COMPARATIVE ANALYSIS OF TAC ON RAILWAY FREIGHT CORRIDORS BETWEEN NORTH ADRIATIC PORTS AND ŽILINA

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Abstract

In recent years, European ports have, due to the increasing traffic between the Far East and Europe, become increasingly important. Large volumes of freight come to ships and it is important to have a link to the mainland via railway, which should have a functional overall system. This research compares three variants of possible routes for railway freight transport from the North Adriatic ports of Rijeka, Koper, and Trieste to Žilina, in the north of Slovakia. The methodology for calculating the minimum package of train access charges for the countries covered by these routes is presented. A comparative analysis of train access charges (TAC) for the minimum access package for the corridors between North Adriatic ports and City of Žilina has also been conducted. The result entailed in this research is the most favourable railway route for freight transport from the North Adriatic ports to the City of Žilina.

Keywords: North Adriatic ports, freight transport, railway, intermodal transport, train access charges

1 Introduction

Globalisation development has led to a substantial increase in trade and sea transport between the Far East and Europe. The increase has placed higher geographical value on the North Adriatic which ensures the development of ports in that area. The ports of Rijeka, Koper, and Trieste are seaports on the north shores of the Adriatic Sea [1], which ensure direct access to the European mainland. Such favourable location is what makes these ports the shortest link between the Central and Central Eastern Europe and Asia, Africa, and Mediterranean countries. The importance of the transport position of the three ports lies in the fact that they are located along the EU core transport network, which is comprised of nine TEN-T network corridors [2]. The Port of Rijeka is the main port of the Mediterranean corridor, while the Port of Koper and the Port of Trieste are main ports of the Mediterranean and Baltic Adriatic corridor, respectively.

The City of Rijeka is located in the west of the Republic of Croatia. It is the third-largest Croatian city and the seat of the Primorje-Gorski Kotar County. The Port of Rijeka is the largest and the most significant in the country. Given its location, the port of Rijeka advantage over the North Sea and Baltic ports lies in the fact that it is the shortest route between Europe and the Far East. For Central and Central Eastern European countries without access to the sea, a faster transport route ensures a faster freight movement and thereby also a reduction in transport costs.

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Koper is a city in south-western Slovenia, the seat of the Coastal–Karst Region and the only coastal city along the 47-km coastline which includes one of the busiest North Adriatic ports – the Port of Koper. Because it is situated along two TEN-T corridors – the Mediterranean and the Baltic-Adriatic Corridor – the port has a great connection to the mainland.
The City of Trieste is the regional capital of Friuli Venezia Giulia situated in the north-eastern part of Italy. The Port of Trieste is situated in the Gulf of Trieste on the North Adriatic coastal belt. Trieste is also where the main longitudinal transport routes intersect with the mainland routes from Central Europe – the Baltic-Adriatic Corridor and the Mediterranean Corridor – which ensures an adequate connection between the port and European cities along the TEN-T European Network. The 18-meter draught, easy access, and outstanding road and rail routes have all turned the port of Trieste into an efficient and competitive port. Good rail connectivity between Trieste and Europe has placed the port among the twenty most significant ports of Europe.
Žilina is the fourth largest city in the Republic of Slovakia. It is situated in the north, near the Czech-Polish border, 200 kilometres from the capital of the country, Bratislava. The city of Žilina is the main industrial centre of the northern confluence of the river Váh, with a fast-growing economy. Strong industry helps develop an area and improve the life standard of residents. Therefore, railway transport is essential for the economy of a country and a region which is why substantial research is made for the role of the international railway transport and regional economy [3]. From a geographical standpoint, Žilina has a quite favourable position. It is located along the firth TEN-T corridor that connects the Baltic ports in Poland to Adriatic ports, and numerous other strong economic centres such as Warsaw, Katowice, Ostrava, Brno and Vienna along the ninth Rhine–Danube corridor [4]. Additionally, Žilina is also situated along the newly planned Amber corridor.
This research will analyse the benefits of the different variants of railway freight transport along the North Adriatic ports – Žilina routes whereby three variants will be shown for each port. The aim of this is to establish the advantages of the variants between the North Adriatic ports and Žilina.

