Improvement of accident prevention measures in cases of spontaneous derailment of railway rolling stock

Aziz Yusupov*, Sunnatillo Boltaev, Sakijan Khudaybergenov, and Mafirat Toxtakxodjaeva
Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. There has been researched on railway station tracks to determine the method of automatically stopping motion content in cases where Motion Content has gone away on its own. Even today, there are mainly cases of spontaneous movement of the composition of the movement to the side where the slope of the Railway Station roads decreases. This leads to many casualties and accidents caused by the spontaneous movement of trains at railway stations. By applying the proposed method of automatically stopping the rolling stock without human intervention, the law of conservation of mechanics, and determining the number of brake shoes set by the system device, the losses that may occur in stopping the rolling stock are achieved. In addition, the features of equipping the places of automatic stopping of the rolling stock with devices in the case of rolling stock leaving by themselves on the existing railway station tracks were considered. Also, the algorithm of operation of the system for automatic stopping of the moving parts that have gone away on their own is given of this system safety to determine semi-Markov chain for based on the system a mathematical model of safety was created. Microprocessor to the system based on by itself gone the rest movement contents to stop intended automated from devices use there is a niche in the station ways account received devices without work to algorithms and trains movement speed mutually dependence provided without by itself moving gone movement units safety provide through accidents took is taken. This prevents potential accidents, increases the reliability of system use, and leads to cost-effectiveness in system use.

1 Introduction

Spontaneous derailment of rolling stock is considered a serious emergency that can lead to train accidents [1, 2]. Even now, due to the lack of knowledge of some employees and their

* Corresponding author: yusupovazitosh@gmail.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).
cold approach to their duties, in particular, due to their failure to follow the rules of locking the trains with brake pads on the station tracks, there are cases of trains moving on their own [19-21].

One of the most striking examples of such incidents was the escape of a PU2-010 electric locomotive with 23 loaded semi-wagons from the Djigaristan station of the "Uzbekkumir" JSC on December 19, 2021, to the Shtolnaya station. As a result, the PU2-010 electric locomotive at Shtolnaya station collided with 10 empty half-wagons and caused 15 half-wagons and PU2-010 electric locomotives to deviate from the railway track and overturn. As a result, the overturned electric locomotives and wagons became unusable. This caused significant economic damage to "Uzbekkumir" JSC [4, 5].

To prevent the above situations, it is necessary to develop measures to further improve the train traffic safety system on Uzbekistan's railways and a new method of solving the problems of preventing accidents in railway transport.

2 Materials and Methods

2.1 Materials

If the wagons leave the station tracks on their own, employees must perform the following tasks:

- in the case of sudden movement of wagons by the station attendant, immediately after learning about this information, using his capabilities, in the form of an emergency signal, he informs the drivers of the trains, the train dispatcher, the attendant of the adjacent station and railway crossings and other employees about it in the form of an emergency signal and notification of taking measures to stop moving wagons and rolling stock;
- the station attendant, together with the train dispatcher, takes measures to send the locomotive in the prescribed manner after the abandoned wagons or two-track railroad haul along the second track to prevent a collision when there are units of movement (locomotives, trains) at the station;
- in cases where the roads are parallel to the railway track in the presence of motor vehicles, they should immediately send a station employee in the wagon with brake pads to stop the departing wagons and prevent a collision;
- the driver of the freight train coming from the opposite direction in the station where the wagons have left by themselves, upon learning of this information, stops the train by emergency braking and takes measures to confine its contents. To take measures to stop self-moving wagons, the driver's assistant should run towards the self-moving wagons from the opposite side with the existing brake levers in the locomotive cabin and place them on the railway tracks. It is also necessary to ensure the safety of drivers and drivers' assistants. Suppose there is a passenger train in this situation. In that case, the driver of the passenger train, after stopping the train and securing the train, informs the head of the passenger train to immediately evacuate the passengers [6, 24, 25].

