ISSN 0554-6397
UDK: 004.032.26
Review article
Received: 4th March 2024.

Petar Stričević
E-mail: stricevicpetar@yahoo.com
Luka Vukić
E-mail: lvukic@pfst.hr
University of Split, Faculty of Maritime studies, Ruđera Boškovića 37, 21000 Split, Croatia

Potential Benefits of the Revitalization of the Una Railroad for the Competitiveness of the Central Dalmatian Ports

Abstract

The non-electrified and obsolete Lika railroad and the interruption of traffic on the Una railroad are limiting factors for the development of the Central Dalmatian ports, as rail transport is not competitive there, and the natural hinterland of these ports is directed to the ports in other regions. For potential decision-making procedure on investments in the modernization and commissioning of the two railroads, this study provides a calculation of how the transport price per freight unit would develop on the route Tovarnik - Solin, comparing it with that on the (competing) reference route Tovarnik - Rijeka, also providing an assessment of this impact on the traffic of the Central Dalmatian ports. The results show that the commissioning of the Una railroad alone, without additional investments in electrification and modernization, would reduce transport costs per unit by 30%, in addition to all the other benefits that an improved railroad connection brings. The modernization of the Lika railroad would reduce unit transport costs by up to 63% and the Una railroad by up to 88% compared to current costs, and the latter would seriously compete with transportation on the reference line. It is estimated that the traffic on the Una railroad to the Central Dalmatian ports would amount to about 3 million tons per year, while the traffic on the Lika railroad would maintain its current volume, with an upward trend. Investing in the modernization and revitalization of railroads and shifting freight transport from road to rail is in line with the EU's strategy for sustainable transport development.

Keywords: Una railroad, Central-Dalmatian ports, competitiveness calculation, revitalization

1. Introduction

As a transport mode, the railway has socio-economic importance in the development of regions as it contributes to the creation of multiplying effects in all areas of activity, which intensifies the competitiveness of the transport route and transport hubs. The construction and maintenance of transport infrastructure are directly related to the economic growth of the geographic area in which the railway is located, consequently, to the economic growth of the whole country. A modern transport infrastructure is a prerequisite for the activation of the economic potential. Railway transport has certain advantages that make it more affordable and environmentally acceptable than other transport modes, and those are massive scale, speed, economy, and the fact that it is independent of climate and weather. A single train replaces up to several hundred trucks, which reduces traffic jams and increases the flow of traffic [1]. Railway enables the transport of large generic types of cargo thanks to the large capacities of standard cars and various advantages, e.g., the option of using open platforms [2]. Disadvantages include changes of routes, which makes railway transport extremely inflexible, as well as unavailability where there is no railroad. Nevertheless, the railway is an important part of modern intermodal and multimodal transport and it makes up around 20% of global trade. Its added value is higher than the one generated by water or air transport. The macroeconomic significance of the railroad network is reflected in the length of railway tracks exceeding 220,000 km, the annual average of over 10 billion passenger journeys, and over 420 billion passenger kilometers [3].

Within the socio-economic contribution, the role and importance of railway transport for the national economy is reflected in the number of employees in this sector [4]. The total number of employees in Hrvatske Željeznice on 31 December 2021 was 4663. The relationship between train-kilometres and the number of employees is expressed through the term of natural productivity whose indicators for the period 2015 – 2019 are presented in Figure 1.

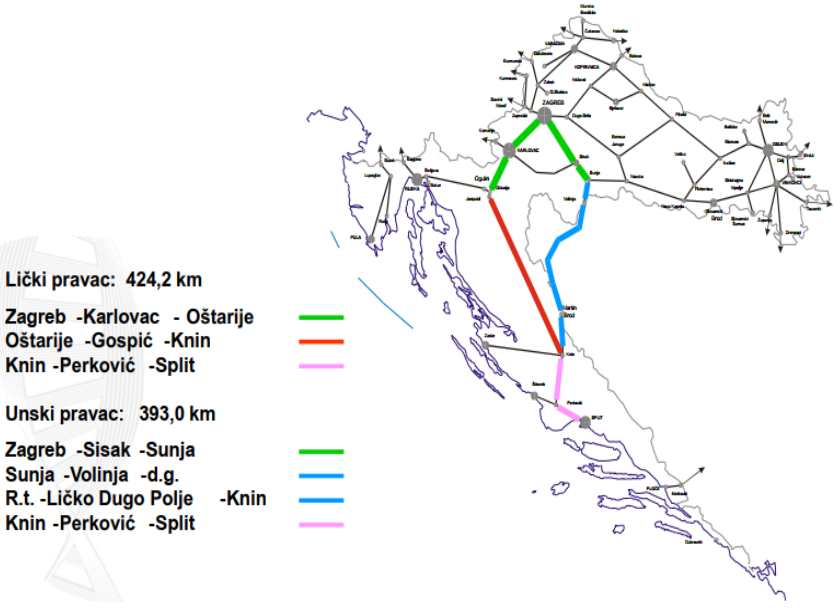
Figure 1. Natural productivity for the period 2016 – 2019 [5]

Data suggest that there was an increase in productivity between 2015 and 2018, as well as a mild decrease in 2019. During 2019, there were 21,842 train kilometers

(2.5% more than in 2018) with twice as many train kilometers in passenger transport as in cargo transport. Passenger transport achieved 951 million passenger kilometers, that is, 9.9 million passengers [6]. Cargo transport achieved 7.738 million gross tonne-kilometers, which represents an increase of 8.9% in comparison to the preceding year. In 2019, the largest Croatian cargo carrier, HŽ Cargo, achieved 62.2% of the total income from the transport of goods [7].

Railway transport sustainability is reflected in safety, reduced emissions, recycling, and taking care of the environment. Useful energy consumption, i.e., the ratio of fuel used and distance traveled, is also of major importance. Lower energy consumption leads to lower transport prices, making it possible the save between 10% and 40% [8]. Electric trains can use up to 90% of the output energy of the electric motor. Regenerative brakes return kinetic braking energy to the system for increased efficiency. Electric locomotives are also leaders when it comes to a reduced need for maintenance [9]. The disadvantages of electric railways include infrastructure and control systems costs [10]. Environmentally speaking, railway transport is the most acceptable form of transport because, despite a share of only 7% of passenger transport and 11% of total transport, it marginally contributes to greenhouse gas emissions (0.5%) [11]. Investments in railway electrification are keys to achieving the aim of sustainable development, and own production of electrical energy makes it possible to achieve energy independence [12]. Nevertheless, 46% of railroads in the EU are not electrified and await sustainable solutions. The costs of classic, overhead electrification are tentatively estimated at 1 – 10 million EUR/km, and the construction indications increase with the increase in traffic and the length of the section [13]. The benefits include shorter travel time, shorter stay at the station, traction and services unification, lower procurement costs, and more reliable transport service [14].

