standardization and modeling of the times spent in the entire cycle of distribution at the station's receiving park and sorting hill, based on the elements that make up them (time spent waiting for the composition to be received, receiving, securing, separating the train locomotive from the group of wagons, processing and commercial inspection of the composition, waiting for the shunting locomotive to be connected to the processed composition, pushing towards the sorting hill and distributing the composition) [1], [2], [4], [6], [9].

However, in the above-analyzed scientific works, the problems of modeling the process of organizing wagon flows, taking into account the rapid elimination of situations arising as a result of the main factors that cause "Unproductive time losses" during the processing of wagons and process control, have not been sufficiently studied. In this regard, in this scientific work, work was carried out to normalize unproductive time losses in the operation of the sorting station receiving park.

3 RESULT AND DISCUSSION

It is known that in the process of transportation, technical stations take the leading place in terms of the volume of work. Technical stations are the main base for efficient organization of the flow of wagons in the railway network. Despite the small number of technical stations in the railway network, they determine the implementation of the transportation plan.

In determining the effectiveness of technical stations' work technology, the practical implementation of the indicator "Wagons standing time at the station" is of great importance.

Currently, various methods (analytical, graphic, table, etc.) are widely used in the world railways to establish the value of this indicator. In particular, analytical methods are widely used in most technical stations.

The waiting time of wagons in the receiving park consists of the following elements [3], [6], [9]: $t_{r.p.}=t_{s/b\ (w)}+t_{s/b}+t_{proc/rec(w)}+t_{proc/rec}+t_{diss(w)}$, hour, there $t_{s/b\ (w)}$ – waiting time of securing and blocking composition in the receiving park, hour; $t_{s/b}$ – time of securing and blocking composition in the receiving park, hour; $t_{proc/rec(w)}$ – waiting time for composition processing in the receiving park, hour; $t_{proc/rec}$ – processing time after composition arrival, hour; $t_{diss(w)}$ – distribution waiting time, hour. The elements causing wagon standing times are illustrated in Figure 2. Current metrics of wagon processing elements are presented in Table 1.

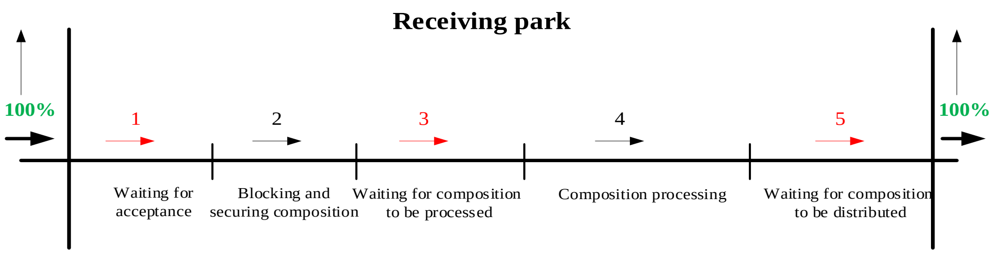

Figure 2: Elements that cause the time that wagons standing in the receiving park.

Table 1: Current metrics of the 5 key elements in wagon processing at the sorting station receiving park.

Name of elements	Criteria	
	Technological operations	Waiting between operations
1. Waiting time of securing and blocking composition in the receiving park, hours		
2. Time of securing and blocking composition in the receiving park, hours		
3. Waiting time for composition processing in the receiving park, hours		
4. Processing time after composition arrival, hours		
5. Distribution waiting time, hours		

Table 2: Distribution of composition at receiving park.

Train number	The number of wagons in trains	Time of receiving to "Ch" station, minutes	The time of fixing and blocking the composition, minutes	Waiting time for processing, minutes	Composition processing time, minutes	Distribution waiting time, minutes	Composition distribution time, minutes
First day (2nd shift)							
1252	47				Left over from the previous shift	00-44	00-45
2580	55	20÷35	00-07	00-03	00-35	00-10	00-45
2036	60	21÷20	00-08	00-05	00-45	03-32	00-55
3002	55	21÷50	00-05	00-13	00-58	04-35	00-37
1250	43	23÷50	00-10	00-18	00-47	03-40	00-38
2592	58	00÷30	00-07	00-05	00-50	03-38	00-32
1262	69	03÷05	00-10	00-15	00-42	01-15	00-48
2002	55	03÷40	00-06	00-34	00-45		Left for the next shift
2586	62	06÷00	00-06	00-14	00-40	00-05	00-40
1256	46	06÷52	00-06	00-07	00-40		Left for the next shift

During the analysis of the elements that make up the waiting time of wagons in the receiving park of the sorting station, it was found that "Unproductive time losses" occurs mainly in inter-operational waiting times.