The railways of the CIS and foreign countries have the following technical means and safety devices to prevent accidents in the event of rolling stock rolling away on their own: protective and blocking dead ends, protective arrows, wheel lowering pins or lowering arrows, lowering spikes, as well as, shock energy damping devices.

The decision to install this or other safety devices is made based on the analysis of the profile and layout of the tracks, including the tracks of wagonrriages separated from the locomotive. [10, 16-20]

During the construction of railway stations, dead-end roads are designed to catch rolling stock when it moves on its own on station or branch roads. The dead-end tracks constructed
for this purpose are designed on the downhill side of the station, where the trains are likely to leave. The end of the dead-end roads is designed in a position that rises against the longitudinal slope of the earth layer and is blocked by a prism-shaped pillar [3, 8]. In any case, safety arrows are used to direct self-moving vehicles to the safe road. In cases where it is impossible to use protective arrows together with these additional devices, wheel derailment devices are installed [7].

"KSB" - "wheel derailment" devices. "KSB" - "wheel derailment" devices are used in Russian railways to prevent wagons from going off the tracks of Shahobcha roads and depots on their own, to the station's train receiving and dispatching tracks, to the tracks loaded with dangerous and discharged loads. There are "manual (KSB-R)" and "electric transmission (KSB-E)" types of these devices [7].

Derailment devices. "Train derailment" is used to prevent an accident in cases where trains lose control from the main cabin or when the wagons go off on their own as a result of other trains leaving the track. An example of this is "Ostragi derailment" [9].

One of the main disadvantages when using the "KSB" type "Wheel derail" and "Train derailment devices" is the large damage caused to rolling stock and railway infrastructure.

At passenger and freight terminals located at the end of dead-end railway lines, there is a risk of collisions at the end of the platform or railway line due to the inability of trains to stop on time or at sufficient intervals and to reduce their speed. When these situations occur, they can cause great damage to the lives of passengers, wagons, rolling stock, and railway infrastructure. To prevent this damage, "Impact energy dampening struts" installed at the ends of dead ends of the station are widely used in the USA and European countries [10].

The disadvantage of shock energy dampening devices is that they are expensive, and the device cannot withstand the impact in cases where the speed of the hit vehicle is higher than 25 km/h.

2.2 Methods

When wagons and moving units suddenly leave at railway stations, they can overcome the situation by means of solid road barriers. However, these measures are insufficient to eliminate the damage to wagons and moving units. It was based on the analysis that the wagons and moving units, which have suddenly left by themselves, increase their inertia speed up to the obstacle of the road and hit the obstacle, causing damage to the wagons and loads.

Based on the above, it will be possible to prevent possible losses by stopping the rolling stock on the station tracks using special devices that operate automatically without the human factor on time during the sudden movement of the rolling stock.

The proposed movement components can be solved by the method of stopping the movement components in the case of spontaneous movement (Fig. 1).
The mechanism of automatic installation of the brake shoe.

Central processor

Brake shoe

ACS-Axle counting system

Fig. 1. The way to automatically stop motion contents in case they go away on their own

In this case, it is necessary to determine the number of brake levers to stop the moving components that have moved by themselves. It is possible to develop the method of determining the number of stitches necessary to stop the motion components that have started moving by themselves, considering the physical parameters of these motion components. We determined the speed of wagons moving by themselves based on the law of conservation of energy [11-15, 22, 23].