The Una railway is a railway section that connects Novi Grad and Bihać in Bosnia and Herzegovina to Knin in Croatia, enabling the connection of the city of Split (Croatia) to the railroad Zagreb (Croatia) – Belgrade (Serbia). It was entirely electrified. The total length of the Una railway is 178 km; the Bosnian-Herzegovinian section from Novi Grad is 124 km long, and the Croatian section to Knin is 54 km long. On seven points it crosses the borders between two states. From the Republic of Croatia's perspective, the railroad connects Pannonia with the coastal part of Croatia, namely Zagreb and Split. That section is 30 km shorter than the unelectrified Lika railway, used as its alternative in recent history [15]. In the war destruction of the 1990s, the Una railway was devastated, and traffic was interrupted. It was partially renewed in the Bosnian-Herzegovinian section, and it is used in local traffic. Figure 2 shows the route of the Lika and Una railway.



Lički pravac - the Lika railway
Unski pravac – the Una railway

Figure 2. Railway sections in the direction Zagreb – Split [16]

In addition to the general advantages of electrified railways compared to unelectrified ones, the Una railway also shows advantages in the longitudinal profile of the route. Figure 3 shows the comparison between longitudinal profiles and the length of the Lika and Una railways.

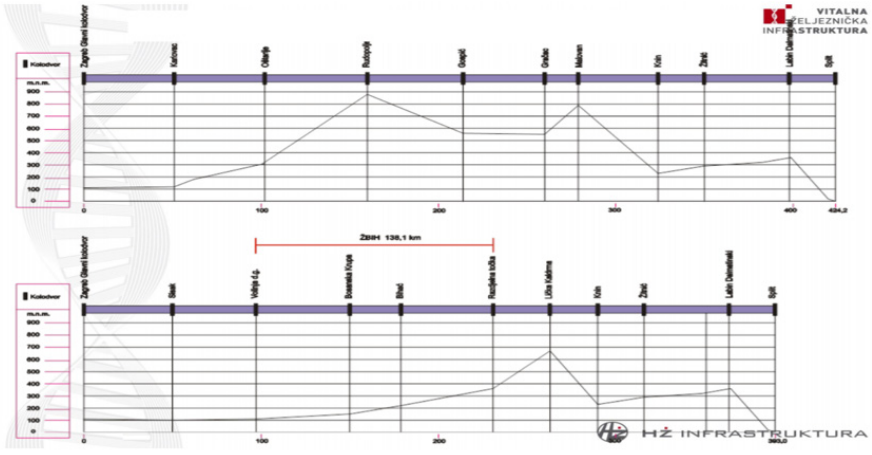


Figure 3. Comparison of longitudinal profiles of the route on the Zagreb – Split section in the Lika direction (above) and the Una direction (below) [16]

On the Lika route, the altitude near Rudopolje reaches almost 900 meters which is 800 meters near Malovan. The Una railway route from Bihać goes through the Una valley (approx. 15 km), and the highest point is Kaldrma station at 673 meters above sea level.

The natural and transit port hinterland of individual ports in the former state is shown in Figure 4, highlighting how, due to the unsatisfactory condition of the railway infrastructure, the market which naturally gravitates to certain ports, becomes the transit port hinterland of more distant ports, e.g., the goods that naturally gravitate to the Port of Ploče are redirected to the ports of Rijeka, Šibenik, and Split because the railway Sarajevo – Ploče hasn't been normalized during the observed period. The gravity fields of the port changed and expanded after the construction of the Una railway [17], and upon its closing, the ports of Split, Šibenik, and Zadar lost a significant part of the natural traffic hinterland.

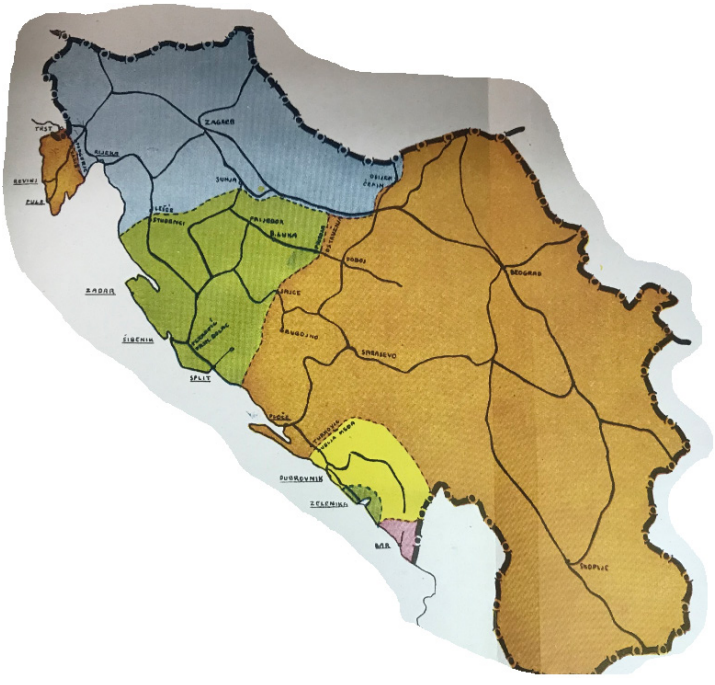


Figure 4. Port hinterland and gravity areas of central Dalmatian ports [16]

According to the available data for 1990, the total traffic on railway area Split/Knin (Lika and Una railway) was 3,400,000 tonnes of goods (1,850,000 tonnes of loading and 1,550,000 tonnes of unloading) [18]. When it comes to loading, the most frequent companies were Petrokemija from Kutina and Dalmacijacement from Split, with approx. 40% share. Between 1985 and 1990, passenger transport was reduced from 1,727,000 to 1,290,413 passengers a year. An intensive passenger and cargo rail transport on longer sections (>100 km) encourages investors for overhead electrification projects, unlike investments in other types of net-zero drives [19].