Unproductive time losses are due to operations such as waiting for content to start blocking and fixing, waiting for content to start technical processing and commercial review, and waiting for the processed content to be distributed using the sorting hill. In this regard, the work process of the "Ch" sorting station under the jurisdiction of "Uzbekistan Railways" JSC was studied. The work process of the station during the night shift (from 20:00 to 08:00 in the morning) was analyzed. Distribution data of composition at receiving park is shown in Table 2.

Freight train No. 1252 (Table 2) was received in the previous shift and the processing of the train was completed on time. However, due to the ongoing distribution work on the sorting hill, this train had to wait for 44 minutes, and 45 minutes were spent on the distribution of the train. Also, during this shift, freight trains No. 2002 and No. 1256 were received in the station's receiving park at 03:40 and 06:52, respectively, and the processing was completed on time. However, in this case, the distribution of both trains mentioned above was transferred to the next shift.

Based on the results of the research carried out at the sorting station, a general time flow map of the composition was developed in the sequence of technological operations from the time the group of wagons was received on the tracks of the receiving park of the station until it was transferred to the tracks of the sorting park of the sorting station. The waiting for fixing and blocking the composition received by the station attendant on the station territory and waiting for fixing and blocking, processing and processing, as well as workers involved in the process of technical-technological operations such as waiting for distribution, and their command and communication procedures were mentioned. The composition received for processing by the station attendant at the station reception park is fixed by the station park officer (DSPP) with the help of brake pins based on the instructions of the maneuver dispatcher, in which the slope of the station according to the location of the receiving park is from station "K" to station "S" since it deviates to the side, it is enough to double-fix the compositions only from the head. There are 8 tracks in the station reception park, and there are a total of 7 stelaj[1] and 63 brake shoes with stelaj for storing brake shoes next to each track, 8 brake shoes in each stelaj are strictly controlled. is used, in which 1 brake shoe is installed on the wheel pair of the first wagon of the train, and then on the wheel pair of the second wagon, 1 brake shoe on the slope, 1 brake shoe against the slope, a total of 3 brake shoe of brake head are installed. After the above process is completed, it retransmits the fix message to the maneuver dispatcher. Next, based on the relevant instructions of the park attendant, the train locomotive driver's assistant separates the locomotive from the train, and the train locomotive leaves the station area with the permission (green) light of the station's route traffic light. For the technical and commercial inspection of the composition, the working team (PTO[2]) starts to check the composition, the current condition of the wagons, wheels, safety seals, cleaning system hoses is checked technically, the standard time set at this station is 60 minutes. In parallel with the technical inspection, the commercial inspection of wagons (PKO[3]) is performed by employees. In this case, PKO employees checked the correctness and availability of documents related to cargo. In the course of the inspection, if a technical malfunction is detected in any wagon, the wagon will be sent to the technical inspection point located at this station to study and eliminate the problem. If there is any problem or deficiency related to the cargo documents, then the wagon will be opened in the presence of witnesses and employees of the internal affairs body and a document in the form of GU-23 will be drawn up.

In order to start the sorting process, all information such as the technical characteristics of each wagon, the station of their destination, whether the goods are classified as dangerous goods or not is obtained from the nature sheet (DU-1) from the technological center of the station, and the sorting sheet is made in 2 copies, the first copy is the sorting sheet to the duty officer and his switcher, the second copy is given to the train former. In this case, with the permission of the sorting hill duty officer, i.e. "DSPG", his signalman changes the direction of the switch towards the designated track of the sorting park, and one or more groups of wagons are separated from the rest of the wagons by the train conductor. A flowchart was created to identify inefficient time losses in the sorting station operation (Fig. 3, 4, 5) [9].

At (Figure 3) when the train arrives at track 6, which is located in the station's reception park, the park shift waits for the train to stop completely (2 minutes), then provides safety information from the station shift (0.5 minutes), and only then begins to pass by the train (0.2 minutes). The process of fixing the train consists of three repeated operations – moving to the side of the stelaj and taking the brake shoes (0.5 minutes), installing it after receiving the "Braking shoes" by going to the side of the contents (0.5 minutes), moving to the fastening and installing the "Braking shoes" (0.5 minutes). The process is thus repeated three times again. After that, the brake shoes were partially removed over the wheel pairs head so that they did not move on their own-that is, nakat[4] (1 minute), and the assistant train locomotive machinist's assistant separates the locomotive from the composition (1.5 minutes) and waits for the station shift permission order (5 minutes). With the permission of the station duty officer, the signal of the route traffic light will be changed to green, which means the order to the train locomotive that it is possible to leave the park. Once the security work is finished, the DSPP will be able to return to the post. In this process, the "Installation of brake shoes" and the separation of the train locomotive from the composition operations are considered useful work. The processes of waiting for the post shift movement composition to stop, waiting for the stop message, and waiting for the permission message until the train locomotive departs are considered inefficient time losses. Thus, the time indicator until the completion of the general fastening and blocking processes was 13.2 minutes, while the useful working time is 3 minutes, with a total process efficiency of 22.7%.