2 Train access charges calculations

Train access charges (TAC) is a model of charging railway operators for the use of railway infrastructure. The fundamental principles of such a model must include: 1) simplicity, 2) transparency, 3) neutrality, and 4) cost dependence [5].
The simplicity indicates that there are no additional, hidden, or ambiguous expressions in the practical application of the model and that the calculation is clear and logical. Transparency means that, regardless of the obligations, the costs will be consistent and fair. Neutrality refers to a railway undertaking having equal approach and relationship to every services user. Since the charging model includes various services, the model itself must be founded upon real generated costs for these services. This way, the model directly adheres to the principles of transparency and neutrality [6].
Every country has its calculation methodology which is why the methodologies of charge calculations must be conducted for every country through which freight will be transported from North Adriatic ports to Žilina [7]. At the same time, only the minimum access package calculation which represents the basic service package provided by the railway undertaking to the operators will be taken into account. The minimum access package charge in Croatia [8][9] is calculated according to the following formula:

$$C = \left[(T + d_m + d_n) \cdot \sum (L \cdot I) \cdot C_{vlkm} + (I_{el} \cdot C_{el})\right] \cdot S \quad (1)$$

whereby C is the total charge amount, T is the train path equivalent, d_m is the charge for the use of tilting technique, L is the line parameter, l is the train path length, C_{vlkm} is the basic price (HRK/trainkm), l_{el} is the length of train path with electric traction, Cel is the additional charge on trainkm price for the train path with electric traction (HRK/trainkm), and S is the coefficient for the single wagon load train. In Slovenia, the minimum access package charge [10] is calculated according to the following formula:

$$\mathbf{U} = \sum_{i=I}\sum_{vv,\, i}^{vv} \mathbf{Q}_{vlkm(vv,\, i)} \cdot \mathbf{F}_{vv} \cdot \mathbf{P}_i \cdot \mathbf{C}_{vlkm} \cdot \mathbf{C}_{vp} \quad (2)$$

$Q_{vlkm(vv,i)}$ refers to the number of train kilometres performed on certain line categories (i) and by the same power car (vv), F_{vv} is the coefficient of the power car category (vv), P_i is weighting of the line category (i), C_{vlkm} is the cost per train kilometre, and C_{vp} the cost of supplement or deduction for the type of transport (depends on the type of the train).
The minimum access package in Italy [11] is calculated using the following formula:

$$\mathbf{A}_c = \mathbf{A} + \mathbf{B} \quad (3)$$

$$\mathbf{A} = \mathbf{A}_{weight} + \mathbf{A}_{speed} + \mathbf{A}_{contact\ line} = \left(\mathbf{T}_{A1} + \mathbf{T}_{A2} + \mathbf{T}_{A3}\right) \cdot \mathbf{l} \quad (4)$$

$$\mathbf{B} = \mathbf{T}_B \cdot \mathbf{l} \quad (5)$$

A_{weight} relates the wear and tear of the track due to the weight of the train, T_{A1} is the train weight parameter, A_{speed} refers to the relates the wear and tear of the track due to the operating speed classes of the train, T_{A2} is the train speed parameter, A_{weight} refers to the wear and tear of the overhead contact line, T_{A3} refers to the use of contact network depending on the traction type, and T_B refers to the service cost, and l refers to the distance travelled.
The Austrian railway undertaking calculates the minimum access charge [12] based on the following formula:

$$\mathbf{T}_{AC} = \mathbf{Trainkm} \cdot \mathbf{z} + \mathbf{Gtkm} \cdot \mathbf{g}_{tk} \pm \ \mathbf{reductions / supplements} \quad (6)$$

Trainkm is the train-kilometre component, z is the train-kilometre coefficient. G_{tkm} is the multiplication of the gross-tonne and kilometres, and g_{tk} is the gross-tonne-kilometres coefficient. Reductions or supplements are infrastructure congestions, delays in minutes, traction unit coefficient, noise bonus, and the number of axles.
The Hungarian minimum access package [13] is calculated using the following formula:

$$A_c = A_{TV} + A_{KV} + A_E \quad (7)$$

$$A_{TV} = a_{TV} \cdot train\ km \quad (8)$$

$$A_{KV} = a_{tkm} \cdot trainkm + a_{gtk} \cdot brtt \cdot trainkm \quad (9)$$

$$A_E = a_E \cdot trainkm \quad (10)$$

where A_c refers to the total charge, A_{TV} is the train route charge, a_{TV} refers to the train route insurance charge per train kilometre, A_{KV} is the train movement charge, a_{tkm} is the train kilometre charge (depending on the track category), gross-tonne-kilometre charge is a_{gtk}, the charge for using electric traction is A_E, and a_E is the charge charged for the use of electric traction per train kilometre.

