Improving Cargo Traffic in the International Transport Corridors of the Far East

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Abstract. This research seeks to mitigate the consequences of ‘abandoned’ trains and to improve the accuracy of cargo ETA for seaport stations. It investigates the reasons why trains are abandoned and defines a procedure for bringing them back into traffic. The proposed method helps avoid uncoordinated train and ship arrivals for more accurate ETA.

1. Statement of problem
The international transport corridors in the Far East are the single most important tool for Russia as a transit country. Development of international transport corridors in the Far East gives Asia-Pacific countries a short route to the Primorye ports, which helps shorten the cargo transportation time and optimize the logistics.

However, transport infrastructure poses limitations that hinder such development and effectively prevent any increase in exports. Seaport stations are no match to the actual capacities of rail and maritime transport. Meanwhile, any bottleneck en route delays delivery, compromises performance, and carries extra costs. The lackluster capacity of seaports has to be compensated by using railway cars as ‘warehouses on wheels’. Any train that is not in traffic (referred to herein as ‘abandoned’ train) will negatively affect both the railways and the ports.

When strategizing upon the infrastructural development of international transport corridors, the railway-seaport interface is not to be ignored. Lack of systematic approach to the cooperation and coordination of ports, freight companies, shipowners, stevedores, and carriers contribute to the train ‘abandonment’.

2. State of the art
Researchers across different schools and fields of science have tried to simulate the efficient operation and development of transport systems. Their efforts produced numerous methods that can handle a variety of problems pertaining to transport systems. Some publications also dwell upon the train abandonment issues: reasons of, and extra costs incurred due to, delaying trains that carry exported cargo to the port.

3. Statement of Problem
This research seeks to mitigate the consequences of ‘abandoned’ trains and to improve the accuracy of cargo ETA for seaport stations. The goal determines the objectives:

- to study the reasons why trains are abandoned;
- to set forth a procedure for bringing trains back into traffic
4. Research Materials and Results

Analysis of 2017–2018 data suggests that for the Far Eastern Railway, 66% of the ‘abandoned’ trains carry coal [1-9].

Why are trains abandoned?
1. Cars with frozen coal idle;
2. shipped coal is non-frozen;
3. inspection upon loading is insufficient;
4. cars lack heating.

2. Failure to reload as planned:
1. insufficient transshipment capacity;
2. lack of free warehousing space;
3. ship non-arrival.

3. Inconsistent arrivals;
4. Uncoordinated ship and train arrivals;
5. Technical failures;
6. Force majeure (winds and storms).

Factorial analysis identifies the distribution of reasons for abandonment: uncoordinated ship and train arrivals (55%); uncoordinated route schedules (15%); failure to reload as planned (14%); cars with frozen coal idle (7%); equipment failures (6%), and force majeure (3%). Thus, addressing the uncoordinated ship and train arrivals will considerably reduce the abandonment rates.

In order to enable regular and consistent delivery of bulk cargo as needed and when needed, we herein propose a transition from ‘pushing’ to ‘pulling’ in organizing the transports. The supply chain from the offloading station to the loading station must be cohesive and coherent; dispatching should be based on the status the destination reports to the point of origin.

This paper defines the key features of a seaport railway station that affect its capacity ($N_{per.}$):

$$N_{per.} = f(N_{pr.p} ; N_{tsl.fr} ; L_{tsl.fr} ; n_{marir} ; m_{pod} ; n_{texn.lin} ; t_{vag} ; Q ; K)$$ (1)

where
- $N_{pr.p}$ is the number of quay tracks;
- $N_{tsl.fr}$ is the number of rear tracks;
- $L_{tsl.fr}$ is the length of rear tracks, $m$;
- $n_{marir}$ is the number of cars per route;
- $m_{pod}$ is the number of dispatches per route;
- $n_{texn.lin}$ is the number of process lines;
- $t_{vag}$ is the time to handle a single car, $h$;
- $Q$ is the cargo turnover, million tons per annum;
- $K$ is the cargo item list (number of coal grades).

In turn, the number of quay tracks depends on the number of berths ($n_{pr.x}$); the number of directly handled ships ($n_{tsl.fr}^{vag}$); the design cycle of process lines ($n_{texn.lin}^{vag}$):

$$N_{pr.p} = f(n_{pr.x} ; n_{texn.lin} ; n_{tsl.fr}^{vag}) \geq 2$$ (2)

$$opt(N_{pr.p}) \geq 2$$ (3)

$$n_{texn.lin} = f(Q)$$ (4)

The number of rear tracks ($N_{tsl.fr}$) is found as follows:

$$N_{tsl.fr} = f(n_{marir} ; m_{pod})$$ (5)

$$m_{pod} = f(Q_{lok} ; L_{tsl.fr})$$ (6)
opt(m_{pod}) \leq 4 \tag{7}

where Q_{lok} is the estimated weight of received cargo, tons.

