Driving Heavy Trains on the Kuzbass to Far East Route

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Abstract. This paper examines a railroad system intended for heavy trains; it dwells upon how the freight traffic is expected to evolve by 2030. This paper results research into specific conditions for heavy haul on the Kuzbass to Far East route and wells upon optimizing such haul on specific legs of the route.

1. Introduction
In early 1983, Dr. William J. Harris, then Vice President for Research of the Association of American Railroads, invited participants of the 1982 conference to Washington to discuss establishing a permanent regulatory body. In summer 1983, railroad officials from Australia, Canada, China, South Africa, and United States founded the International Heavy Haul Association (IHHA).

In 1994, Russian Railways joined the Association. Later, Norway’s and Sweden’s railways, both members of the Nordic Heavy Haul Association, joined the IHHA.

Advancements in heavy haul thanks to efforts of professionals from a variety of fields is reviewed by William J. Harris (USA), James Lundgren (USA), Harry Tournay (South Africa), and Willem Ebersöhn (South Africa). [15, 17, 21]

Brian G. Bock defines heavy haul as arrangement of freight train operations, which trains are heavy, long, and carry large axial load. [25]

Russia began developing this technology in the mid-1980s when it required greater capacity while the freight load on the trunklines reached 100 to 120 million tons.

One specific feature was that the technology used the existing tracks that carried both passenger and freight traffic.

In-depth studies were carried out to analyze the interaction of tracks and rolling stock, brakes, distributed traction, critical weight of trains, coefficients of traction, and other issues. A pilot 42-thousand ton train ran on a leg of the Trans-Siberian Railway at that time. [7]

As of today, Russian Railways operate 6-thousand ton trains. Trains of 6 to 18 thousand tons are planned for launching by 2030 to transport ore, coal, and oil. Comprehensive studies are on the way to increase axial load to 30 tons for specific railroads in Russia. [13,14]
2. Research methods

Heavy haul solutions use mathematical statistics, mathematical modeling, statistics collection methods, and state-of-the-art risk management science.

3. Research essentials

Today, OAO RZD is facing intensive growth of freight traffic towards ports, border crossings, and major industrial facilities in the Far East. This is due to a number of external economic factors and market situation. Russia’s economy makes heavy use of raw materials; this and the global crisis have forced industrialists to search for new markets—those that are accessible by the East-West international transport corridor backed by railways and Pacific ports, including those on the route under consideration. Increasing the weight capacity of freight trains is a priority, as it can make railways perform better in the current market situation.

Freight traffic is projected to grow significantly at approaches to ports in Primorsky Krai, as it is expected to reach 144.9 million tkm/km by 2020 and 159.5 million by 2025. [4]

Figure 1 shows the distribution of freight traffic by cargo categories.

![Figure 1. Distribution of cargo by type in 2020 and 2025.](image)

A significant increase in traffic will mean some legs of the Trans-Siberian Railway (East-Siberian and Far-Eastern railroads) will lack capacity. [6] Besides, this will also alter the loads on all legs of the route. The structure of freight traffic towards the NV station is clearly dominated by coal.

The Kuzbass to Far East route uses the Trans-Siberian Railway. Its 6,298 km long exclusive of branches. The route goes via stations of five railroads in Russia. This is entirely a dual-track route equipped with state-of-the-art IT and communications, see Figure 2.
Innovative gondolas can be assembled into coal trains of up to 7,100 tons. [5]

Coal routes follow the Trans-Siberian Railway from Kuzbass stations of the West-Siberian Railway towards ports in Primorsky Krai. Figure 3 shows the distribution of weight on this route.

Figure 2. Kuzbass to Far East route.

4. Results

This route has more than 20 limited-capacity legs where freight trains are pushed; 70% of these legs are electrified.

Heavy trains are mainly driven by 4ЭС5К or х2ЭС5К СМЕТ locomotives (2ЭС5К, which is an electric multiple unit).

There are notable organizational difficulties and problems that could be solved in favor of heavy haul under specific circumstances.

To that end, consider how the electric locomotive parameters correlate with the operating capacity. The performance of a locomotive is defined as the gross cargo turnover divided by the size of locomotive fleet. [1]

\[ W_l = \sum \frac{p_l}{M_p}. \]

Annual cargo turnover is defined as: [1]

\[ \sum p_l = 365 \cdot W_l \cdot M_p. \]
However, the performance of a locomotive can also be found from the leg-specific speed and the daily runtime by the formula: [1]
\[ W_i = Q_{hr} \cdot V_{ych} \cdot T_{sys} \]

For electric locomotives that have a specified design performance, the required turnover can be attained by:
1. increasing the train weight, which will proportionately decrease the leg-specific speed,
2. increasing the leg-specific speed, which will proportionately decrease the weight

When trying to cut cargo transport costs, the question arises whether speed or weight is a higher priority. [2]

The performance of an electric locomotives is proportional to the power of its traction engines. Increasing the weight of a train driven by a single electric locomotive increases the traction coefficient and the traction force. Partial infrastructure upgrades might be required. Going beyond 8 thousand tones (a >50% increase) will require considerable infrastructural upgrades.