The Una railway revitalization project, created as a joint interest of the Ministry of Communications and Transport of Bosnia and Herzegovina and the Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, as the revitalization and renewal initiative, means forming teams that use their expertise to create a feasibility study, which justifies the interest for investment [20]. The ports of Zadar, Šibenik, and Split, as well as the regions from north-western Bosnia and Herzegovina, show the biggest interest. The priority objectives include major savings in transport costs for all significant concessionaires in Dalmatian ports, strengthening the role, significance, and competitiveness of the ports, and expanding the ports' hinterland. The Una railway revitalization would significantly reduce transport costs through Sisak, Bihać, and

Knin to the Port of Šibenik for the needs of Petrokemija from Kutina, which is also the majority owner of the Port of Šibenik. The Port of Zadar concessionaires Gaženica Luxury Real Estate and other economic operators from Zadar are also interested in the Una railway renewal because, at the current connection level, it is not possible to expand the port hinterland to Bosnia and Herzegovina [21]. With investment in the modern railway infrastructure of the Una railway, The Northern port of Split could realize its full potential. Cargo terminals under the authority of the Port Authority Split in limited conditions achieve more than 3 million tonnes of cargo a year (2022). The modernization and electrification of the Una, as well as the Lika railway, would enable the provision of transport services in accordance with the standards of sustainable development [22]. In addition to the central Dalmatian ports, the revitalization of the Una railway would also encourage the development of Knin and Sisak as important railway and logistics hubs [23].

This research aims to examine the competitiveness of potential opening for traffic of the Una railway in the conditions of the current state and the conditions of revitalization which entails a complete re-electrification of the railway direction route. For the achievement of the set aims, a model will be developed, including the review of transport costs and focusing on fuel expenses and the total distance to compare the performances of the Una and Lika railways. The competitiveness model is based on the budget which includes three experimental stages: a calculation of the total distance of traction by aggregating technical, technological, spatial, and other factors; the projection of transportation costs (fuel) in the existing conditions in the case of potential, complete electrification, i.e., potential electrification and railroad modernization (railway direction reconstruction); the projection of economic activities of ports' hinterland after investments in the revitalization of the Una railways, and effects thereof on the traffic of central Dalmatian ports. The formulation of research arguments in the form of an analysis of selected parameters, especially the cost of fuel, was carried out after the increase in the price of cargo transport during 2021 by the existing service provider on the Lika railway by 6 EUR/t, emphasizing the cost of fuel and the limited port hinterland (shortage of cargo) as fundamental predictors of carrier profitability [24]. Based on the adopted business decisions of service providers, which significantly undermine the perspective of conducting business of port terminals concessionaires in central Dalmatian ports, the aim is to point to the potential usefulness of the establishment of traffic and modernization of the Una railway and the effects of electrification and modernization of the Lika railway, the only railway connection of the central Dalmatian ports to the rest of Croatia.

2. Methodology

In order to examine the competitiveness of the Una railway, and under the assumption of examining the existing condition and revitalization thereof, a model that includes the examination of two parameters, the calculation of transportation costs

(focusing on fuel costs) and the distance, was created. The mentioned inputs will be used to compare the Una railway with the railroad M604 on the section of the Lika railway that is sections Oštarije – Gospić – Knin – Split (Figure 5).

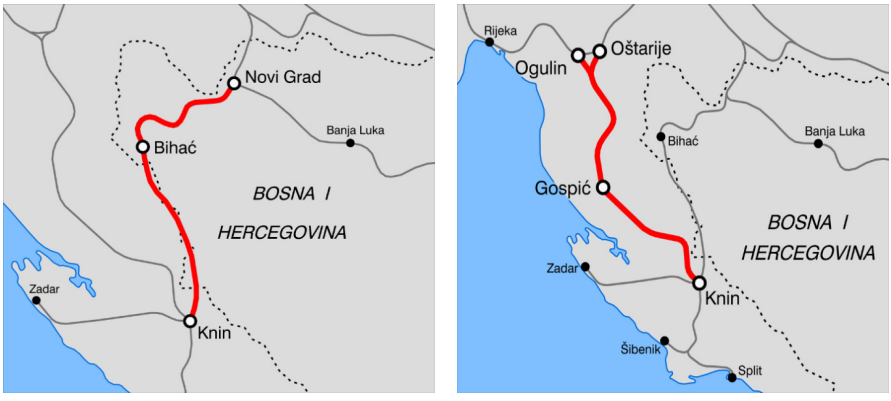


Figure 5. Comparison between the Una railway (left) and the Lika railway (right) routes [25, 26]

In the calculation model, the competitiveness of both directions will be used under the conditions of hypothetical electrification and modernization of railroads, that is, the effects thereof on transport expenses (fuels). It should be noted that the calculation doesn't take into consideration the costs of modernization and railway infrastructure renewal. The research is based on the methodology taken from Vukić et al. [27], that is, on the data from HŽ Cargo [24] and the data obtained following consultations with experts in railway services and traction, especially those which refer to traffic on the Una railway. It is important to highlight that data on unit fuel costs on the Una railway aren't available, but they are the result of market conditions and other commercial factors and current data on fuel costs on other comparable railways in Croatia. The chart flow on the concerned research model is shown in Figure 6.

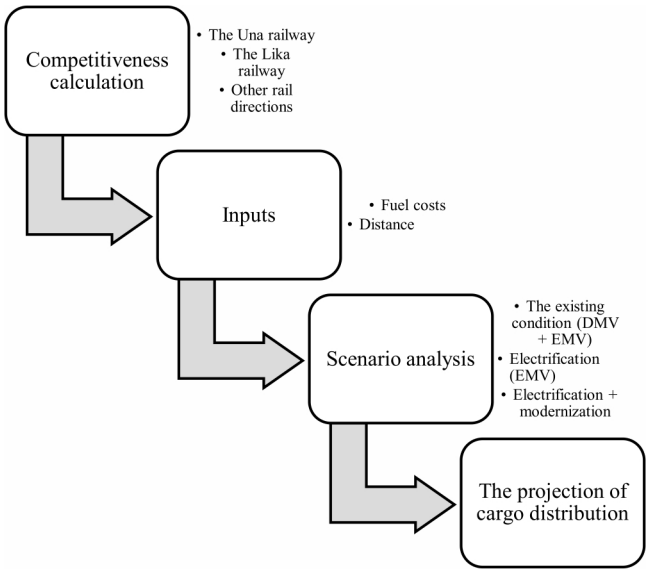


Figure 6. Research flow chart

Railroad sections on the Lika railway route and other routes that don't include traffic on the Lika railway, and which are considered in this research are the following:

◊ Tovarnik – Solin,
◊ Tovarnik – Ogulin and
◊ Ogulin – Solin.