Analysis of transshipment capacities of Far Eastern ports and shipper terminals shows that these parameters do not match the carrying capacity of rail transport. This is why the procedure and timing of bringing an ‘abandoned’ train to a seaport station is important.

The paper proposes a method for scheduling such arrivals at offloading stations, which is based on finding when cargo operations are to be complete so as to schedule the arrival of a train carrying matching cargo appropriately.

Pursuant to the queueing theory, the seaport station and adjacent site can be represented as a channel-buffer-channel system, see Figure 1. The site receives the flow U at rate \( \lambda \). As the cargo is transported on the site, the limited buffer capacity causes the flow rate to change to \( \lambda_1 \), which produces an order queue \( U_1 \), which is a sequence of orders queued for buffering. Some part of the flow \( U_1 \) goes directly to the buffer. The seaport station provides buffering and adjusts the flow rate to coordinate the channel \( p_2 \).

If \( t_{opt} \) equals the time to reload cargo from a train to a ship, the processing rate of the channel \( p_2 \) is:

\[
\mu_{p_2} = \frac{1}{t_{opt}} \tag{8}
\]

Normalized processing rate of the channel \( p_2 \) is:

\[
\psi_{p_2} = \frac{\lambda_2}{\mu_{p_2}} \tag{9}
\]

Then, the mean number of orders in the buffer and that of those queued in the channel \( p_2 \) \( (L_{nak}) \), as well as the mean duration of stay in the buffer \( (T_{nak}) \) can be found as follows:

\[
L_{nak} = \frac{\psi_{p_2}^2}{(1 - \psi_{p_2})} \tag{10}
\]

\[
T_{nak} = \frac{\psi_{p_2}}{\mu \cdot (1 - \psi_{p_2})} \tag{11}
\]
If the flow $U$ exceeds the capacity of the buffer $C_{nak}$, some part of the flow $U_1 = C_{nak} - L_{nak}$ goes to the buffer, while the remainder $U_2 = U - U_1$ is queued in the channel $p_1$ until the buffer is free. Time to free up the buffer can be found by the formula 11. The time the buffer receives the flow $U_2$ in full or in part ($T_{pod}$) is found as follows:

$$T_{pod} = T_{nak} + t_{podv.lok}^{of} + t_{prosled}.$$  

(12)

where $t_{podv.lok}^{of}$ is time to locomotive arrival;

$t_{prosled}$ is the time to proceed from the site to the seaport station.

If $T_{plan}^{gr}$ is the ETC for the completion of cargo handling, then the cargo ETA adjusted to enable continuous station-based operation ($T_p$) is as follows:

$$T_p = T_{pod} - T_{plan}^{gr}.$$  

(13)

When planning the arrival of abandoned trains, consider:

- Losses of car-hours due to early arrival;
- Losses due to the downtime of handling mechanisms;
- Losses due to ship downtime;
- Losses due to abandoned trains wasting the infrastructural and maintenance resources.

For the assessment criterion, this research uses a minimum total cost of car idling from arrival at the offloading station to dispatching for cargo loading ($P_{vag}$), the downtime of handling mechanisms ($P_{pvm}$), and the ship downtime ($P_c$):

$$\sum_{i=1}^{n} P_{vag}^i + \sum_{j=1}^{n} P_{pvm}^j + \sum_{k=1}^{n} P_c^k \rightarrow \min$$

Abandonment is not and will not be fully avoidable, not in the nearest future. However, the proposed method helps avoid uncoordinated train and ship arrivals for more accurate ETA.

5. Conclusions

1. Analysis of transshipment capacities of Far Eastern ports and shipper terminals shows that these parameters do not match the carrying capacity of rail transport; meanwhile, such match is absolutely necessary for optimal transportation.

2. This paper finds that lack of ship-train coordination, insufficient port capacity, and other factors there is numerous ‘abandoned’ trains at the port approaches.

3. Factorial analysis identifies the distribution of reasons for abandonment: uncoordinated ship and train arrivals (55%); uncoordinated route schedules (15%); failure to reload as planned (14%); cars with frozen coal idle (7%); equipment failures (6%), and force majeure (3%).

4. Analysis of transshipment capacities of Far Eastern ports and shipper terminals shows that these parameters do not match the carrying capacity of rail transport.

5. The paper proposes a method for scheduling such arrivals at offloading stations, which is based on finding when cargo operations are to be complete so as to schedule the arrival of a train carrying matching cargo appropriately; this method will minimize total cost of car idling from arrival at the offloading station to dispatching for cargo loading, the downtime of handling mechanisms, and the ship downtime:

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