If such trains end up being slower than normal trains, the leg-specific capacity will drop.

Stations on the route have sufficient receiving and departure tracks at 1,050 m or more in length. Some stations, however, lack tracks that could contain 71 conventional cars or more.

Standard freight train weight is 6,000 to 6,300 or 7,100 tons, which matches the length-based capacity of tracks on the route. A train comprising innovative cars, each carrying 75.5 tons, will weigh 7,100 tons; a train of the existing rolling stock will weight 6,000 to 6,300 tons.

Container transport is expected to grow. Imported goods shipped from Far Eastern ports make up for a significant portion of the traffic. For container trains, the standard weight is 3,000 tons in either direction.

How many trains are needed can be found by the formula: [2]
\[ N_{gr}^{orp} = \frac{10^6 \cdot \sum G_{grp} \cdot K_p}{365 \cdot Q_{neto}^{grp}} \]

For number of required trains as a function of heavy train proportion, see Figure 4.
Figures 5, 6, 7 show the required number of freight trains as a function of heavy-train weight (7,100, 8,300, and 9,100, respectively), as well as their proportion in the total freight train traffic.

**Figure 5.** Required number of freight trains as a function of heavy-train weight (7,100) and their proportion in the total freight train traffic.

**Figure 6.** Required number of freight trains as a function of heavy-train weight (8,300) and their proportion in the total freight train traffic.
Figure 7. Required number of freight trains as a function of heavy-train weight (9,100) and their proportion in the total freight train traffic.

Table 1 presents the calculated required capacity for Trans-Siberian Railway legs in 2020 and 2025 given that its traffic includes passenger trains.

**Table 1.** Required capacity of Trans-Siberian Railway legs in 2020 and 2025.

| Leg name                     | Required capacity, pairs of trains per day |
|------------------------------|--------------------------------------------|
|                              | 2020 | 2025 |
| East-Siberian Railroad      | 104  | 118  |
| Trans-Baikal Railroad       | 99   | 111  |
| Far-Eastern Railroad        | 115  | 135  |
| Incl. Ugl to Sm              | 66   | 91   |
| Kzn to NV                    | 35   | 41   |

Capacity utilization rate is the criterion, by which the permissible line load is determined. Table 2 shows these values in the context of comprehensive optimization of operations on the Kuzbass to Far East route.

**Table 2.** Capacity utilization rate.

| Leg name         | Capacity utilization rate |
|------------------|---------------------------|
|                  | 2020 | 2025 |
| East-Siberian Railroad | 1.05 | 0.98 |
| Trans-Baikal Railroad     | 1.21 | 1.15 |
| Far-Eastern Railroad      | 1.38 | 1.14 |
| Kh2 to Usk                | 1.43 | -1.16 |
Checking the station capacity on the route showed stations did not have a margin of capacity during ‘rush hours’, a situation exacerbated by seasonally uneven distribution of traffic and railroad maintenance in summer. [11]

The following actions can help upgrade the infrastructure for continuous heavy train operation:

- Organize train traffic on the route;
- Set forth and meet infrastructural requirements;
- Address the bottlenecks;
- Rearrange the bottlenecks;
- Run pilot heavy trains and optimize the route schedules and maps;
- Launch scheduled heavy haul service.

OAO RZD’s R&D units are facing the following technological and process tasks pertaining to heavy haul, see Figure 8.

Figure 8. Technological and process tasks pertaining to heavy haul.

Figure 9 shows one possible method for handling heavy trains on the Kuzbass to Far East route.
Heavy trains are driven by four-compartment locomotives, both pushers and pullers. Most heavy trains are shunted at loading stations serving the coal mines in Kuzbass. Heavy trains are also shunted at Kh2.

Kuzbass stations shunt 7,100-ton trains and dispatch them for Far-Eastern ports. However, the rugged terrain of the region forces an upper limit on train weight: 6,300 tons, as it features multiple steep slopes and tight turns. This is why 800 tons of total weight is detached at some stations so that the train could proceed to its port of destination. [9]

Cars are detached at Kh2 and are then coupled into additional 6,300-ton trains. Khabarovsk 2 can shunt 6,300-ton trains to be further pulled by 2*2ЭС5К locomotives. This will be easily done after the station’s even-numbered shunting yard is reconstructed.

Figure 10 shows the train handling procedure.
Most of handling is performed at Kh2, Rzh, Sm, NV. The third option is the most cost-effective option judging from the research team’s calculations.

5. Conclusions

The paper presents its authors’ studies behind scientifically sound technological solutions and arrangements for continuous heavy haul on the Kuzbass to Far East route. These solutions make railway transport more competitive. Given that cargo traffic is on the rise, arranging heavy haul and repairing the infrastructures are both critical not only for this specific route, but also for the routes that pass along it.

An unresolved issue remains, which is that radio connectivity that controls the brakes might be ineffective in tunnels unless on the line of sight.

Heavy trains can be efficient on some routes provided such routes meet specific conditions (heavy cars with car and locomotive axial loads of up to 30 tons, special design of tracks and other carrying infrastructures).

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