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Reconstruction of Railway Transport System in the Service of the Port of Rijeka Container Terminal Development

Abstract

In this article, authors emphasize the significance of the reconstruction of the railway transport system for development of the port of Rijeka container terminal.

The most important projects related to Rijeka's rail transport system are the multimodal platform development and interconnection to the Adriatic Gate Container Terminal, and the future construction of a new high-efficiency railway Rijeka – Zagreb.

Reconstruction of the "Brajdica" railway station and building extension of the railway infrastructure has increased the loading/unloading capacity of the port Rijeka for container delivery by rail.

The aim of this article is to show how the reconstruction of the "Brajdica" railway station and terminal within the port of Rijeka container terminal has improved the efficiency of the dispatch/delivery of containers by railway.

Construction of a new high-efficiency railway Rijeka - Zagreb will create a significant shortening of railway connections of Southeast Europe with its central and western parts and will improve conditions of traffic exploitation, i.e. future development of the port of Rijeka container terminal.

Keywords: railway transport system, railway station Brajdica, the port of Rijeka container terminal, the Adriatic Gate Container Terminal, high-efficiency railway Rijeka - Zagreb

1. Introduction

The development of the Trans-European rail network has covered the Croatian territory through the transport corridors and their branches. Although investments in the rail network of the Republic of Croatia have been neglected for decades, the tendency of investments in rail transport has gradually increased in recent years, as there is a significant potential for increasing freight transport by rail [1], [2].

An important prerequisite for the efficient operation of Rijeka as a transit port for Central European countries and for further economic development of the area in its hinterland is the modernization of land transport links between the hinterland and the port. The existing land connections, railway in particular, do not meet modern technical and transport requirements [2].

Current investments in development and modernization of the port of Rijeka are not accompanied by development of the railway infrastructure in the hinterland [3]. Therefore, the reconstruction will include a complete overhaul of the existing railway transport node with the modernization of the tracks on the part of the railway line Botovo - Zagreb and construction of a highly efficient railway line Zagreb - Rijeka.

With the completion of the trans-European corridors on the territory of the Republic of Croatia, the port of Rijeka will have a connection to the European transport infrastructure, i.e. to other transport centers in Central Europe.

Based on the financial resources allocated to management and supervision, maintenance, reconstruction and modernization, efficient railway systems create a high level of productivity and transport capacity [4].

Various methods and techniques such as GNSS method and Intelligent Expert Combination Weighting Scheme are used for quality reconstruction of railway infrastructure. The analysis has shown that the accuracy of track axis reconstruction using mobile GNSS [5] measurements is suitable for use in rail transport. By applying the scheme, authors [6] use the method objectively and reasonably for study of the expert weight in group decision making and they also evaluate the railway reconstruction program. Authors of the article [7] analyze the evaluation of applicability of the mobile laser scanning method. The obtained results are compared with those of the stationary measurement method used in the railway industry. In addition, the MLS method is successfully used for railway infrastructure monitoring. It is explained in more detail and provides a new approach to detect structures in accordance with the geometry of the railway line.

Several articles underline the importance of energy saving as one of the most important components, which is extremely important in terms of sustainability of the railway infrastructure. Authors of the article [8] analyze how sustainability is interpreted and evaluated in early phases of major public investments. Authors [9] determine specific characteristics of railway corridors and identify problems and cultural-historical specifics related to the industrial cultural heritage of the railway. According to author analysis [10], there is a possibility of applying multi-criteria methods to select the route

variant most favorable for the environment.

In many examples, reconstruction of rail transportation system involves the use of simulation tools to support the design and optimization of the infrastructure process. Using simulation technology in the research [11], authors solve the problem of optimal infrastructure configuration and planning in a way that evaluates decisions and applies the appropriate methodology.

According to researches [12]–[14], simulation can also be used in infrastructure design and optimization using tactical and strategic planning tools.

Application of the simulation model is also used to calculate rail utilization. In the article [15], authors evaluate the degree of rail utilization by analyzing the volume of freight traffic. By simulating certain scenarios, models that correspond to the degree of rail utilization and greenhouse gas reduction are evaluated. In view of growing environmental awareness, the study [16] attempts to compare emissions and transit times for an environmentally and a time-oriented routing of large freight transports in the European rail/road network. By solving the problem of terminal and service selection, optimal routes for different destinations are found.

Reconstruction of rail transportation system is affected by many challenges in the design and planning of the rail transportation system in terms of continuous change and transformation. Therefore, authors [17] study the concept of railway transport service, i.e. the important factors for continuous functioning of freight transportation. Further analysis by the authors has shown that it is necessary to solve the problems of design and planning of works with reconstruction projects on the marshalling yard and the construction of a new railway transloading yard. Certainly, when reconstructing railway, it is important to examine or evaluate any potential risks of the reconstruction. In the study [18], authors examine the risk factors in the railway reconstruction, but the evaluation framework is based on the fuzzy multi-criteria decision-making approach.