The final destination in Solin has been considered primarily due to data availability regarding individual key parameters. Differentiations in the terrain configuration, i.e., the routes of individual railway directions coincide with the total number of trains, i.e., train compositions and the number of locomotives for traction. The latter is an extremely important input of the research because increasing the number of locomotives in a single composition proportionally increases the total distance expressed in *rt* (distance as a product of the number of wheel revolutions and wheel circumference), a unit which marks the actual number of kilometers (km) traveled of the machine. Furthermore, due to the calculation of total transport costs (fuel), Tovarnik – Rijeka route is also under consideration, as it represents a starting (reference) point of the calculation, that is, a sample calculation, primarily due to data availability regarding unit prices of electrical energy consumption of an electrified railroad, but also as an ultimate aim of the price of transport services on a competitive direction which is to be achieved/exceeded. The unit costs of transportation (fuel) along the Una railway will be calculated based on data on the costs generated on the remaining sections for which data already exist, which are the subject of analysis in this paper, and data obtained through consultations

with experts in the subject area. For the Una railway, the following route is analyzed:

◊ Bosanski/Novi Grad – Bihać – Knin (total length 178 kilometres) as a part of rail road direction Tovarnik – Bihać – Knin – Solin.

Given that EMV (electric motor vehicle) and DMV (diesel motor vehicle) operate on part of the railway routes considered in this paper, the obtained unit costs of transportation will be applied to the section of the Una railway according to the determined scenarios. Individual scenarios depend on the condition of the railroad and the level of electrification. There are cases in which one part of the direction uses EMV, and the other part, which is unelectrified, uses exclusively DMV, which significantly increases total transport costs. An example of a model of cargo train traction using a DMV locomotive on the Lika railway is shown in Figure 7, from which it can be seen that with an increase in the gross mass of the train, the need to include additional locomotives in the composition increases, especially on the most demanding sections where the slope of the track, measured in per-milles (‰), is extremely demanding.

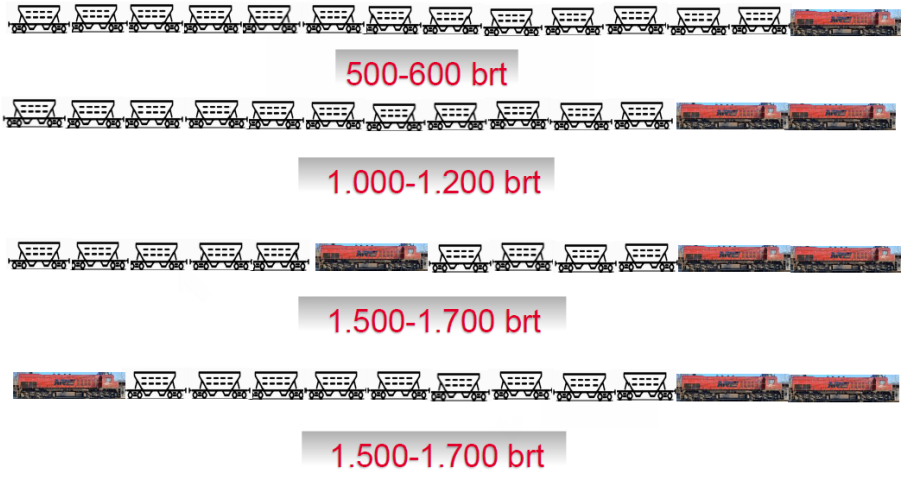


Figure 7. Models of cargo train tractions on the Lika railway [28]

In addition to the traction strength, it is necessary to consider other factors which affect the calculation of transport costs and the overall competitiveness of the rail road section: terrain configuration, the number and condition of the locomotives (traction strength reduces through its life cycle) and the total gross mass of the cargo which can be shipped [28].

For the needs of this research and based on the data from HŽ Cargo [24], as well as the data obtained upon consultations with private service providers (for the Una railway), cargo transport is shown with a gross mass of 2,400 tonnes, i.e., net mass of 1,600 tonnes (m) in 32 cars on the selected railroad routes (z) and individual rt traction

distances (s). The total distance (in km) of train traction (rt) from Table 15 depends on the number of locomotives (EMV or DMV) in the train composition consisting of 32 cars, affected by the terrain configuration, that is, the slope of the track, which coincides with the relevant resistance (daN/t). For example, on the Tovarnik – Solin railroad, a train with a net mass of 1,600 tonnes and 32 cars is divided into two trains with 16 cars in Ogulin (800 net tonnes). Each light train is pulled by diesel locomotives to Perković (3 MW), where three (3) cars are removed from each train due to slope increase and railroad (resistance). After the arrival of two trains with a total of 26 cars to the destination (Solin), it is necessary to deliver the remaining six (6) cars from Perković. To calculate the fuel costs on the Una railway, taking into consideration data limitation, unit values of energy cost (in EUR/km) used to pull trains along the considered routes are the electrified route Tovarnik – Ogulin and Ogulin – Solin where DMV operates, will be applied to the railroad direction z5 Tovarnik – Bihać – Solin. Table 1 shows the existing distances on the railroad directions under consideration based on the criteria of total traction length (rt). When it comes to the Tovarnik – Bihać – Solin (z5) direction, the base calculation predicts the usage of electric traction to Bihać (current state), and on the Bihać – Knin – Solin route the diesel engine traction (without the line electrification, and reconstruction).

Table 1. Length of individual railroad directions and traction length (rt) [27, 28]

Direction *z* (m = 1600 net tonnes)	**Length in *km* (EMV and/or DMV)**	**Number of locomotives**	**Traction**	**Traction length *s (rt)** in *km***
Tovarnik – Rijeka (*z1*)	521	3	EMV	1582 (*s1*)
Tovarnik – Ogulin (*z2*)	401	3	EMV	1203
Ogulin – Solin (*z3*)	322	4	DMV	2263
Tovarnik – Solin (*z4*)	723	5	EMV + DMV	3466 (*s2*)
Tovarnik – Bihać – Solin (*z5*)	562	4**	EMV + DMV	2,248 (*s3*)

** rt = axle circumference x number of revolutions*
*** estimation after consultations with carriers*

The second part of the experimental phase of this work includes the projection of transportation costs (fuel) after the potential and complete electrification of the considered railway routes, and under the conditions of electrification of the railways along with the modernization or reconstruction of the railway route, intending to reach the required level of quality equivalent to the performance of the section Tovarnik – Rijeka as a research reference point. The intention is to determine the level of fuel costs after the planned investments in the renewal and modernization of railways, with

a focus on the Una railway, the realization of which would significantly improve the competitiveness of railway traffic routes to central Dalmatian ports and the profitability to transport providers.