At Figure 4 the total time required from the time the train enters the station area at the signal of the entrance traffic light to the start of the work on the

[1] Stelaj - where the brake shoe is stored.
[2] PTO - point technical inspection.
[3] PKO - point commercial inspection.
[4] Nakat - pushing wagons towards the brake shoe by maneuvering the locomotive to fix the composition.

station (about 14 minutes), and even then, the process of securing the train consists of three repeated operations going to the stelaj and taking the brake shoes (0.5 minutes), after receiving the "Braking shoe" and installing it next to the composation (0.5 minutes), going to the place of fixation and installing the "Braking shoe" (0.5 minutes). The process of waiting until the locomotive is separated from the train and pushing wagons towards brake shoe (2 minutes), the assistant driver of the train locomotive separates the locomotive, this process takes time (1.5 minutes). After the completion of all the above processes, it is possible to start maintenance and commercial inspection of wagons, based on the technical standard (60 minutes) given at the station where the research was conducted. To cancel the blocking order after these actions, the park duty officer sends a message to the station duty officer to remove the blocking, and the process takes (2 minutes) to complete. The train former takes the sorting sheet and comes to the train (10 minutes) and takes the his work place (1 minute).

While the total (94 minutes) time for the waiting and processing process is rectified, then the useful working time (64.5 minutes), the time for fixing the composition in the above processes, separating the train locomotive from the composition and processing "Technical and commercial inspection" corresponds to the useful working time, while the time spent in the other process is excess expectations. We can see that the useful working time is 68.6% of the total time, depending on the time indicators mentioned. At (Figure 5) to wait for the sorting of the composition after the maintenance and commercial inspection of the composition received on the 6th odd road of the receiving park (5 minutes) and for the shunting dispatcher to open the station shunting traffic lights and prepare the route to start the sorting of the composition (2 minutes) is required. The shunting locomotive goes to the 6th odd track in the receiving park from the back of the train (5 minutes) and is connected by the train engineer to move the wagons in the push method, this process takes time (2 minutes). After the shunting locomotive is connected, the DSPP removes the brake shoes securing the train (2.5 minutes). The driver of the shunting locomotive waits for the permission order from the sorting hill duty officer to start movement (2 minutes), the shunting locomotive moves the train to the arrow of the sorting hill (5 minutes), waits for the arrow to open and the traffic light of the sorting hill opens, and moves the wagons towards the hill (10 minutes), announcing the start of sorting through (1 minute), and sorting wagons based on the plan of the sorting sheet (45 minutes). In the course of sorting, if there are dangerous goods and oversized wagons in the group of wagons, these wagons should be pulled to the sorting park with the help of a shunting locomotive without dropping them from the hill (15 minutes). The total time in the sorting process is found to be (94.5 minutes) and from this (58 minutes) we can see that the useful working time is 61.3% of the total time.

In order to increase the speed of freight transportation and wagon turnover in railway transport, it is necessary to organize the work technology effectively and to automate it using modern technologies, taking into account many parameters. In this case, as we will see on the example of the "Ch" sorting station where the research is carried out, the steps of receiving and sending trains to the station are carried out by the station duty officer. The receiving park tracks number 3, 4, 5, 6, 7, 8, 9, 10 (via the main line) receive trains from stations "K" and "S", and the 4th post shift welcomes all trains in front of the incoming track.

In order to effectively organize the work process, the operator of the station duty officer informs the station on duty in advance about the trains scheduled to arrive at the station and their arrival time, the characteristics of the wagons and cargo, through the nature sheet form (DU-1). The Operator directly assists the station shift in the process of receiving and dispatching trains sent from the adjacent station. In the process of sending the new composition drawn up at the sorting station, the composition will be accepted to the 37, 38, 39, 40, 41, 42, 43, 44-tracks of the departure park, and after all documents have been formalized, the train will be connected to the locomotive and the compositions will be sent to the adjacent station. In this work, a software tool was developed to control trains that are accepted, shipped and passed without stopping to the "Ch" sorting station on the basis of modern technologies. Before the development of this system, a context diagram (Fig. 6) and IDEF0 (Fig. 7) diagram are presented using the IDEF0 design method.

