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INCREASING THE EFFICIENCY OF THE TRANSPORT OF SINGLE WAGON CONSIGNMENTS – A TOOL FOR SUNSAITABLE FREIGHT TRANSPORT

Abstract. The segment of transport of single wagon consignments is specific in comparison with the transport of complete trains in terms of significantly higher technological complexity, which increases the capacity requirements for means of transport, railway infrastructure, consumption of traction energy, employees involved in this transport, and ultimately the cost of transport. In many EU countries, the transport of single wagon loads is supported by the State on the basis of the Community Guidelines on State aid to railway undertakings. This aid may be granted as aid for the use of infrastructure or aid to reduce ancillary costs. This aid is allowed by the EU with a view to achieving sustainable freight transport if it is demonstrated by a study that the transport of single wagon loads has lower ancillary costs than alternative modes of transport. In the long term, there is a need to increase efficiency in this transport segment. One option is to change the technology of the operator. This paper uses a case study to show how a change in technology can reduce the carrier's cost of transporting single carload shipments and thus increase the overall economic efficiency of this transportation segment.
Keywords: efficiency of transport, single wagon consignments, cost of the operator, service technology

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Introduction

Sustainable freight transport is one of the main objectives set out in EU transport policy. In the context of single wagon consignments (SWG) transport, the EU allows support for this transport segment in the form of state aid. The transport of SWU is in most cases economically inefficient, but from an ecological point of view it is particularly important when this transport is carried out for the most part on electrified lines. However, it is necessary that this transport should also be implemented, given that in the event of its cancellation, downstream transports are very often cancelled and road transport is also implemented.

Rail freight transportation is involved with highly complex logistical processes and requires a lot of resources such as locomotives or wagons. Thus, cost-efficient strategies for routing freight cars in a cargo network are of great interest for railway companies (Frisch et al., 2022). Even though almost all transports of SWU are economically inefficient, it is necessary to optimize the costs of these transports as much as possible by using appropriate means of transport, train routes and optimising the technology of operation. In a case study on selected lines in Jesenice (Czech Republic), we investigated how a change in operating technology will affect the costs of the carrier.

1. Methodology

A change in service technology affects the carrier's direct costs, which can be calculated in different ways. The most commonly used methods are costing on the basis of costing formula items or the use of a cost rate methodology for individual cost sub-items. In our case study, we used the cost rate methodology, taking into account cost items that change due to a change in operator technology. These cost items include:

- energy costs,
- locomotive costs,
- the cost of using the railway infrastructure,
- locomotive crew costs,
- train crew costs.

Energy costs

The energy costs are influenced by the gross weight of the train, the distance, the type of locomotive used (individual locomotives have different traction electricity or traction diesel consumption) and the track conditions (in particular the gradient of the track). When calculating preliminary costs or costing for decision-making processes, the specific traction energy consumption for each type of locomotive is considered, which represents the average consumption of the locomotive under different loads and track conditions. The energy cost can be calculated according to formula 1 as follows (Dolinaynova, Nedeliakova, 2015):

$$Ne = \frac{\sum hrtkm^c * me * k_{tn} * S_e}{1000} \quad (1)$$

where:
n_e - Energy costs [CZK],
$\Sigma hrtkm^c$ - total gross tonne kilometres [hrtkm],
m_e - specific energy consumption [l/1000 hrtkm],

k_{tn} - traction coefficient,
S_e - energy rate [CZK/l].

Cost of locomotives

The cost of locomotives is calculated as the multiplication of the locomotive rate and locomotive km and the cost rate per locomotive according to formula (Dolinayová, Nedeliaková, 2015):

$$N_{hdv} = \Sigma rkm * S_{rkm} \quad (2)$$

where:
N_{hdv} - cost of locomotives [CZK],
Σ_{rkm} - sum of locomotive kilometres [rkm],
S_{rkm} - rate per locomotive kilometre [CZK/rkm].

The cost rate per locomotive is calculated for each locomotive series based on the total cost of the locomotive over a certain period of time and the performance of the locomotive during that period. All costs, i.e. capital costs, the cost of 'operational treatment' of the locomotive, the cost of regular and extraordinary repairs and maintenance of the locomotive are taken into account in the locomotive cost.

Cost of using the railway infrastructure

Infrastructure costs vary from country to country. This is due to the fact that countries have different ways of charging for rail infrastructure. In the Czech Republic, the method and amount of charging are determined by the Network Statement on Nationwide and Regional Railways. In our study, we took into account the charges for the minimum access package, which is composed of an application for the allocation of line capacity, the development of a timetable according to the allocated capacity allowing the use of the allocated line capacity according to the agreed timetable. This is accompanied by access to services related to operation.