The final part of the research includes the projection of the economic activities of the port hinterland after potential investments in the revitalization of the Una railway and their effects on the traffic of central Dalmatian ports. It should be noted that the projection is based primarily on the estimation which takes into consideration historical records on cargo transport along the Una railway and the traffic of additional cargo due to the penetration of new markets in response to the assumption of investments in railway infrastructure. The data of the annual cargo traffic in the ports of Split, Zadar, and Šibenik for the period 2017 – 2022 (Figure 8), i.e., the traffic on the existing Lika railway, were used as the basis for the projection of the effects of the revitalization of the Una railway on the traffic of central Dalmatian ports.

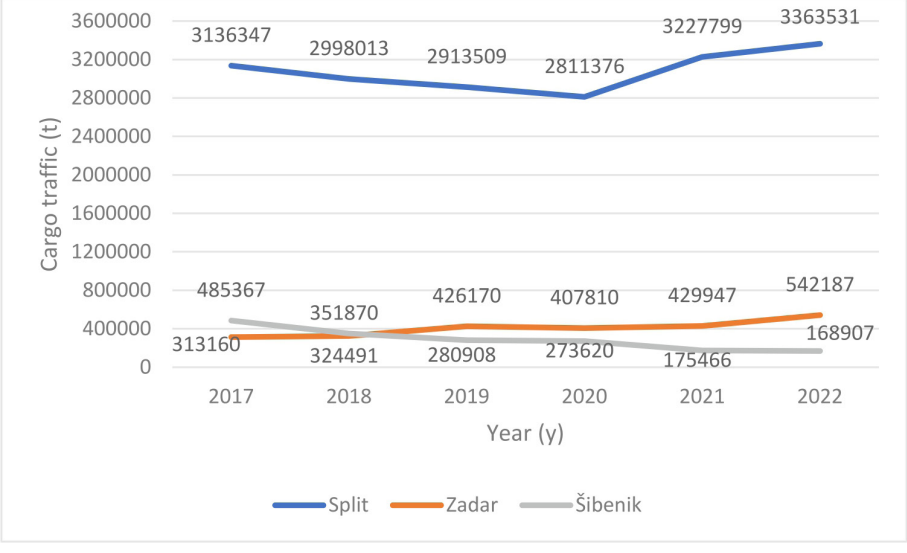


Figure 8. Annual cargo traffic in Dalmatian ports in the period 2017– 2022 [29, 30, 31]

The share of individual ports in the total traffic of central Dalmatian ports is one of the factors of competitiveness, and based on this indicator, a hypothetical projection of the distribution of cargo in the conditions of revitalization of the Una railway can be made. More than 82% of the total traffic share of Dalmatian ports in 2022 is accounted for by the Port of Split; 13% by the Port of Zadar, and the rest by the Port of Šibenik. Furthermore, the nature of the cargo itself, together with the capacity and purpose of the port terminals determine the possibility of accepting cargo in those ports. Therefore, the highlighted factors will be considered when projecting the effects of renovation and

modernization of the Una railway on seaport traffic. The calculations were performed in MS Excel.

3. Research results

By applying the existing prices of the energy sources used on the observed railway routes, the total costs of the trains are by default expressed as a unit price of transportation per ton of transported cargo (*EUR/t*) (Table 2). The number of costs of the transport generated on the railroad direction Tovarnik – Bihać – Solin is an estimated value obtained by aggregating transport costs on Tovarnik – Rijeka (EMV) and Ogulin – Solin (DMV) routes, and it was adapted based on the parameters of railway route length and the number of driving machines.

Table 2. Costs on railroad direction based on the criteria of a traction length (rt) [27, 28]

Direction m=1600 tonnes	**Fuel costs**						**Traction length (*rt*)**
	EMV		DMV		EMV + DMV		
	EUR	EUR/t	EUR	EUR/t	EUR	EUR/t	
Tovarnik – Rijeka (*z1*)	5930	**3.71**					1582 (*s1*)
Tovarnik – Ogulin (*z2*)	3481						1203
Ogulin – Solin (*z3*)			18,030	11.27			2263
Tovarnik – Solin (*z4*)					21,511	**13.44**	3466 (*s2*)
Tovarnik – Bihać – Solin (*z5*)					15,197**	**9.49***	2248 (*s3*)

**estimation based on transport costs of the remaining observed sections in the table*

Table 3 shows the dynamics of energy source costs according to the default settings, i.e., the effects of realization of investments in electrification and combined electrification and modernization of the observed railways on the cost of transportation. Electrification of railways presupposes exclusively EMV traffic. Electrification and modernization of railways also imply a complete reconstruction of the sections of the observed railways, which reduces the total length of railway traction (*rt*) and the number of locomotives (engines) in use.

Table 3. Potential fuel costs after electrification (x1, x2, x3) and railway electrification and modernization (x4, x5, x6) with total traction lengths [27, 28]

Direction	Electric energy costs *x*		Traction length *s* in *km (rt)*
ELECTRIFICATION	*EUR*	*EUR/t*	
Tovarnik – Solin [*x1=z1* (s2/s1)]*	12,992	8.12	3466 (*s2*)
Ogulin – Solin *(x2=x1-z2)*	9511	5.94	2263
Tovarnik – Bihać – Solin *(x3)*	5638	3.52	2248
ELECTRIFICATION AND MODERNIZATION			
Tovarnik – Solin [*x4=z1*(s3/s1)]*	8130	5.08	2169 (*s3*)
Ogulin – Solin [*x5=z1*(s4/s1)]*	3621	2.26	966 (*s4*)
Tovarnik – Bihać – Solin** *(x6)*	1879	1.17	1686

***Estimation based on transport costs on the remaining observed sections in the table*

The realization of hypothetical investments significantly reduces transportation costs per ton and consequently strengthens the competitiveness, attractiveness, accessibility, and importance of the central Dalmatian seaports and increases the carriers' profitability.

The cargo distribution projection among the central Dalmatian ports, taking into consideration the setting up of traffic on the Una railway and excluding the potential effects of additional modernization, is shown in Table 4. The assessment of the available cargo in the port hinterland is set as a low, conservative limit of availability, which would be distributed among the central Dalmatian ports following the existing relations of the average share of the total traffic.