The height between the points A and B is the speed of the wagons when approaching the stopping point \( h_{AB} \), and \( u \) is the value of the slope angle \( i \), and the length of the path \( l_{AB} \) is found by multiplying by, and the formula is expressed in the following form.

\[
V_B = \sqrt{V_A^2 + 2 \cdot g \cdot l_{AB} (i - \omega_{0}^*)}
\]  

(1)

where is: \( V \) – speed of movement of wagons, m/s; \( \omega_{0}^* \) – is the main relative resistance to movement of moving units, kgf/ts. Based on the number of axles of wagons is the composition of the movement, separate specific resistances are obtained for wagons with 4 and 8 axles. the length of the road covered by wagons, m;

As it is known, the determination of the number of stops necessary to prevent wagons from leaving by themselves on railway station tracks is mentioned in the regulatory documents. Taking into account the value of the slope of the road section given above and the value of the slope of the road section, determining the number of brake steps necessary to stop the wagons when they run away by themselves is expressed as follows using the formula of the speed of the wagon depending on the slope.

\[
K = \frac{n}{200} \cdot (k \cdot \left( \frac{V_A^2}{2gI_{AB}} + \omega_{04}^* + \omega_{08}^* + 1 \right)}
\]  

(2)

where is: \( K \) is the required amount of brake shoes;
\( n \) is the number of arrows in the composition (group);
\( \omega_{04}^*, \omega_{08}^* \) – are basic resistance to the movement of 4- and 8-axle wagons at average speed, kgs/t;
\( K \) is the coefficient used in the types and conditions (empty and loaded wagons) of wagons or units of a movement locked with brake shoes.
**Operation algorithm of the automatic stopping of moving parts in cases of spontaneous departure.** The method of automatic stopping of the movement components in the case of spontaneous movement proposed in Figure 1 above can be in one of the following two cases:

1) Information from the axle counting system is being transmitted to the central processor (wagon axles are being counted) or, conversely, if the information from the axle counting system is not being transmitted to the central processor due to a malfunction in the system, the status of the rail chains controlling the free occupancy of the road on which the rolling stock is standing will change following the status of the traffic light. If the enabling light of the traffic light is activated, in this case, the system evaluates that the wagon has not left on its own. Also, when the wagon is running on its own, it refuses to set the stop head automatically on the rail track. This means that the wagon did not move on its own, and the system automatically determines that the route is prepared for the train from the station road.

2) Data from the axle counting system is being transmitted to the central processor (wagon axles are being counted) or, conversely, if the data from the axle counting system is not being transmitted to the central processor due to a malfunction in the system, the status of the rail chains controlling the free occupancy of the road on which the rolling stock is standing does not correspond to the status of the traffic light. If the prohibiting light of the traffic light has not changed to a permissive light before the wagon moves from the station road, in this case, the system estimates that the wagon has left on its own. Also, it ensures that the stop head is automatically set on the track using a mechanism that sets the wagon on its own. This means that the wagon has moved on its own, and the system automatically determines that the route for the train has not been prepared from the station road. And the algorithm for implementing these two cases is developed in Figure 2.

Their reliability and safety when using the system of automatic stopping of moving parts in the event of their self-departure. Therefore, to ensure safety at railway stations and to increase the reliability of the operation of a special device that works automatically without human intervention during the sudden movement of rolling stock on station tracks, railway signaling centralization blocking (SCB) devices, according to the proposed method we will consider the occurrence of possible dangerous malfunctions in the process of working in integral connection with mathematical modeling.

A system of automatic stopping of moving parts in the case of self-departure. It is possible to check several transition states with a Markov chain when determining system security when implemented using [26, 27].

Application of a system of automatic stopping of moving parts in the case of self-departure. Following the procedures, it is necessary to include several cases:

- **P₀** is the system is in the set state, i.e., the system of automatically stopping the moving parts if they leave on their own, and the SCB devices are in the set state;

- **P₁** is the system is in the correct state, i.e., the system of automatically stopping the moving parts if they leave by themselves is in the correct state, but the SCB devices are in a faulty state;

- **P₂** is the system in a faulty state, i.e., automatically stopping the traffic in the event of spontaneous departure, the SCB devices are in a faulty state or a faulty state.
Does the "ACS" count the wagon axles on the track where the wagon is located?