The price for the minimum access package shall be composed of the price for the allocation of infrastructure capacity, the price for the use of the line by running a train and the price for access to service facilities. The calculation of the costs is carried out according to formulae 3 and 4 from the Network Statement on Nationwide and Regional Railways, 2022 (Network Statement on Nationwide and Regional Railways, 2022):

$$Czi = K1 + K2 * route\ length + K3 * the\ number\ of\ days\ of\ running\ the\ train \quad (3)$$

where:
$C_{ži}$ - price for the use of railway infrastructure [CZK],
K1 - rate for processing and determination of timetable and allocation of line capacity [CZK],
K2 - rate of train path construction [CZK/km],
Route length - the distance of the route between the starting point and the destination of the route [km],
K3 - rate per day of train path allocation [CZK/day],
Number of train running days - number of days for which the route is allocated [days].

Calculation formula for the calculation of the price for the use of railway infrastructure:

$$C_v = C_s + C_{pk} \quad (4)$$

where:
C_v - price for the use of the line by the train [CZK],
ΣC_s - price for the use of the line by one sub-train [CZK],
C_{pk} - price for the use of access roads for passengers on a passenger train [CZK].

Costs per locomotive crew

Locomotive crew costs are made up of locomotive crew performance time, time of ancillary tasks and rates per hour of work. It is necessary to calculate the running time of the locomotive and to determine the length of the driver's preparatory work. This time is composed of the time of arrival at the locomotive, putting the locomotive into operation, termination of the locomotive operation, arming with traction diesel, etc. The calculation of the cost is carried out on the basis of formula 5 as follows (Dolinayova, Nedeliakova, 2015):

$$Nrč = ((\Sigma rkm\ /\ Vú) + \gamma) * Z_{rč} * S_{hrč} \quad (5)$$

where:
$N_{rč}$ - cost per locomotive crew [CZK],
Σrkm - sum of locomotive kilometers [rkm],
Vú - section speed [hr],
γ - driver's ancillary performance [h],
$Z_{rč}$ - number of locomotive crew members,
$S_{hrč}$ - rate per hour of work of the locomotive crew [CZK/ hour].

In formula 5, a simplified methodology for calculating the driver's performance is used due to the fact that in preliminary calculations it is not possible to take into account the real train running time. However, the use of section speed provides sufficiently reliable results for the preliminary calculation. The hourly rate for the locomotive crew takes into account all costs incurred by the employer per employee, i.e. personal costs, costs of examinations and training arising from the subject of work, costs of compulsory medical examinations, etc. (Dolinayova, Nedeliakova, 2015).

Train crew costs

Given that the transport of SWU is carried out by handling trains, it is necessary to consider the cost of the train crew (freight train conductors). The trains are accompanied by a leader shunter and a shunter. The cost of the train crew can be calculated on the basis of formula 6 (Dolinayová, Nedeliaková, 2015):

$$N_{vlč} = (Tj + Tm + \delta) * Z_{vlč} * S_{vlč} \quad (6)$$

where:
$N_{vlč}$ - cost per train crew [CZK],
Tj - train running time
Tm - handling time (shifting, hitching, unhitching of wagons at individual stations, etc.)

δ - ancillary performance of the train crew [h],
$Z_{vlč}$ - number of train crew members [pcs],
$S_{hvlč}$ - rate per hour of train crew performance [CZK/ hour].

Secondary train crew performances are mainly related to the start and end of the working shift and other actions that are not performed directly on the train. The hourly rate for train crew performance shall take into account all costs incurred by the employer per employee, similar to that of a locomotive crew.

The unevenness of transport was also taken into account in the costing. This is a negative characteristic of rail transport that undermines the efficiency of the transport system. The unevenness is known as time and directional unevenness. Temporal non-uniformity lasts for certain periods of time—a year, a month, a week. In passenger transport, it is also possible to observe temporal irregularities within a single day—transport peaks. During peak periods, the volume of traffic reaches its highest value. The reverse is the case for peak traffic. This is when the volume of traffic reaches its lowest value. Temporal unevenness can be regular, for example seasonal, but it can also be exceptional. Temporal unevenness can also be caused by the production of agricultural products that cannot take place in other seasons (Dolinayová et al., 2016).

Directional non-uniformity can be distinguished for each direction over a certain period of time. Transportation performance is not the same in both directions in the same time period, which may be a year, a month, or a day (Pribula, 2022). The direction that has the higher performance is called the loading direction. The opposite direction is called the empty direction. Directional non-uniformity can be expressed through the directional non-uniformity factor. This coefficient expresses the ratio between the amount of goods transported in the loading and empty directions. The values of the coefficient are always less than one. The objective is to have coefficient values close to one (Dolinayová et al., 2016).