In Slovakia [14], the minimum access package is calculated as follows:

$$U = \sum_{i=1}^{U_i} U_i \tag{11}$$

$$U_1 = u_1 \cdot l \tag{12}$$

$$U_2 = u_2 \cdot l \tag{13}$$

$$U_3 = \frac{u_3 \cdot {brtt}/{vl} \cdot l}{1000} \tag{14}$$

$$ {brtt}/{vl} = m_L + n_{vag} * \left(m_{vag} + tara_{vag}\right) \tag{15}$$

$$U_4 = \frac{u_4 \cdot {brtt}/{vl} \cdot l}{1000} \tag{16}$$

U_1 is the maximum charge for requesting and assigning capacity, U_2 is the traffic management and organization charge, U_3 is the infrastructure service use charge, U_4 refers to the use of electric traction, l represents the distance, m_L is mass of the locomotive, n_{vag} indicates the number of carriages, $tara_{vag}$ is the carriage mass, $brtt_{vl}$ is the overall train weight, and $u_{1,}$ u_2, u_3, and u_4 are fees charged for a component on a route.

3 Case study: A comparative analysis of TAC on railway freight corridors between North Adriatic ports and Žilina

The comparative analysis for all three ports was carried out in three variants for each port. The following corridors were analyzed for Rijeka: 1) Port of Rijeka–Hungary–Žilina Teplička, 2) Port of Rijeka–Slovenia–Austria–Žilina Teplička, and 3) Port of Rijeka–Slovenia–Hungary–Žilina Teplička. The corridors from the Port of Koper included: 1) Port of Koper–Austria–Žilina Teplička, 2) port of Koper–Hungary–Žilina Teplička, and 3) port of Koper–Croatia–Hungary–Žilina Teplička. The corridors from the port of Trieste included: 1) Port of Trieste–Austria–Žilina Teplička, 2) Port of Trieste–Slovenia–Hungary–Žilina Teplička, and 3) Port of Trieste–Slovenia–Croatia–Hungary–Žilina Teplička [15].
The first 929.30-km corridor originating in Rijeka continues through Hungary to Žilina in the north of Slovakia. The entire track of the corridor is electrified by an AC 25 kV, 50 Hz system, apart from the final section, Púchov–Žilina, which uses a 3 kV electrification. The number of tracks depends on the section. The maximum axle load is 22.5 tons and the longitudinal load varies across sections – the minimum being 6.4 tons per metre. The second section passes through Slovenia and Austria where there is the issue of non-interoperability. Each of these countries has its voltage system which requires a locomotive change at border crossings. Alternatively, multi-system locomotives can be used. The corridor is 822.23 kilometres long. The third corridor is the longest, measuring 988,76 kilometres. The shortest section thereof passes through Croatia (31 kilometres). Electrification systems along the corridors vary - Croatian section uses a 25 kV 50 Hz system, Slovenia electrifies the track with 3 kV, and Hungary and partly in Slovakia, the track again uses the 25 kV 50 Hz electrification system. The final section of the corridor is again electrified using 3 kV.
The first corridor from the port of Trieste goes through Austria to Žilina and is 798.62 kilometres long. It uses three different electrification systems. The Italian section and a part of

the Slovak track are electrified with the direct 3 kV system, the Austrian section uses alternating 15 kV 16 ⅔ Hz current system, and the part between the Austrian-Slovakian border and Puchov uses the 25 kV and 50 Hz system. The Austrian and Slovakian section has a maximum axle is 22.5 tons per axle and the longitudinal load is 8 tons per meter. The second corridor – 988.90 km – stretches from Trieste to Žilina via Slovenia and Hungary. The corridor is mainly double-track with either 3 kV direct or 25 kV 50 Hz alternating current system. The third corridor, Trieste – Žilina, crosses Slovenia, Croatia and Hungary and is the longest – 1086.30 km. The maximum loads and number of tracks differ between sections, as does the track electrification systems. The Italian-Slovenian part of the corridor and the Puchov – Žilina section use a direct 3 kV electrification, while the remaining part of the track uses the 25 kV 50 Hz system. For the comparison to be fair, the same train composition was used on all routes - a single locomotive and 21 Sgs carriages, approximately 500 meters in length and 1281 tons in weight, not counting the locomotive weight (Table 1).