Table 4. Projection of cargo distribution among central Dalmatian ports following revitalization of the Una railway

Sea ports	Average share in total traffic (2017 – 2022)	Estimation of the available cargo ~ 3 million tonnes
Split	81%	2,430,000
Zadar	11%	330,000
Šibenik	8%	240,000

The estimation of 3 million tons of available transit cargo in Dalmatian ports due to the revitalization of the Una railway is the result of historical traffic indicators recorded during the 1980s (about 2 million tons), the transfer of part of the cargo from the Lika railway to the Una railway due to the shorter distance and lower transportation costs

(about 500,000 tons of cargo) and additional cargo due to the expansion of the total port hinterland (500,000 tons).

4. Discussion

The unsatisfactory condition of the railway infrastructure is one of the factors of the stagnation of the central Dalmatian ports due to the outdated and expensive Lika railway and the suspension of traffic on the Una railway. That limits their gravitational area and prevents development despite numerous comparative advantages within the framework of geographical, traffic, technical, and organizational factors of competitiveness. Increased transport costs and limited traffic, especially on the return trip, when trains are returned empty towards the heartland, diminish the financial business aspect. When comparing the existing transport costs per unit of transported cargo, which are the consequence of EMV and DMV train traffic in the observed directions, a significant difference is observed in the energy sources costs which are generated on the reference electrified route Tovarnik – Rijeka (3.71 EUR/t) compared to directions of the Lika railway, on the route Tovarnik – Ogulin – Solin (13.44 EUR/t), and the Una railway (if reopen but without electrification and reconstruction), on the route Tovarnik – Bihać – Solin (9.49 EUR/t). However, with the premise of the re-electrification of the Una railway, its competitiveness in terms of transportation costs increases significantly compared to the Lika railway. In addition to the lower costs of energy sources (fuel) of the Una railway obtained in this research, the profitability of service providers in railway transport will greatly depend on the level of railroad electrification and modernization. The Una railway electrification will reduce fuel costs by 63%. In the case of electrification and reconstruction of the Una railway, costs would be reduced to around 1.17 EUR/t., i.e., 88% reduced when compared to the initial cost amount per unit of transported cargo. According to such projection, transport costs would be as much as three times reduced compared to reference values on the Tovarnik – Rijeka railroad. The stated facts indicate the importance of traffic revitalization, but also the Una railway reconstruction in the context of strengthening economies of central Dalmatian ports and expanding the port hinterland to new, currently unavailable markets due to the unsatisfactory condition of railway infrastructure. The Lika railway electrification would reduce transport costs by 40%, while modernization and electrification reduce transport costs by up to 63% compared to the existing cost level. Assuming the average five-year share of traffic of individual seaports in the total traffic of central Dalmatian ports, at the projected level of cargo availability in the amount of 3 million tons, as well as other traffic, technical, commercial, geographical and similar factors, the results of cargo distribution indicate the predominance of the Port of Split (81%) receiving more than 2.4 million tons of cargo, followed by the Port of Zadar (11%) and the Port of Šibenik (8%). Recent investments in the port infrastructure of the Port of Zadar and planned investments in the Port of Šibenik could have a significant effect on relations

between ports regarding the distribution of available cargo due to the revitalization of the Una railway and modernization of the Lika railway. In perspective and based on technical/technological and traffic limitations of the Port of Split, the aforementioned ports could have a more significant participation in the available cargo market and thus justify investments in port infrastructure. These projections do not take into consideration the modernization of the seaports with the increase in capacities and a complete revitalization of the Una railway, the realization of which expects an additional flow of goods and the opening of new perspectives.

With the revitalization of the Una railway, the central Dalmatian ports are connected to the markets of Central and Southeast Europe, especially Hungary, and Serbia, the north-western part of Bosnia and Herzegovina, remote areas of Croatia (Posavina, Slavonia) and the port of Vukovar with a connection to the Rhine-Danube corridor. The average annual traffic on the railway until 1990, approx. 2 million passengers and 4 million tons of cargo, suggests the revitalization of the entire region and a quick return on investment [22]. Bosnia and Herzegovina has abundant natural resources and minerals traded on the international market, and the following commercial activities are particularly significant: transportation of cellulose wood from Ripač and Bosanska Krupa stations to Austria and Italy, manganese ores from Bosanska Krupa (Otokla) station, iron ores from Bihać, plaster from Kulen Vakuf and numerous other raw materials which may become drivers for economic growth for both countries. The potential tourism development, with the attractive flow of the Una River and a shorter journey from Zagreb to Split, benefits passenger transport. Optimizing transportation costs and reducing the total distance between the north and south of Croatia, increasing the capacity of the railway, and electrifying the entire section ensure more affordable and more competitive transportation compared to other traffic routes. Reduced environmental pollution by using electricity, based on the principles of sustainability, additionally reaffirms the prosperity of the route. A graphical representation of the existing and projected markets of the Port of Split is shown in Figure 9.