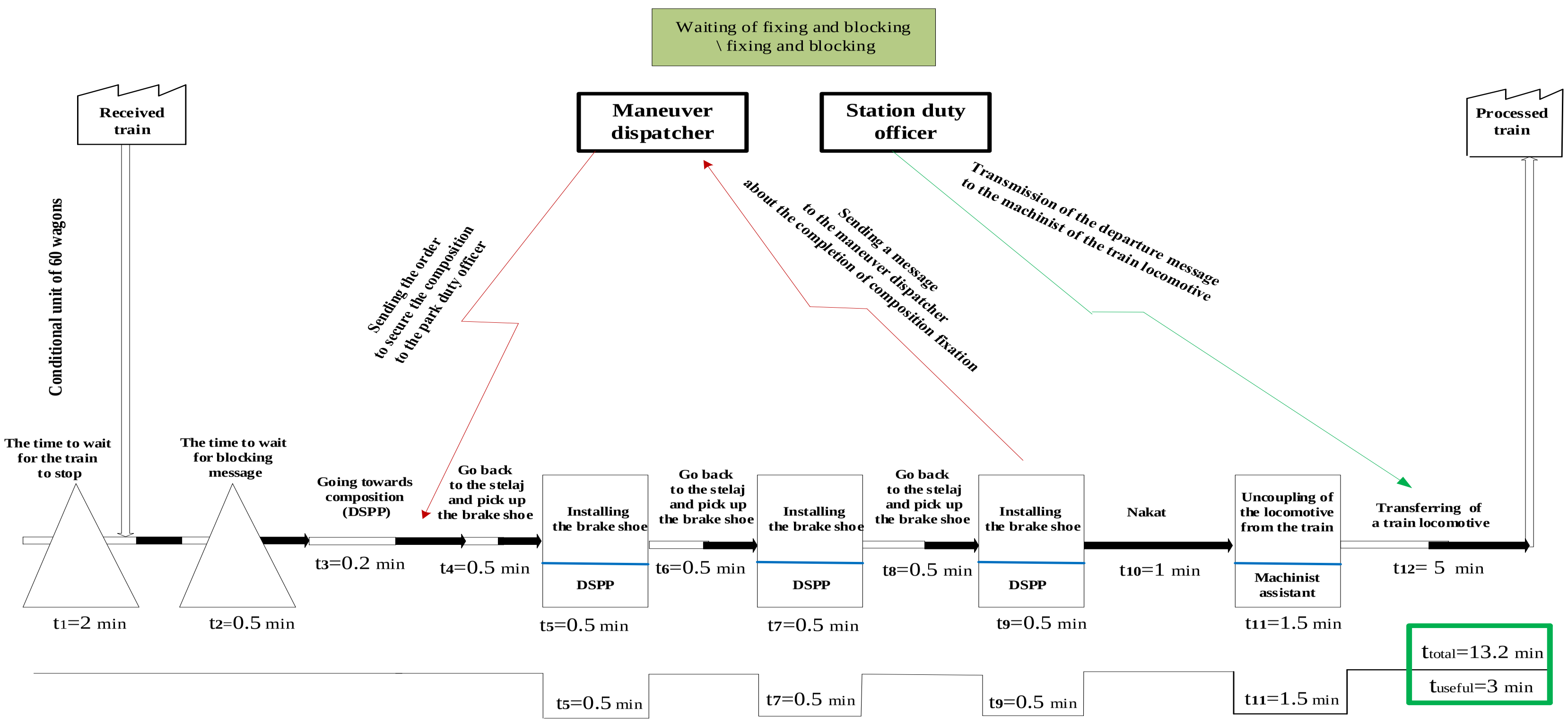

Figure 3: The flowcharting of the current status of the processes of securing and blocking trains received on the odd track №6 of the receiving park of the “Ch” sorting station.

