Effective organization of technologies for speeding up freight transportation in railway transport

Jamshid Qobulov¹*, Jamshid Barotov¹

¹Tashkent State Transport University, 100167 Tashkent, Uzbekistan

Abstract. The modern measures necessary to elucidate the stopping of cars during the delivery of cargo have been analyzed the regulatory and legal framework for the delivery of goods by rail. A mathematical model was developed for the relationship between the daily run of wagon consignments and the distance of transportation on the basis of drawing up a technological scheme that takes into account the entire sequence of operations performed with wagons along the route. This made it possible to determine the impact of the delivery of goods "just in time" on operational standards, taking into account the features of technological processes of railway transport. The authors have developed a formula for determining the total number of operations from the train station to the specified stations, as well as the scheme of calculation of railway carriages from the waggages to the designated station.

1 Introduction

One of the factors that has a great influence on the country's economy in the performance of the transportation agreement concluded between the shipper in rail transport is the timely provision of transportation services at a high level. One of the main requirements imposed on railway transport by the shipper and the load receiver when providing Transport services is to deliver the goods to the destination specified in its term.

According to the legislation to calculate the delivery time of goods, the main thing is that there are two different methods [1-5]:

– rules for the transportation of goods by rail (when transporting domestic goods).
– agreement on cargo transportation on international flights by rail (IFTA).

The terms of delivery of goods include the time of shipment and reception of goods, the time of arrival of goods and the time of realization of additional actions established on the road trip, as well as the time that allows you to extend the delivery period, taking into account which the circumstances provided for by the railway Charter of the Republic of Uzbekistan. It is considered that the cargo is delivered at the time of the stop of importation of cars for unloading due to employment of the unloading front or other reasons that depend on the

*Corresponding author: jam.uzb@mail.ru

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recipient of the cargo, if the cargo is arrived at the specified railway station later than the specified delivery period (Article 63 of the railway Charter of the Republic of Uzbekistan).

The railway will be responsible for the delay in the delivery of an empty car under the jurisdiction of the organization and individuals or which they rent. In accordance with paragraph 128 of the railway Charter of the Republic of Uzbekistan “the railway pays a fine to the client for the delay in the delivery of the cargo” if the delay does not prove that is not his fault [2].

In modern conditions, more attention is paid to the implementation of issues of non-timely delivery of goods by rail transport with the help of appropriate control technologies. However, in violation of technological norms in the fulfillment of the delivery period, these measures may not give the expected result. In this case, it is advisable to identify the main reasons for the delay of goods along the way, develop measures to eliminate them by improving the norms of the method for determining the delivery time of goods and the technology of the transportation process.

In this article, a clear routing of the calculation period for the delivery of cargo is provided in the method we offer. This developed a mathematical methodology for ensuring the execution of the operations performed at the station [1,3,5].

The initial formula for the perception of operations performed at the station and the sections when delivering cargo:

$$
egin{align*}
T_{sh.} + \left[ \left( \frac{L_{d_i}}{v_{v_i}} \right) / 24 \right] + t_o & \leq T \\
T_{sh.} + \left[ \left( t_{v_i-d_i} + t_{s_i-d_i} \right) / 24 \right] + t_o & \leq T
\end{align*}
$$

where: $T$ - shipping time, daily;
$t_{sh.}$ - time spend on the shipment of cars from the station, daily;
$t_{v_i-d_i}$ - time, hours spend on the operations performed at the station;
$t_{s_i-d_i}$ - time, hours spend on the movement of the station train;
$L_{d_i}$ - shipping distance by rail transport, km;
$v_{v_i}$ - daily movement speed of the car, km / h;
$t_o$ - for additional operations, daily.

In this case, according to the delivery time of the cargo, $T$ is deterhoured mainly by the day. The period of delivery of goods is carried out in the case of $2 \leq T$. In this $2 > T$ case, the delivery time of the cargo is considered unfulfilled. The value of $T$ is calculated as belonging to the whole number $TCZ\{2,3,4,\ldots\}$.

According to the regulations of the Republic of Uzbekistan on railway transport, the stages of their movement along the road can be implemented as follows. When calculating today's cargo delivery, the daily speed is deterhoured based only on statistical data. There is a need to study each operation separately in order to identify the defects during the delivery
of goods. When calculating the delivery time of goods, it is done depending on the types of shipment. These include car, small, container, grouped and routed shipment.[2, 8, 10-13].

In accordance with paragraph 40 of the charter, cargo transportation is accepted at a high speed (freight speed) and with an increased tariffs payment (high speed). The shipping speed is deterhoured by the carrier in the shipping letter.