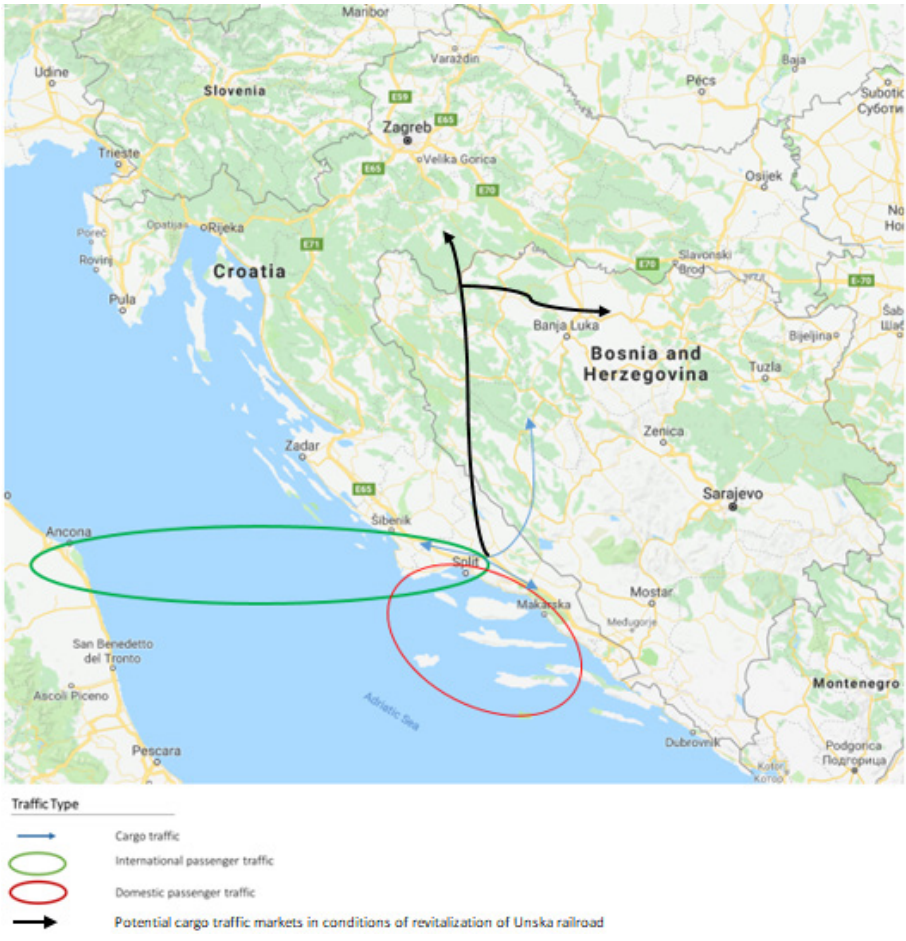


Figure 9. Existing and projected markets of the Port of Split [32]

In the context of the revitalization of the Una railway, the following fact is highlighted: the current state of the active railway infrastructure touching the Dalmatian port (the Lika railway) is worrying, insufficient, and limiting, preventing development according to market requirements. The trend of shifting cargo from the road to the railway is widely accepted throughout the EU [33], and the reduced external costs of electrical railways and negligible traffic congestion outweigh investments in railway infrastructure [34]. In addition, in 1983, Spenny and Mott concluded that the net return on investment in the electrification of railways in the USA exceeded all projection expectations [35]. Nevertheless, the ultimate objective is the abolition of fossil fuels and the transition to renewable energy sources, including the production of electricity

[36], so expectations of a quick net return are reduced. Climate protection is expensive but necessary.

Taking into account that this is a projection, some categories of estimates are probably overestimated, and others are underestimated (e.g., certain types of cargo that were not available before are available now and, analogously, certain goods that were transported are no longer subject to trade), while potential internal and external factors were not considered (e.g., anthropogenic and natural disturbances). The limitation of this research was also the impossibility of collecting generated data in Bosnia and Herzegovina, so it is necessary to conduct field research to collect real data on potential goods that would be diverted to central Dalmatian ports in the case of reopening of the Una railway. That includes the ports of Split, Zadar, and Šibenik, i.e., main concessionaires conducting business in certain port areas, as well as the existing and potential companies that own cargo. Given that the research has relied on the reference railway line Tovarnik – Rijeka, it is suggested that in the next stages of the research, the calculation of transport costs on the analyzed railway lines should be carried out in cooperation with the railway infrastructure manager and existing service providers. Such an approach would certainly contribute to an increased objectivity and trustworthiness of research results.

5. Conclusion

The competitiveness of seaports depends to a large extent on an efficient railway network, i.e., logistic activities that significantly increase railway quality, thus enabling efficient cargo distribution in the port hinterland as a primary demand point. This research results show that the revitalization of the Una railway significantly influences the reduction of transport unit price while strengthening competitiveness, attractiveness, availability, and importance of central Dalmatian seaports and increasing the profitability of railway transport. Even without the reconstruction and modernization, the Una railway shows comparative advantages over the Lika railway regarding the use of drive mode, route length, and longitudinal profile, opening new markets and sustainability. In transport cost items, the complete renovation of the Una railway would represent serious competition to the reference railway, the Tovarnik – Rijeka route.

6. Literature

1. Floridarail (2022), 4 Sustainability Benefits of Rail Freight Transportation. Available from: https://www.floridarail.com/news/4-sustainability-benefits-of-rail-freight-transportation/ (accessed on 23 November 2022).
2. PCC Group (2022), Advantages of rail transport. Available from: https://www.products.pcc.eu/en/blog/advantages-of-rail-transport/ (accessed on 24 November 2022).
3. Dragić, Ž., Ivezić, T. (2008), Industrijski kolosijeci i konkurentnost željeznice u prijevozu robe, Željeznice 21 2008; 7(3):24-36.
4. Pupavac, D. (2017), Zaposlenost u željezničkom prometu: pogledi unatrag i pogled u budućnost, Željeznice 21 2017; 16(4):7-13.