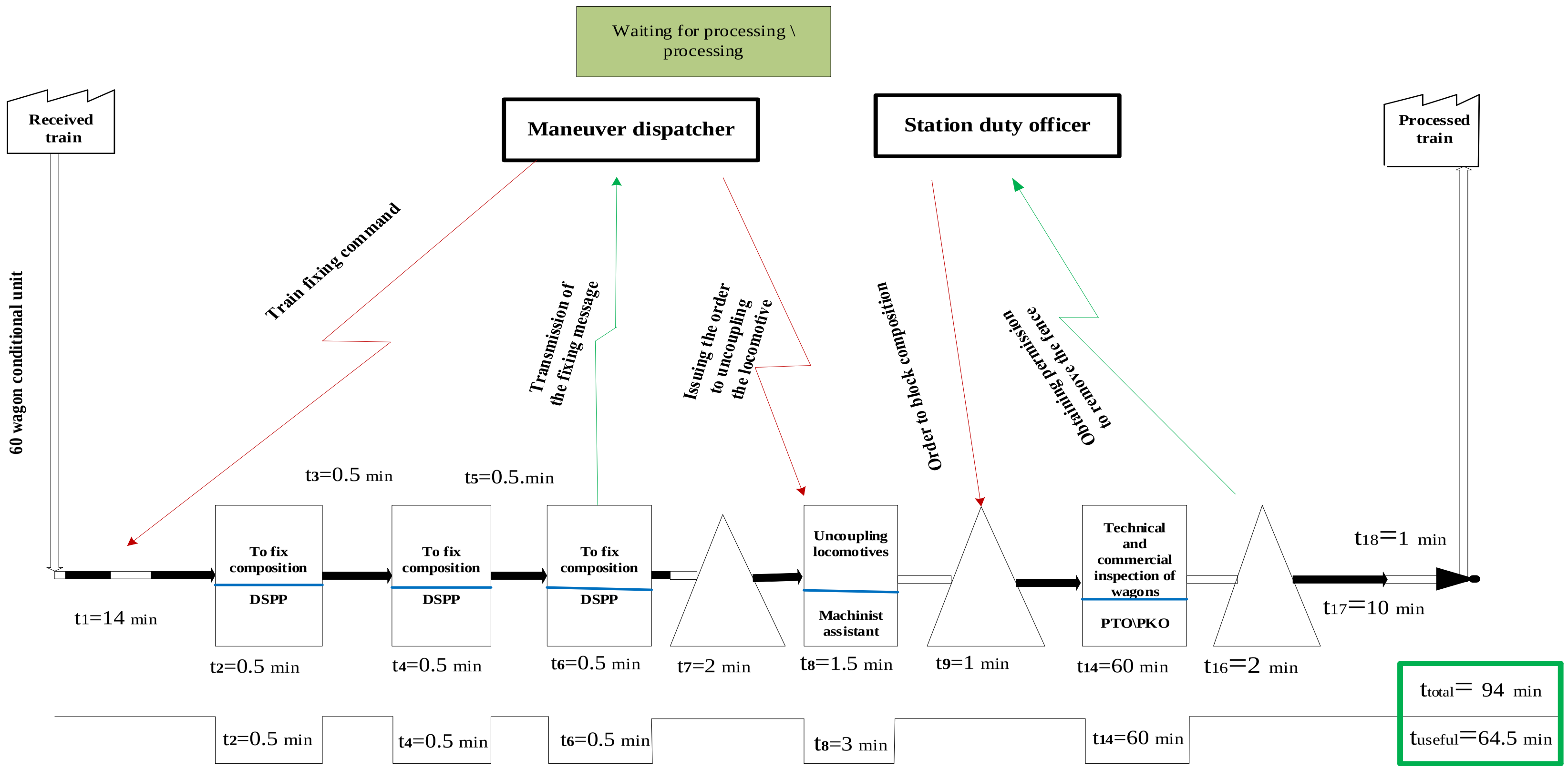

Figure 4: The current flowcharting of processing processes of trains received on the odd track №6 of the receiving park of the “Ch” sorting station.