Table 1 An overview of the routes, access charge and journey time of the corridors

Route	Variant	Transport length [km]	Access charge [€]	Journey time [h]		
				v = 30 km/h	v = 50 km/h	v = 70 km/h
Port of Rijeka - Žilina Teplička	1.	929.30	2704.20	31.00	18.60	13.30
	2.	822.23	3176.34	27.40	16.40	11.70
	3.	988.76	2758.84	33.00	19.80	14.10
Port of Koper - Žilina Teplička	1.	836.17	3209.90	27.90	16.70	12.00
	2.	1002.40	2907.93	33.40	20.00	14.30
	3.	1000.30	2816.19	33.30	20.00	14.30
Port of Trieste - Žilina Teplička	1.	798.62	3938.13	26.60	16.00	11.40
	2.	988.90	2797.68	32.90	19.80	14.10
	3.	1086.30	2822.73	36.21	21.70	15.50

The freight corridor with the shortest journey time, not taking the charges into consideration, is the Trieste–Žilina Teplička via Austria – 798.62 kilometres. The journey time of an express train that combines multimodal transport and does not stop along the way is 11.4 with an average speed of 70 km/h (all journey times do not include stops to change traction systems). Other routes have approximately the same journey time – the Rijeka–Slovenia–Austria–Žilina Teplička corridor measures 11.7 hours for 822.23 kilometres, and the Port of Koper – Austria – Žilina Teplička route of 836.17 kilometres has a 12 hour journey time. If time is not a factor and the objective is to reduce transport costs as much as possible, the best corridor is the Port of Rijeka to Žilina via Hungary. The length is 929.3 kilometres and is covered in 13.3 hours at an average speed of 70 km/h - not taking into account the stops for traction change. Variant 3 (Rijeka–Žilina Teplička) and variants 2 and 3 (Port of Koper–Žilina Teplička) and variant 3 (Port of Trieste–Žilina Teplička) are 988–1003 kilometres long with an average journey time of 14 hours and 15 minutes and access charge 2750–2910 euros.

4 Conclusion

Geographically, North Adriatic ports have an exceptionally favourable position compared to other European ports. It is the significantly shorter journey time that contributes most to their importance - it is 6 times shorter compared to North Sea ports. The Port of Trieste has the largest volume due to its long tradition in freight transport and continuous investments in maritime and mainland infrastructure. The Port of Koper consistently invests in its infrastructure, particularly the railway, which ensures its competitiveness in the market. The Port of Rijeka has been experiencing issues because for years there have been no infrastructural improvements. This has led to a situation where the port's railway transport is less competitive than road transport. In container transport, the port of Koper dominates with 988,501 TEU units in 2018. The Port of Trieste is keeping up with Koper, increasing its annual volume – 725,426 TEU units in 2018. The Port of Rijeka trails behind with 260,375 TEU units in 2018. However, it should be noted that this is the port's record which indicates an upward trend of TEU units every year.

This research has compared three variants of possible corridors between North Adriatic ports – the ports of Rijeka, Koper and Trieste – and the north of Slovakia, i.e. Žilina. Ultimately, the analysis has examined the length of the corridors, journey times, access charges – taking into account only the minimum access package. The analysis has also concluded that that the shortest corridor (shortest journey time) is the Trieste–Austria–Žilina Teplička corridor. The only issue that arises here is the high charge. Given that most of this corridor passes through Austria, where charges are highest, which makes the corridor more expensive than the others. The corridor which is more favourable for the operators for whom the cost is not a more decisive factor than the journey time. For others, the most favourable corridor is the Rijeka–Hungary–Žilina Teplička. Compared to the shortest one, this corridor is 130.70 km longer, which amounts to approximately 2 hours. However, access charges are 1233.93 euros lower. The two corridors tower over the others at approximately the same range in terms of transport route and access charge.

Railway operators demand various services and make their own respective decisions as to how much they will pay for the service. Similarly, every port and every terminal provide various additional services, reception capacities, freight storage and different levels of connectedness to the mainland. What ultimately determines the corridor choice is up to the transport user, the one that dispatches freight. They can opt for a North Adriatic port that can provide the best services at a given cost. The corridors they choose will be based on time and financial conditions.

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