The aim of this article is to analyze the impact of the reconstruction of the “Brajdica” railway station and terminal within the port of Rijeka container terminal, i.e. the Adriatic Gate Container Terminal, upon the efficiency of handling and delivery/dispatch of containers by rail.

Following the aim and purpose of the research, the working hypothesis has been defined as follows: the reconstruction of the railway transport system improves the efficiency of the dispatch/delivery of containers by railway.

2. Logistics and transport features of the port of Rijeka container terminal

The container terminal “Brajdica”, Adriatic Gate Container Terminal, is located within the port of Rijeka, at the point where the Adriatic Sea is deepest on the European mainland. In an extremely favorable position, in the naturally protected Kvarner Bay through the Kupa Valley, the “Brajdica” container terminal has the possibility to establish high quality connections with Zagreb and further through the Pannonian Plain

to the Danube region and Central Europe [19]. For this reason, the Northern Adriatic is the part of Europe that provides the closest access to the sea for the Central European countries. On the northern side of the bay, through the Postojna Gate, the terminal relates to the eastern alpine area. Furthermore, on the southern side of the Kvarner Bay, the container terminal is connected by maritime routes to the Mediterranean Sea and the area of east Suez. Within the “Brajdica” container terminal, there are located two berths with sea depth of 14.8 meters with the possibility for handling two post-Panamax vessels at the same time. At the 17-hectare terminal area, a total annual throughput of 600 000 TEU can be achieved using the terminal equipment shown in Table 1.[20]

Table 1 - Terminal equipment [20]

<i>Terminal equipment</i>	<i>Number of units</i>
Panamax container cranes	2
Post-Panamax cranes	2
RTG storage handling gantry cranes	6
RMG rail gantry cranes	2

A developed road and rail infrastructure is a key factor connecting the port with the hinterland and enabling an uninterrupted cargo flow. The location of the terminal on the strategic EU transport route Rijeka-Zagreb-Budapest as part of the Mediterranean corridor TEN -T plays an important role in the transport system of Croatia. Strategic investments in port and railway infrastructure increase the traffic capacity of this transport route and eliminate bottlenecks [21].

Table 2 - Railway distance (in kilometers) of the port of Rijeka and North European ports to certain Central European economic destinations [22]

Railway	Rijeka	Hamburg	Rostock
Budapest	592	1406	1166
Bratislava	602	1022	980
Prague	806	686	644
Vienna	580	990	984
Linz	557	911	923
Munich	563	777	876

Reconstruction and modernization of the rail network in Rijeka should follow the dynamics of the port of Rijeka development. Construction of new railway lines in the transport sector of Rijeka will solve the interconnection of the port area and connections with the hinterland. Also, construction of a new high-efficiency rail

Zagreb-Rijeka on the railway line State border-Botovo-Zagreb-Rijeka will contribute to the implementation of the European regional integration in terms of connecting the Alps-Adriatic and Mediterranean-Danube regions. In addition, construction of the high-efficiency railway will enable faster flow of cargoes from the port of Rijeka to the interior of Croatia, and through it to the Central European countries that gravitate to the port of Rijeka [23].

3. Railway traffic connecting the port of Rijeka AGCT with the hinterland

Access from hinterland is a crucial component of port competition and its significance has grown as the intermodal transport has increased. In addition to increasing the speed and capacity of hinterland transportation services, it increased competition in hinterlands which had been previously dependent on local ports [24].

A few decades ago, 90% [1] of all freights were transported by rail. Construction of new motorways brought the port of Rijeka “closer” to European cities, but it also brought an enormous decrease in the share of freight transported by rail. With the implementation of the European Union’s transport policy, the share of freight transported by rail started to increase, a trend that continued until the economic crisis of 2008. After that, the share of freight transported by rail has been gradually increasing.

The analysis of container traffic at the port of Rijeka shows a positive trend in the port turnover in the period from 2015 to 2023. Improvement of the port of Rijeka infrastructure is particularly related to the railway infrastructure. Railway transport at the port of Rijeka has increased since 2015, in particular the dispatch and delivery of containers by rail.

Table 3 - Share of land transport in container turnover on the “Brajdica” container terminal [25]

Year	Port throughput (TEU)	Road transport (TEU)	Railway transport (TEU)	Lorries %	Wagons %
2015	161 883	124 725	37 158	77	23
2016	177 401	132 984	44 417	75	25
2017	210 377	147 173	63 204	70	30
2018	227 375	162 422	64 953	71.4	28.6
2019	271 817	168 643	103 174	62	38
2020	303 626	176 746	126 880	58.3	41.7
2021	312 321	171 828	140 493	55	45
2022	373 343	197 349	175 994	53	47
2023	385 794	207 913	177 881	53.9	47.1

According to data in Table 3, the container throughput in the eight-year period shows an increase by almost 140%. In the year 2015, the share of railway transport in the total container throughput was by 54% lesser than the road transport. Despite the liberalization of railway transport in Croatia in 2014, the largest increase in dispatch and delivery of containers by rail was achieved in 2019 [26]. In 2023, the dispatch/delivery of containers by road amounted to 54% TEU and by rail 46% TEU. Therefore, the share of container freight in road transport is still larger than in rail transport. In addition, it is important to note that the dependence on road transport has gradually decreased. Compared to 2015, the share of containerized freight was by 23% lesser in the total amount dispatched/delivered by road in 2021.