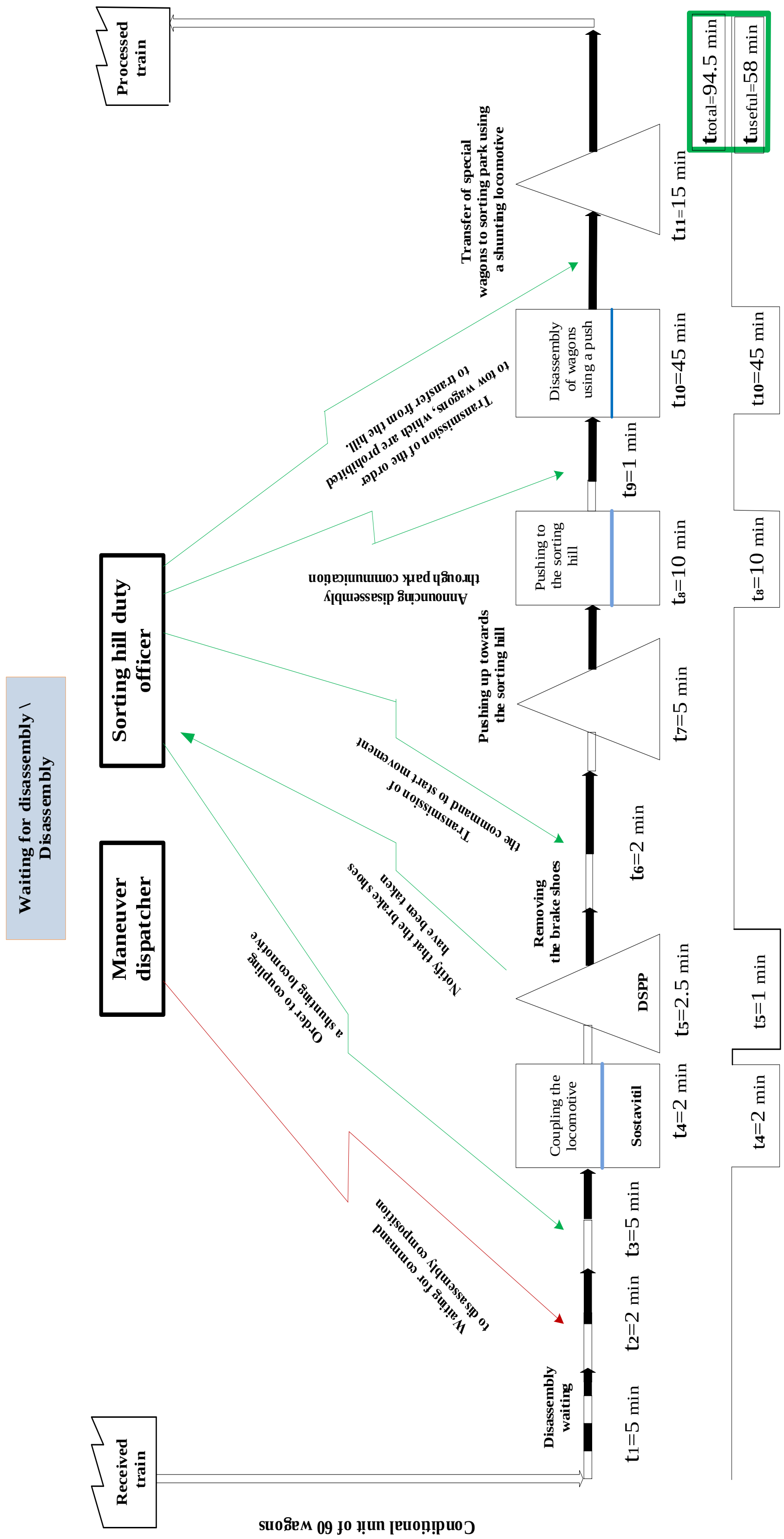

Figure 5: The flowcharting of the current state of the distribution of the received composition to the odd road №6 of the receiving park of the “Ch” sorting station is shown.

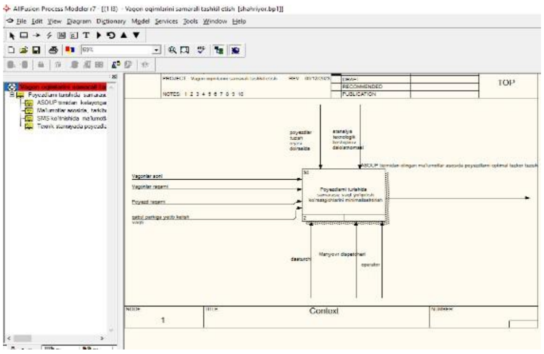

Figure 6: Context diagram.

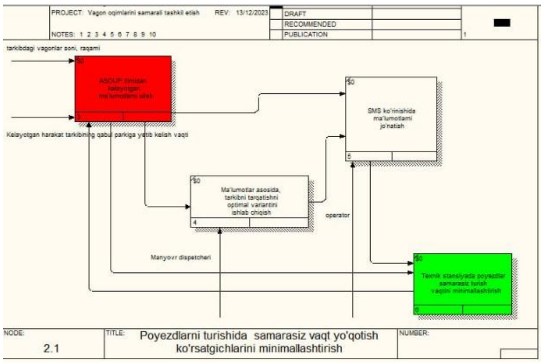

Figure 7: IDEF0 diagram.

IDEF0 is developed on the basis of a structural analysis and design methodology, has been approved as a USA standard and is successfully used in many projects related to the description of the activities of enterprises. IDEF0 can be used to model a wide range of systems.

The use of IDEF0 for new systems is aimed at identifying requirements and defining functions for the further development of the system that meets the requirements and implements the selected functions.