Designing the movement of trains according to the route consists in developing new methods according to today's technological processes. In this case, it is necessary to improve the duration of the processes from the start of the train to the last situation.

\[
t_{v_i-d_j} + t_{s_j-d_j} = \sum_{i=1}^{i=n} t_{s.tекс_i} + \sum_{j=1}^{j=m} t_{уч_j}
\]

Here \(\sum_{i=1}^{i=n} t_{s.tекс_i}\) - the time of technological processes performed at the station is deterhoured from \(i\) to \(n\), \(\sum_{j=1}^{j=m} t_{уч_j}\) - the time of movement of the train on the section is deterhoured from \(j\) to \(m\).

Since the principle of perforhourg the operations performed at the station is the same, but the performed technological processes are different types of cargo shipment, \(t_{s.tекс_i}\) is developed separately by shipment types.

The total time spent on processing cars (\(t_{прот}\)), and the time of idle waiting (\(t_{wa}\)), can be deterhoured by the following expression:

\[
t_{прот} = (t_{рo.pre} + t_{tr.re} + t_{sec.fen} + t_{unc/coup} + t_{rec} + t_{сор} +
+ t_{bac} + t_{acc} + t_{re.com} + t_{des} + t_{br.dev} + t_{dep}) / 60, \text{hour}
\]

where: \(t_{рo.pre}\) - is the route preparation, hour; \(t_{tr.re}\) is the train reception, hour; \(t_{sec.fen}\) - is the securing and fencing the train in the reception yard, hour; \(t_{unc/coup}\) - is the time of uncoupling and coupling of the locomotive to the train, hour; \(t_{rec}\) - are the technical and commercial inspections of cars in the receiving and dispatching depot, hour; \(t_{сор}\) - is the sorting of the received train, hour; \(t_{bac}\) -is the backing of cars, hour; \(t_{acc}\) - is the accumulation of cars, hour; \(t_{re.com}\) - is the rearrangement of the train to the departure yard after the end of its composition, hour; \(t_{br.dev}\) - is the check of braking devices, hour; \(t_{dep}\) - is the train departure, hour.

\[
t_{wa} = (t_{рo.pre} + t_{tr.re} + t_{rec} + t_{сор} + t_{acc} + t_{re.com} +
+ t_{des} + t_{loc} + t_{dep}) / 60, \text{hour}
\]
where: $t_{\text{ro,pre}}^\text{wa}$ - is the waiting time for route preparation, hour; $t_{\text{tr,ret}}^\text{wa}$ - is the waiting time for the train upon arrival, hour; $t_{\text{tec,com}}^\text{wa}$, $t_{\text{des,com}}^\text{wa}$ - are the waiting times for technical and commercial inspection in the receiving and dispatching yard, hour; $t_{\text{sor}}^\text{wa}$, $t_{\text{cop}}^\text{wa}$ - is the waiting time for the classification of wagons of the train arrived at the marshaling yard, hour; $t_{\text{ace}}^\text{wa}$ - is the waiting time for the accumulation of trains at the marshaling yard, hour; $t_{\text{re,com}}^\text{wa}$ - is the waiting time for the train rearrangement in the departure yard, hour; $t_{\text{loc}}^\text{wa}$ - is the waiting time for a locomotive to be hitched to the train, hour; $t_{\text{dep}}^\text{wa}$ - is the waiting time for train departure, hour.

The total time spent for processing cars at technical stations is [1, 14-16]:

$$\sum t_{\text{pro}} = t_{\text{pro}} + t_{\text{pro}}^{\text{wa}}, \text{hour} \quad (5)$$

The total time spent for the processing of cars at technical stations is determined by formula (3). If a car is processed at several technical stations, the total time is

$$\sum_{i=1}^{n} (\sum t_{\text{pro}})_{i}.$$ .

Time spent on technical processes with wagons without processing $\sum t_{\text{wit,pro}}$ is:

$$\sum t_{\text{wit,pro}} = (t_{\text{ro,pre}} + t_{\text{tr,ret}} + t_{\text{sec,km}}^\text{wa} + t_{\text{tec,com}}^\text{wa} + t_{\text{loc}}^\text{wa} +$$

$$+ t_{\text{br,dev}} + t_{\text{dep}}^\text{wa} + t_{\text{dep}}^\text{wa}) / 60, \text{hour} \quad (6)$$

where: $t_{\text{ro,pre}}$ - is the preparation of the route to the transit yard, hour; $t_{\text{tr,ret}}$ - is the train reception, hour; $t_{\text{sec,km}}$ - is the securing and fencing the train in the transit yard, hour; $t_{\text{tec,com}}$ - is the technical and commercial inspection of cars in the transit yard, hour; $t_{\text{loc}}^\text{wa}$ - is the waiting time for locomotive, hour; $t_{\text{br,dev}}$ - is the time to check the braking devices of the train, hour; $t_{\text{dep}}^\text{wa}$ - is the waiting time for the train to depart from the transit yard, hour [1, 7, 8].