2. Case study

The Jesenická region is located in the north of the Czech Republic near the border with Poland. The center is the town of Jeseník. The adjacent area served by freight trains is Javornicko, stretching around the town of Javorník ve Slezku. The area is relatively mountainous and consists of forests. The whole region is relatively remote from other regions. The industry in the area is not very developed. It is more of a rural region, suitable for recreation and tourism. Agriculture and forestry predominate in the region. In addition, there are also smaller enterprises focusing on different sectors.

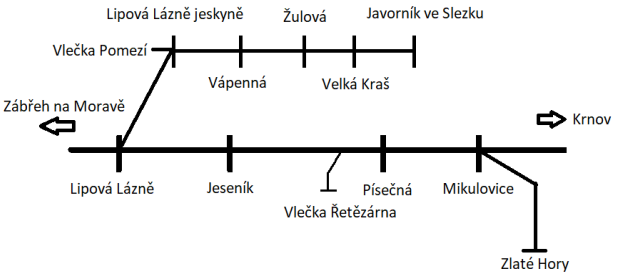


Fig. 1. Map of railways and towns in Jesenicko region

Road transport connects the region with other regions of the Czech Republic and also connects the region with border areas in southern Poland. The region also has a well-developed bus service, which connects mainly villages with adjacent towns. Rail passenger transport is quite widespread. Passenger trains connect the region with other regions of the Czech Republic. At the same time, due to the local conditions, rail transport also goes to Poland, to the border town of Głuchołazy. Rail freight transport is not very attractive. Jesenica is served by one pair of handling trains. This train also serves sidings and sidings. The railway lines in Jesenicko with selected tariff points are shown in Figure 1. These are the following railway lines:

- 292: Šumperk – Krnov,
- 295: Lipová Lázně – Javorník ve Slezku,
- 297: Mikulovice – Zlaté Hory.

These trains are challenging in terms of gradient. For some freight trains, it is also necessary to consider the use of an auxiliary or pusher locomotive due to the gradient conditions of the lines. Freight train services are also restricted by the bypassing of wagons at Głuchołazy station. Passenger trains on this line use reversible trainsets.

2.1. Description of the current service

At present, loading docks and sidings in the Jesenicko area are served by handling and through freight trains. The whole process starts and ends in Ostrava. The actual servicing of the Jeseníky region is carried out from Krnov, where wagons are transported by freight trains from Ostrava together with other wagon consignments for other adjacent regions.

Servicing of the area is carried out from Krnov and takes more than ten and a half hours with the technology shown in Figure 2. Trains run every working day, except for some selected days. The train is divided into two parts at the beginning of the service and each part proceeds according to a specific technology. Each section serves a specific part of the Jesenik region.

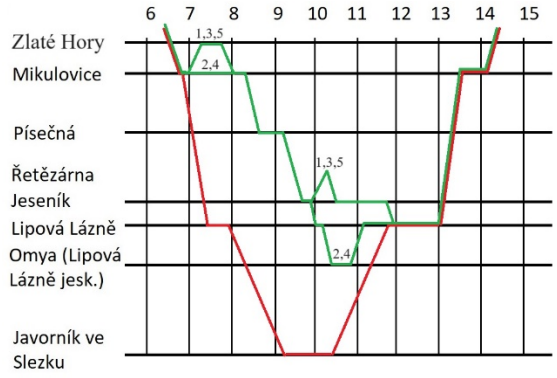


Fig. 2. Nowadays technology of service

The first part of the set (in red) has very similar technology serving that part of the region. The operation of some stations and sidings depends on the current customer order, but the basic part of the operation of selected stations and sidings is unchanged. The second part of the train (in green) has a slightly more complex servicing technology. It is dependent on the current day of the week. Places with more loading and unloading are served three times a week while places with less loading and unloading are served only twice a week. On the return journey, the two trainsets are combined into one train, which then continues on to Krnov and then on to Ostrava with other groups of wagons.

The transport of goods is uneven in the case study. The predominance of the goods distribution is from the area before the delivery to the area. The data provided by the data warehouses shows that of all the wagons arriving and departing from the area, 85% were loaded and only 16% were unloaded. The loaded direction in this case was the delivery from the area and the unloaded direction was towards the area. The unevenness of the figures was due to the fact that the wagons were being used for other deliveries in the area, and so there was no empty run of wagons. An empty wagon run means a loss to the company in that the wagon is not being used efficiently and there is no revenue from the traffic. For this reason, the number of empty wagon runs needs to be minimised.

2.2. Proposal for a change of service

The current operator model includes two different operator variants during one day. The proposed model also has two service variants, but only one variant per day outside the exceptions. This can save one train crew consisting of a driver, a leader shunter and a shunter. In addition, there is a reduction in transport journey costs as well as energy costs.