For existing systems, IDEF0 can be used to analyze the functions performed by the system and map the mechanisms for performing these functions.

The result of applying IDEF0 to a system is a model of a system consisting of hierarchically ordered diagrams, document text, and interconnected functions through cross-links.

A context diagram is a model that represents a system as a set of hierarchical actions in which each action changes some kind of object or set of objects. The highest action of the hierarchy is called the action of the context - this is the highest level that directly characterizes the system. The following levels are called decompositions of work and represent sub-processes of activity.

We divide the context diagram into 4 functional blocks (Figure 6):

- Train lines information;
- Filling the DU-2, DU-3 train and locomotive movement journal;
- Filling out chronometry transfer tables;
- Proper organization of maneuver work.

In this case, the working window of the instrumental instrument (Fig. 8 and Fig. 9), created to effectively organize the movement of trains, is presented. In the working window of the software tool, the process of sending a train to an adjacent station is presented. In this process, the "Poyezd qo'shish, adding train" button is pressed to run the program, and in the working window there is an opportunity to enter information that belongs to the train. In this case, the train number, train index, type of movement and road number will need to be entered.

If the data entered during the Figure 8 data entry process changes at this time or is entered incorrectly, the "O'zgartirish, change" button listed in Figure 9 that allows it to be edited is pressed, and the possibility of reediting this data appears.

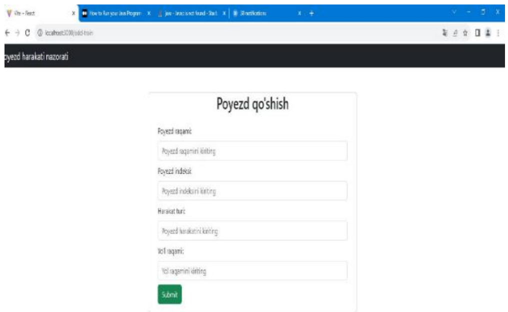

Figure 8: Adding train information.

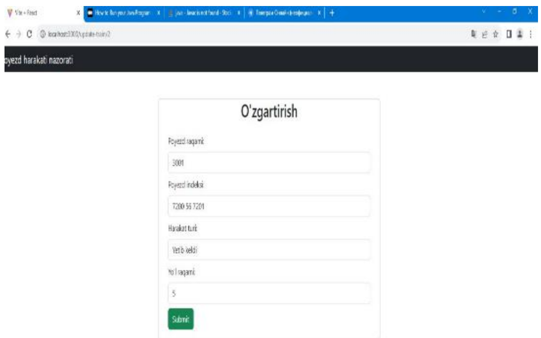

Figure 9: Editing entered train information.

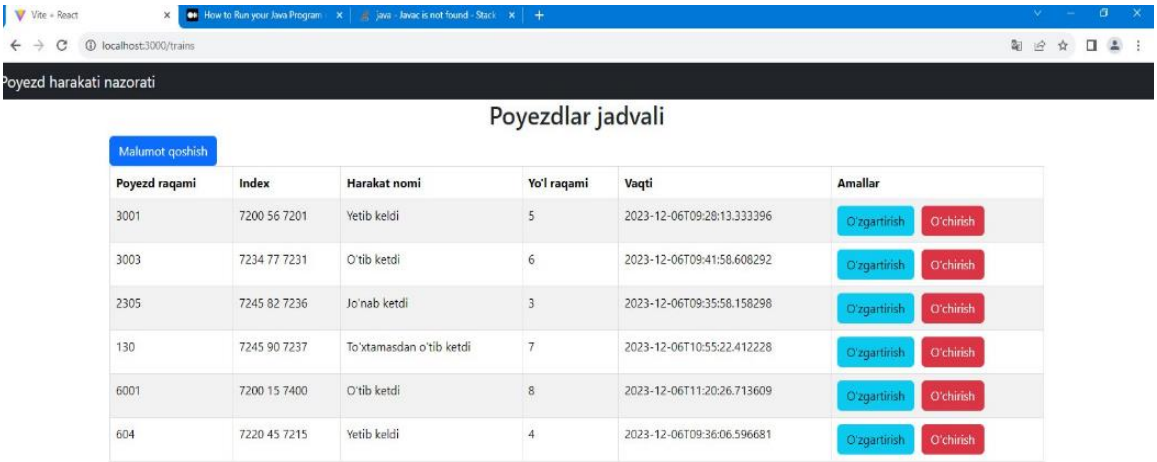

Figure 10: Train traffic control stay.