Traffic light, ACS, transfer mechanism

Does the "ACS" count the wagon axles on the track where the wagon is located? No

Is the rail circuit free on the track where the wagon is located? No

Axles of wagons are considered

Has the enabling traffic light turned on? No

Has the enabling traffic light turned on? Yes

A route has been prepared from this station path

The route has not been set from this station path, the wagon left on its own.

Automatic start of the shoe laying mechanism

End

Fig. 2. Algorithm of the method of automatic stopping of movement components when they are left on their own
We can determine the indicators of the processes that connect several cases in accordance with the system's automatic stopping of the traffic groups in the case of self-departure. We can include the following parameters as indicators of the connecting processes, which vary depending on the speed of the movement components in the state of departure and the distance of the fixation section of the maximum length sufficient for the system to work:

- $\lambda_{01}$ is the speed of transition of signaling, centralization, and blocking devices to a malfunctioning state;
- $\mu_{10}$ is the average time it takes for signaling, centralization, and blocking devices to be restored to their normal state;
- $\lambda_{12}$ is the speed of transition of the system configuration and alarm centralization blocking devices from the faulty state to the state of system failure (the alarm centralization blocking devices are faulty or unchanged);
- $\mu_{21}$ is the average time it takes for SCB devices to recover from failure;
- $\lambda_{02}$ is the speed of transition of the system and SCB devices from the state of order to the failure state of the system and SCB devices;
- $\mu_{20}$ is the average time required to restore the system and SCB devices from a faulty state to a state of order.

A system of automatic stopping of moving parts in case of self-departure We form the Fokker-Planck (Kolmogorov) equation by solving semi-Markov process differential equations following the connections between the implementation processes using

$$\begin{align*}
\frac{dP_0(t)}{dt} &= -\lambda_{01}P_0(t) - \lambda_{02}P_0(t) + \mu_{10}P_1(t) + \mu_{20}P_2(t) \\
\frac{dP_1(t)}{dt} &= \lambda_{01}P_0(t) - \lambda_{12}P_1(t) + \mu_{21}P_2(t) - \mu_{10}P_1(t) \\
\frac{dP_2(t)}{dt} &= \lambda_{12}P_1(t) + \lambda_{02}P_0(t) - \mu_{20}P_2(t) - \mu_{21}P_2(t)
\end{align*}$$

(3)
\[ P_0(t) + P_1(t) + P_2(t) = 1 \]

where is: \( P_0, P_1, P_2 \) are probabilities of occurrence of situations 1, 2, 3.

By changing the expression of the above equation (3) into the Laplace equation, we get the following expression.

\[
\begin{align*}
    sP_0 - 1 &= -\lambda_{01}P_0 - \lambda_{02}P_0 + \mu_{10}P_1 + \mu_{20}P_2 \\
    sP_1 &= \lambda_{01}P_0 - \lambda_{12}P_1 + \mu_{21}P_2 - \mu_{10}P_1 \\
    sP_2 &= \lambda_{12}P_1 + \lambda_{02}P_0 - \mu_{20}P_2 - \mu_{21}P_2
\end{align*}
\]

(4)

That is if we change the expression of equation (4) to the Laplace table based on \( F(s) = 1 / s \rightarrow f(t) = 1 \), we get the following expression:

\[
\begin{align*}
    (\lambda_{01} + \lambda_{02})P_0 - \mu_{10}P_1 - \mu_{20}P_2 &= 1 \\
    \lambda_{01}P_0 - (\lambda_{12} + \mu_{10})P_1 + \mu_{21}P_2 &= 0 \\
    \lambda_{12}P_1 + \lambda_{02}P_0 - (\mu_{20} + \mu_{21})P_2 &= 0
\end{align*}
\]

(5)