The total time spent on technological operations for cars without processing at each technological station is

$$\sum_{i=1}^{m} \left( \sum t_{\text{wit,pro}} \right)_{i}.$$ .

This article examines the time spent on technological operations at the station and the time spent on site hikes until the freight wagons are loaded at the technical stations and reached the cargo location after the train is shipped.

After the departure of the train station, we determine the time of movement of the train from the station by the following formula:
\[ t_{\text{distance}} = \frac{L_{\text{distance}}}{v_{\text{distance}}} \text{, hour} \]  

\( L_{\text{distance}} \) - distance between technical stations, km;

\( v_{\text{distance}} \) - speed of the train on the track, km/hour.

The time taken to receive the train at the technical station along the route is deterhoured by the following formula:

\[ t_{\text{receive}} = t_{\text{prepara.route}} + t_{\text{train.receipt}} + t_{\text{fixing.content}} + t_{\text{disp.locom}} \text{, hour} \]  

where is:  
- \( t_{\text{prepara.route}} \) - preparation of the train route, hour;
- \( t_{\text{train.receipt}} \) - train receipt, hour;
- \( t_{\text{fixing.content}} \) - fixing content, hour;
- \( t_{\text{disp.locom}} \) - displacement from the locomotive, hour.

After the train is accepted, the wagons are technically and commercially inspected (\( t_{\text{wag.str}} \)). The time spent for technical and commercial inspection is calculated by using the following formula [5]:

\[ t_{\text{wag.str}} = t_{\text{technic}} \left( \frac{\tau \cdot m_c}{x} \cdot 60 \right) + \alpha \text{, hour} \]  

where:
- \( \tau \) - average time of a technical inspection of a wagon, (\( \tau = 0.014-0.016 \));
- \( m_c \) - the number of wagons in train, wagon;
- \( x \) - the number of employees in the brigade of technical inspection;
- \( \alpha \) - time spent for additional operations, hour.

We consider the factors that influence the wagons' stall during the train process at the technical stations.

In the carriageway selection, sorting is carried out by shunting locomotives. From the time in the way of content distribution is deterhoured using the following formula:

\[ t_{\text{distribution}} = T_{\text{sorting}} + T_{\text{stopping}} \text{, hour} \]  

where:
- \( T_{\text{sorting}} \) - wagons sorting time, hour;
- \( T_{\text{stopping}} \) - wagons stopping time, hour.

The formula for deterhouring the time spent on technological operations in the classification of wagons on the road to cessation is as follows [2,6]:

\[ T_{\text{sorting}} = A \cdot q_o + B \cdot m_c \text{, hour} \]  

where: \( A \) and \( B \cdot \) - normal coefficients within hourutes.
\(m_c\) – number of wagons in structure;
\(q_o\) – the number of average connections when the contents are reached.

In this case, A and B are manufactured depending on the number (no) of operations on disconnecting wagons. In order to reduce the distance between the wagons, the extra time spent on concentration is deterhoured by the following formula [1, 6-8]:

\[T_{\text{stopping}} = 0,06m_c, \text{ hour} \]  

(12)

here: 0,06 – coefficient used for consolidation of one wagon, hour;
When collecting wagons on one track or discontinuance of concentration on the path of sediment, the normal time is deterhoured by the following formula:

\[t_{\text{path.sediment}} = T_{\text{nt}} + T_{\text{ho}} \text{, hour} \]

(13)

here: \(T_{\text{nt}}\) – the technological time associated with the operation of wagons on the sidewalk. This technological time is in accordance with the technical regulations (PTE). Operations related to the carriage of wagons in accordance with the rules of technical use are as follows: correction of carriages by 100 mm or more, longitudinal lifting of wagons. \(T_{\text{nt}}\) is deterhoured by the following formula:

\[T_{\text{nt}} = B + E \cdot m_c, \text{ hour} \]

(14)

here: \(V\) and \(E\) - when designing the content depends on the average number of connection operations on one wagon, norms of coefficients,
\(T_{\text{removing}}\) – removing the distance between the carriageways on the sidewalk paths by the sedimentation path:

\[T_{\text{removing}} = 0,04 \cdot m_c, \text{ hour} \]

(15)

here: 0,06 – calculation of the cost of spending one wagon.
Once the formation is complete, we define the technological time of transfer to the content wagon's pickup fleet by the following formula:

\[t_{\text{transfer}} = A_{\text{transfer}} + B_{\text{transfer}} \cdot m_{\text{transfer}}, \text{ hour} \]

(16)

here: \(A_{\text{transfer}}, B_{\text{transfer}}\) - normative coefficients. Carriages and the transfer of all semi-arc A and B standard can be defined as the total of the road,

\[A_{\text{transfer}} = \sum a, B_{\text{transfer}} = \sum b; \]