After all information about the train is entered into the system completely and without errors, the instrumental tool allows the responsible employees at the station to effectively organize work in advance to receive, process and sort the trains at the receiving park of the sorting station, which in turn prevents unproductive time losses when re-routing trains. The interface for controlling train traffic using this tool is illustrated in Figure 10. In scientific work on the standardization of time losses in the operation of the sorting station, the technological processes of processing wagon flows were standardized mainly on the basis of the creation of flowcharting and systematic analysis of the results of graphic modeling [4]. As a result, the error was 15-20% [4]. An instrumental tool based on the method of algorithm theory and the Python programming language makes it possible to reduce such problems to 10-15%.

4 CONCLUSIONS

It was found that a large part of the unproductive time losses in sorting station operations is due to the human factor. It was determined that it is necessary to improve the current methods of standardizing the performance of railway stations (graphic modeling, systematic analysis, flowcharting) based on information technologies. For this purpose, an instrumental tool was created based on the method of algorithm theory and the Python programming language to standardize unproductive time losses in the work of the receiving park of the sorting station. As a result of the implementation of the instrumental tool in the production process, 76 minutes of time were saved in the work of the receiving park. By effectively organizing the technological process in the receiving park of the sorting station, it was possible to reduce the time spent on securing and blocking of composation from 13.2 minutes to 3 minutes, the time spent on waiting for reprocessing and reprocessing operations from 94 minutes to 64.5 minutes, and the time spent on waiting for and distributing the compositions after the reprocessing operations are completed from 94.5 minutes to 58 minutes. In addition, this mechanism creates the opportunity to rationally regulate the value of each element of the time of the wagons' stay in the receiving park, to monitor the activities of station employees online, and to start preparing for technological operations before the train arrives by obtaining advance information about the trains.

REFERENCES

[1] B. Li, S. Jiang, Y. Zhou, and H. Xuan, "Optimization of train formation plan based on technical station under railcar demand fluctuation," pp. 448-463, 2023, [Online]. Available: https://doi.org/10.1080/21681015.2023.2221699.

[2] G.I. Nesterenko, M.I. Muzykin, V.L. Horobets, and S.I. Muzykina, "Study of car traffic flow structure on arrival and departure at the marshalling yard," Bulletin Dnipropetrovsk National University of Railway Transport, vol. 61, no. 1, pp. 85-97, 2016.

[3] D. Butunov, K. Mukhammadiev, S. Abdukodirov, S. Buriyev, and M. Toxtakxodjaeva, "Improving the standardization of wagon standby time at the sorting station," in E3S Web of Conferences, vol. 549,

p. 04003, 2024, pp. 1-11, [Online]. Available: https://doi.org/10.1051/e3sconf/202454904003.

[4] R. Schönemann, "Productivity and Scheduling of Intermodal Terminals in a Railroad Network Context," in Heart 2014 Conference, 2014, pp. 1-16.

[5] W. Zhou, X. Yang, J. Qin, and L. Deng, "Optimizing the Long-Term Operating Plan of Railway Marshalling Station for Capacity Utilization Analysis," The Scientific World Journal, vol. 2014, pp. 3710-3723, 2014.

[6] M. Marinov, I. Sahin, S. Ricci, and G. Vasic-Franklin, "Railway operations, time-tabling and control," vol. 41, no. 1, pp. 59-75, May 2013.

[7] S. Jumayev, S. Khudayberganov, A. Bashirova, and M. Akhmedova, "Measures to reduce the loading of stations depending on their geoposition," in E3S Web of Conferences, vol. 371, p. 06011, 2023, [Online]. Available: https://doi.org/10.1051/e3sconf/202337106011.

[8] J. Barotov, J. Kobulov, S. Saidivaliyev, S. Sattorov, G. Fayzullayev, and A. Kibishov, "Effective organization of acceleration of local train movement at railway transport departments," in E3S Web of Conferences, vol. 515, p. 02002, 2024, [Online]. Available: https://doi.org/10.1051/e3sconf/202451502002.

[9] I.V. Demyanovich, "Principles of Lean Production for Increasing the Efficiency of Railway Transport," Transport Systems and Technologies, no. 15, pp. 45-58, 2020, [Online]. Available: https://doi.org/10.2139/ssrn.1234567.

[10] N.M. Aripov, Sh.Sh. Kamaletdinov, N.S. Tokhirov, S.K. Khudayberganov, A.M. Bashirova, and M.D. Axmedova, "Simulation modeling of train traffic based on GIS technologies," in AIP Conference Proceedings, vol. 2612, p. 060025, 2023, [Online]. Available: https://doi.org/10.1063/5.0113986.