5. Hrvatske Željeznice (2020), Godišnje izvješće 2019, Zagreb. Available from: https://www.hzinfra.hr/wp-content/uploads/2020/10/Godisnje-poslovno-izvjesce-za-2019..pdf (accessed on 10 January 2024)
6. Klečina, A., Štefičar, S. (2010), *Revitalizacija industrijskih kolosijeka*, Savez za željeznicu, Zagreb, p. 23.
7. Bogović, B. (2006), *Prijevozi u* željezničkom *prometu*, Zagreb: Fakultet prometnih znanosti.
8. Palnik, L. (2018), 6 Surprising Advantages of Rail Transport Over Road Transport, Available from: https://www.partnership.com/blog/post/6-surprising-advantages-of-rail-transport-over-road-transport (accessed on 23 November 2022).
9. Najman, E. (1969), *Električna vuča i elektromotorna vozila*, Tehnička enciklopedija, III, 44/45, pp. 689-706, Leksikografski zavod Miroslav Krleža, Zagreb. Available from: https://tehnika.lzmk.hr/tehnickaenciklopedija/elektricna_vuca_i_elektromotorna_vozila.pdf (accessed on 23 November 2022).
10. La Solar Group (2022), How much electricity are trains using? Available from: https://la-solargroup.com/how-much-electricity-do-trains-use/#:~:text=Diesel%20electric%2C%20electricity%20or%20steam,the%20beginning%20days%20of%20railroads (accessed on 23 November 2022).
11. HŽ Infrastruktura (2022), Ekološke prednosti željeznice. Available from: https://www.hzinfra.hr/naslovna/drustvena-odgovornost/ekologija/ (accessed on 23 November 2022).
12. Mann, J. (2022), Infrastructure investment to accelerate rail decarbonisation, Railway Technology, October 18, 2022. Available from: https://www.railway-technology.com/features/infrastructure-investment-to-accelerate-rail-decarbonisation/?cf-view (accessed on 11 January 2024).
13. NPROXX (2021), How Hydrogen-powered trains can solve the electrification gap, 11th November 2021. Available from: https://www.nproxx.com/how-hydrogen-powered-trains-can-solve-the-electrification-gap/ (accessed on 11 January 2024).
14. Massel, A. (2018), Operational criteria in the justification of electrification of railway lines, MATEC Web of Conferences 180, 06005. Available from: https://doi.org/10.1051/matecconf/201818006005 MET'2017 (accessed on 11 January 2024).
15. Leksikografski zavod Miroslav Krleža (2023), *Unska* željeznička *pruga*, Hrvatska enciklopedija, mrežno izdanje. Available from: https://www.enciklopedija.hr/clanak/63245 (accessed on 10 January 2024).
16. Vučić, D. (2014), Prometna povezanost južne Hrvatske, HŽ Infrastruktura, Okrugli stol 06.11.2014. Dubrovnik. Available from: https://dokumen.tips/documents/5uskotracna-zeljeznicka-pruga-gabela-uskopolje-dubrovnik.html?page=3 (accessed on 10 January 2024).
17. Jelinović, Z. (1957), *Borba za jadranske pruge i njeni ekonomski ciljevi, Građa za gospodarsku povijest Hrvatske*, sv. 6, pp.353, JAZU, Zagreb.
18. HŽ Infrastruktura (2001), Prugom Zagreb - Bihać - Knin, Željezničar - *List hrvatskih* željeznica 2001; 45(663).
19. Zenith, F., Isaac, R., Hoffrichter, A., Thomassen, M.S., Møller-Holst, S. (2020), Techno-economic analysis of freight railway electrification by overhead line, hydrogen and batteries: Case studies in Norway and USA. Proceedings of the Institution of Mechanical Engineers, *Part F: Journal of Rail and Rapid Transi*t. 2020; Available from: 234(7):791-802. doi:10.1177/0954409719867495 (accessed on 11 January 2024).
20. Sarajevo Construction (2023), Obnova Unske pruge. Available from: https://www.sa-c.net/news-archive/bih-news/obnova-unske-pruge-bih-i-hrvatska-pokazuju-spremnost-na-saradnju-pocele-konkretne-aktivnosti (accessed on 10 December 2023).
21. Bičak, D. (2018), Unska pruga ojačala bi luku u Gaženici, Poslovni hr. Available from: https://www.poslovni.hr/hrvatska/unska-pruga-ojacala-bi-luku-u-gazenici-344570 (accessed on 12 December 2023).
22. Vuko, Lj. (2021), Obnova Unske pruge značila bi novi život srednjodalmatinskim lukama, Jutarnji list, 25.05.2021. Available from: https://novac.jutarnji.hr/novac/next/obnova-unske-pruge-znacila-bi-novi-zivot-srednjodalmatinskim-lukama-i-gradovima-na-njezinoj-trasi-15075813 (accesseed on 11.02.2023.).
23. Mikuličin, I., (2018), Kako oživjeti zamrli željeznički promet, Slobodna Dalmacija 09.04.2018. Available from: https://sibenski.slobodnadalmacija.hr/sibenik/vijesti/zupanija/kako-ozivjeti-zamrli-zeljeznicki-promet-u-dalmaciji-i-gospodarski-uzdici-zvonimirov-grad-za-kninsku-je-tugu-lijek-unska-pruga-540260#&gid=1&pid=5 (accessed on 15 November 2022).

24. HŽ Cargo (2023), Troškovi prijevoza Ličkom prugom, Dionica Ogulin - Solin (M604), Interni dokumenti.
25. Wikipedia (2023), Unska pruga. Available from: https://hr.wikipedia.org/wiki/Unska_pruga (accessed on 1 September 2023).
26. Wikipedia (2019), Lička pruga. Available from: https://sh.wikipedia.org/wiki/Li%C4%8Dka_pruga (accessed on 1 September 2023).
27. Vukić, L., Rogošić, F., J. Bočina, J., Kutle, M. (2023), The Lika Railway as a Constraint Factor of Maritime Freight Transport in Dalmatian Ports, Book of Proceedings, 10th International Maritime Science Conference, May 8th&9th, 2023, Solin, Croatia.
28. Brkić, M. (2022), Osvrt na ograničenja vuče vlakova za učinkovitije povezivanje srednjodalmatinskih luka s aspekta prijevoznika RCC-HR, Split: Rail Cargo Group.
29. Lučka uprava Split (2023), Promet putnika i tereta. Available from: https://portsplit.hr/luka-split/statistike/ (accessed on 10 January 2024).
30. Lučka uprava Zadar (2023), Promet tereta. Available from: https://www.port-authority-zadar.hr/centar-za-korisnike/statistike/ (accessed on 2 August 2023).
31. Lučka uprava Šibenik (2023), Promet tereta u tonama. Available from: https://portauthority-sibenik.hr/statistika/ (accessed on 10 January 2024).
32. Vulić, L., Lušić, Z., Pušić, D., Galić, S. (2019), Trends and Perpectives of Cargo Traffic Activities in the Port of Split, Conference Proceedings of the 1st International Conference of Maritime Science and Technology *NAŠE MORE* 2019 / Koboević, Žarko (ur.) Dubrovnik: Sveučilište u Dubrovniku, 2019.
33. RailwayPRO (2023), The way Austria works for its future, Railway Pro Magazine, September 7, 2023. Available from: https://www.railwaypro.com/wp/the-way-austria-works-for-its-future/ (accessed on 11 January 2024).
34. Oxera (2017), Investment in rail: the economic benefits, Note prepared for Rail Delivery Group October 2017. Available from: https://www.raildeliverygroup.com/files/Publications/2017-10_benefits_of_investment_in_rail.pdf (accessed on 11 January 2024).
35. Spenny, C. H., Mott, G. B. (1983), Cost /Benefit Evaluation of Electrification of a U.S. Rail Network, *Transportation Research Recor*d 1983; 939:35-44. Available from: https://onlinepubs.trb.org/Onlinepubs/trr/1983/939/939-007.pdf (accessed on 11 January 2024).
36. Rozentāle, L., Mo, G.B., Gravelsins, A., Rochas, C., Pubule, J., Blumberga, D. (2020), System Dynamics Modelling of Railway Electrification in Latvia. *Environmental and Climate Technolog*ies 2020; 24(2):247-257. Available from: https://doi.org/10.2478/rtuect-2020-0070 (accessed on 11 January 2024).