\(m_{\text{transfer}}\) Average number of wagons in transmitted content.
When designing the content of the sorting park, the content is transmitted through the shunting locomotive.
When dispatching trains, the following parameters should be taken into account [4, 9]:

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https://doi.org/10.1051/e3sconf/202338905042
\[ t_{\text{dispatching trains}} = t_{\text{locomotive waiting}} + t_{\text{chec.tra.bra}} + t_{\text{send.train}} + t_{\text{dispatch}}, \text{ hour} \] (17)

Here is \( t_{\text{locomotive waiting}} \) - train locomotives waiting time, hour;
\( t_{\text{chec.tra.bra}} \) - time of checking of train brake equipment, hour;
\( t_{\text{send.train}} \) - to send a train of standby time, hour;
\( t_{\text{dispatch}} \) - the dispatch time of train, hour.

At the technical station it is recommended to specify the general duration of the trains being processed through the following formula:

Total time of technological operations on acceptance and departure of trains at the site station, hour:

\[
 t_{\text{st.dis}} = \left( t_{\text{receive}} + t_{\text{wag.str technic}} + t_{\text{distribution}} + t_{\text{path.sediment}} + t_{\text{transfer}} + t_{\text{wag.str technic}} + t_{\text{dispatching trains}} \right), \text{ hour} \] (18)

Thus, the total time of the technological process, which takes place at the time of the train travel to each site and the station, can be summarized by the following formula:

\[
\sum t_{\text{distance}} = t_{\text{distance}}^1 + t_{\text{distance}}^2 + \ldots + t_{\text{distance}}^n
\]

\[
\sum t_{\text{st}} = t_{\text{st}}^1 + t_{\text{st}}^2 + \ldots + t_{\text{st}}^n
\] (19)

The total time spent until the shipment from the station to the destination station is specified, that is, \( (\sum t_{\text{distance}} + \sum t_{\text{st}}) \). The distance between the sender and the receiver stations \( L_{\text{load}} \) km, the speed of the load according to the Shipping Procedure \( v_{\text{twenty}} \) km a day, will be \( t_{\text{twenty}} = \frac{L_{\text{load}}}{v_{\text{twenty}}} \) [2, 10].

Currently, cargo, adopted to ensure the terms of delivery of cargo to send not later than the date of receipt or the next day; reducing stopping of wagons in technical and freight stations; increase the speed of train movement; it is necessary to pay special attention to the improvement of interaction of railway transport with other types of carriages in cargo transportation, as well as other technological processes within the established timeframe [1].

These factors, which negatively affect shunk operations in the stations, include the delay of stationed wagons on stationary and station routes, maintenance after the technical and commercial inspection of the wagons, the timely implementation of trains at stations, is generally locomotive deficiencies in the plot [2,3].

This article exahoures the time spent on technological operations at the station and the time spent on site hikes until the freight wagons are loaded at the technical stations and reached the cargo location after the train is shipped.
After the departure of the train station, we deterhour the time of movement of the train from the station by the following formula:

The effectiveness of using the developed method for deterhouring the time spent on technological operations at stations and the time of delivery of goods consists in:

- accurate forecasting of the delivery time to JSC "UTY" and, as a result, the reduction of costs to pay a fine to customers for delayed goods delivery;
- sufficient accuracy in calculating the tihour of cargo delivery, taking into account the features of technological processes performed at stations operated by railway transport, and an account for the technological capabilities of the transportation process in railway infrastructure. This will allow deterhouring and planning the amount of work to be performed at each station;
- correct forecasting of cargo delivery times, which will reduce unproductive time losses during operation at the station and develop rational action plans. This, in turn, will improve the working conditions of the service personnel and ensure their safety.

As a result of the application of recommendations aimed at improving the technology of organizing freight transportation, taking into account the delivery time by rail, the economic efficiency was estimated at 429 million soums by reducing fines associated with delayed delivery of goods to customers.

The implementation of research results into practice will lead to further improvement of the quality of transport services provided to consigners, increase the attractiveness of rail transport, efficient use of wagons and increase the competitiveness of rail transport.

2 Conclusions

The method of accounting for the time spent on waiting between technological operations performed with wagons along the route was optimized in calculating the time of delivery of goods by rail. This method makes it possible to timely and reasonably develop an action plan to prevent deviations from the standardized time to perform technological operations with trains at stations. A model was developed for calculating the delivery time of goods based on the methods of algebraic filler and hourors to correctly deterhour the time spent en route by a loaded wagon. This allowed predicting (with sufficient accuracy, at the stage of planning) the time of arrival of a loaded wagon at the station to unload goods. A mathematical model was developed for the relationship between the daily run of wagon consignments and the distance of transportation on the basis of drawing up a technological scheme that takes into account the entire sequence of operations performed with wagons along the route. This made it possible to deterhour the impact of the delivery of goods "just in time" on operational standards, taking into account the features of technological processes of railway transport.

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