The main criteria that most influenced the change in train crews was the weight of the goods transported and the number of stops with loading docks attendants. Loading docks and sidings that had a small number of stops with loading dock attendants were assigned to secondary service in the design. Loading docks and sidings with a higher volume of traffic and a higher frequency of service were assigned to the primary service. There were some exceptions due to local and line conditions. An important factor was the time constraints of the staff who were doing the servicing. There was also a need to match freight trains with passenger trains running on the lines in question. As this is a single-track line with fewer passenger trains, this task was somewhat easier.

The number of wagons and the amount of goods transported varied for each direction and each loading point. The number of wagons brought in or moved out was the same. In some cases the differences in annual performance were high. For this reason, the design was adapted to the loading points with higher transport volumes. However, in order to make the proposed variant more efficient, some of the places with higher traffic volumes were reassigned to secondary service. This distribution allows for greater uniformity in the number of wagons transported to or from the area. At present, two to three locomotives are needed to carry trains. In the proposed variant only one locomotive is envisaged, with two locomotives in the case of higher loading. This will save on locomotive costs and reduce the need for locomotives.

The proposed service condition, shown in Figure 3, optimises the service based on certain criteria described above. Freight places and sidings that have frequent service have been selected as the preferred service area. Based on the design, servicing will be performed there more frequently than at less busy freight yards. The most important freight yards would be serviced a total of three times a week while the less busy freight yards would only be serviced twice a week.

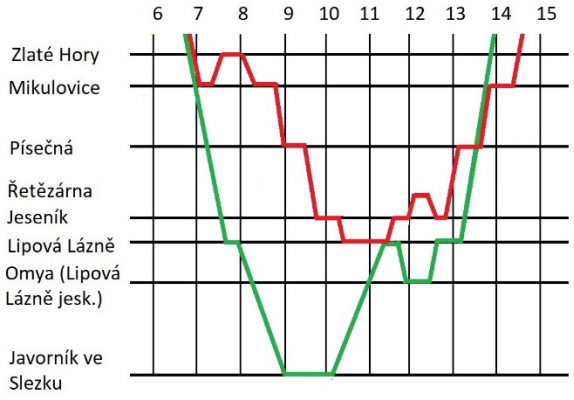


Fig. 3. Proposal technology of service

The proposed servicing technology is similar to the current one, but is less costly due to the complexity of servicing. The technology is adapted to the passenger trains that run on the line. No other freight trains is currently operating there.

Results

The change in service technology has changed the number of locomotives needed to service the area with handling and through freight trains, thus saving locomotive and energy costs. Due to the gradient of the track, it will also be necessary to have a second locomotive on some days which will not be manned by a driver. The locomotives are technically adapted for running in pairs,

operated from a single position and by a single driver. A saving of one driver per day has been achieved by not operating two trains at the same time. After the change, the area will be served by only one train. Similarly, it will not be necessary to consider two train crews, but only one train crew. The proposed technology will reduce the total amount of gross tonne-kilometres with which the charge for the use of the railway infrastructure is associated. The reduction can lead to savings in the cost of using the railway infrastructure.

Table 1: Economic comparison of the current and proposed service variant (Source: Author)

	Nowadays service	Proposed service	Difference
Locomotive costs	100%	67%	-33%
Energy costs	100%	87%	-13%
The cost of using the railway infrastructure	100%	92%	-8%
Locomotive crew costs	100%	53%	-47%
Train crew costs	100%	79%	-21%
Costs together	100%	77%	-23%

The proposed service can achieve an overall cost savings of up to 23% compared to current costs. The highest cost savings is on the locomotive crew, up to 47%. The smallest saving was on the cost of using the railway infrastructure. A saving of 8% of current costs could be achieved on current infrastructure costs. With the modification of the current service under the proposed option, savings could be achieved on all types of costs. Savings in other costs ranged from 13% to 33% compared to nowadays costs.

Conclusion

The efficiency of transporting SWG is influenced by many factors. In the case study, we focused on the technology of serving the region with handling trains and continuous freight trains. Based on the change in servicing technology, there were cost savings for the carrier. In the proposed variant of servicing, increased efficiency of employees was achieved, namely in the consumption of employee labour. More efficient use of locomotives and wagons was also achieved. The increased efficiency has resulted in a reduction in costs of all types that are directly related to the servicing of the region. The proposed service was based on the same amount of goods transported as at present.

Transportation of SWG is costly and often inefficient for the carrier, but by changing the servicing technology, cost savings can be achieved. Direct or indirect economic instruments can also be used to support the transport ofSWG, provided that the country in question has a comparative, transparent, substantiated and quantified cost analysis between rail transport and alternative options based on other modes of transport.

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