Expression of the generated equations (5) We calculate the system of equations using the Krammer method. In the mathematical calculation of the probability of occurrence of cases in the resulting expressions, we calculate the solution of expression (6) by setting the following boundary condition \( P_i(t) | t \to \infty \):

\[
\begin{align*}
    P_0 &= \frac{(\lambda_{01} + \lambda_{02})(\mu_{20} + \mu_{21}) + \mu_{10}\lambda_{00}}{\lambda_{01} + \lambda_{02}} \\
    P_1 &= \frac{(\lambda_{01} + \lambda_{02})(\mu_{20} + \mu_{21}) - \mu_{01}\lambda_{10} - \mu_{02}\lambda_{20} - \mu_{00}\lambda_{01} - \mu_{10}\lambda_{10} - \mu_{20}\lambda_{20} - \mu_{21}\lambda_{21}}{\lambda_{01} + \lambda_{02}} \\
    P_2 &= \frac{(\lambda_{01} + \lambda_{02})(\mu_{20} + \mu_{21}) - \mu_{01}\lambda_{10} - \mu_{02}\lambda_{20} - \mu_{00}\lambda_{01} - \mu_{10}\lambda_{10} - \mu_{20}\lambda_{20} - \mu_{21}\lambda_{21}}{\lambda_{01} + \lambda_{02}}
\end{align*}
\]

(6)

3 Results

The principles of operation of braking systems for self-moving vehicles are based on manual train movement and maneuvering. With the help of the Markov diagram, we determined the safety of the system of automatic stopping of the traffic components in the case of the following states of the system: P1, P2, and P3.

NB JT TsSh 129-2003 according to safety standards for axis counting systems, the intensity of dangerous system disturbance should not exceed \( 9.2 \times 10^{-9} \) 1/h, for arrows \( 10^{-9} \) 1/h [28].

Figure 4 shows the Markov diagram of the automatic stopping system and the SCB devices in the event of spontaneous departures \(( t = 131,400 \text{ hours})\).
The results obtained from the calculation work were calculated for the time of $T=131,400$ hours, the probabilities of the safe operation of the system. For the same specified time, we will be able to determine the probabilities of the system's handling and faulty operation.

4 Discussion

A higher level of security distinguishes the proposed method from the existing stopping traffic formations. There is currently no way to stop existing animations while moving alone.

To prevent rolling stock standing on station roads from moving by itself, the railway officials will stop the rolling stock by installing brake pads. This process is wagonried out with the help of the human factor. Blocking of rolling stock on station roads is not always wagonried out according to the instructions; that is, due to the irresponsibility of workers, accidents occur due to the rolling stock moving down the slope of the road.

Currently, to reduce the manual labor in locking the rolling stock, there are mechanical devices for the planned locking by the station attendant. Considering that this type of device implements the scheduled stopping of rolling stock and that the devices are installed between the tracks of each station with a slope, this leads to an increase in economic costs.

Considering that the proposed method is unplanned, that is when a sudden situation occurs. Without the human factor, the station's traffic content is suspended on tupik roads; we can see that this method is reliable and cost-effective compared to the existing methods.
5 Conclusion

Drawing conclusions from foreign experiences on methods of preventing accidents in cases of self-derailment of rolling stock, it was determined that there is a need to develop guidelines for the "Procedure of cooperative behavior of employees in cases of self-departure of rolling stock" in the conditions of the railways of Uzbekistan.

In situations where trains lose control from the main cabin or when wagons run off on their own and run into the path of other trains, using the devices analyzed above to prevent an accident can cause huge damage to the rolling stock and the railway infrastructure, and the cost of the devices exceeds the operating costs that are considered to lead to an increase.

Concluding the above, the algorithm of operation of the system, which works automatically without the human factor, was developed during the sudden movement of rolling stock on station roads. To determine the safety of this system, a mathematical model of system safety was created based on the semi-Markov chain. Mathematical calculations were also wagonried out, and results were obtained. The obtained results showed the safe operation of the automatic stopping system when the proposed movement of the contents leaves by itself.

Acknowledgments

The authors express their gratitude to the joint-stock company "Uzbekistan Railways" and the scientific research department of the Tashkent State Transport University for the opportunities created in conducting scientific research and the provided information.

References