4. Reconstruction of railway infrastructure of the port of Rijeka container terminal

Once started, the liberalization of the railway sector moved the focus from investments in road transport to investments in railway infrastructure. As part of the development of a multimodal platform at the port of Rijeka and the connection with the “Brajdica” container terminal, reconstruction of railway station “Brajdica” was carried out and an intermodal container terminal was built. Reconstruction of the station and construction of a new container terminal are intended to meet technical requirements for interoperability in accordance with Directive 2008/57 / EC and technical specifications for interoperability (TSI) for the conventional rail system of the Trans-European Rail network [27].

4.1. Reconstruction of the “Brajdica” railway station and terminal

The “Brajdica” container terminal, i.e. its yard, berth and operational area were upgraded in the year 2013, increasing its annual capacity to 600,000 TEU. To expand the capacity of the railway station of “Brajdica”, reconstruction measures were also necessary. Reconstruction works started in the same year and ended in September 2020. The modernization includes the extension of the reception and handling tracks, connection of the terminal to the station, provision of the station with the necessary equipment, and construction of a horizontal extractor in the tunnel along the existing railway line. Three stages of reconstruction were planned for the Rijeka railway station and the “Brajdica” container terminal. [28]:

- Stage 1a - Construction of the “Brajdica” container terminal
- Stage 1.b - Reconstruction of the “Brajdica” railway station
- Stage 2 - Construction of a new shunting track

Reconstruction stages were further divided into phases. Accordingly, phase 1.a was divided into phase 1.a.1, which included construction of the „Brajdica“ container terminal i.e. the railway part of the terminal, and phase 1.a.2, which included

construction of the connection of the terminal tracks with the railway, reconstruction of the connection of railway station “Brajdica” with the breakwater and construction of foundations and piers of the contact network [28]

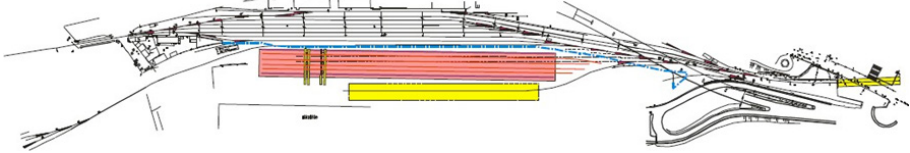


Figure 1 - Phase 1.a.1.[28]

Phase 1.a.1. included construction of crane tracks and of storage and handling areas of the “Brajdica” container terminal, construction of tracks, switches, drainage and water supply of the “Brajdica” container terminal, electrical works and foundations, piers and portals of the contact network of the “Brajdica” terminal.

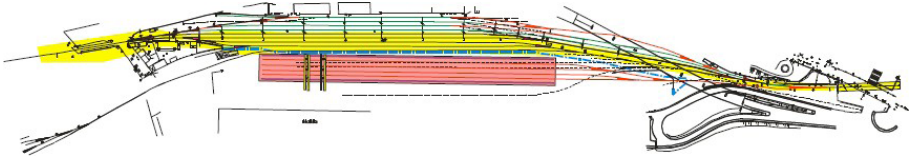


Figure 2 - Phase 1.a.2.[28]

Phase 1.a.2 included construction of the connection of the terminal track to the railway, reconstruction of the connection of the “Brajdica” railway station to the breakwater, construction of an access ramp for fire-fighting vehicles, and foundations and piers of the connection network to the existing track.

Stage 1.b. was divided into five phases. These five phases included reconstruction of tracks of the Rijeka “Brajdica” railway station, construction of facilities for signal-security, telecommunication devices, and power plant, and construction of foundations, pillars and portals of the contact network. In addition, construction of the contact network in the reconstructed railway station “Brajdica”, construction of the contact network on the upper edges of the container terminal tracks, and installation of signal-safety and telecommunication devices [26]

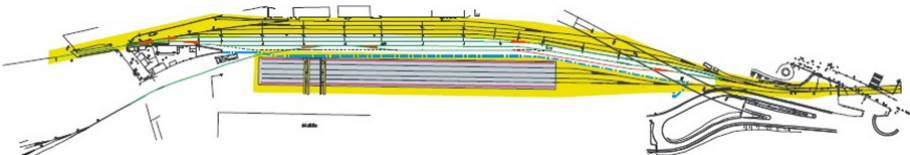


Figure 3 - Phase 1.b.1.[28]

The last stage, shown in figure 4, consisted of a single phase. That phase included construction of a new shunting track, widening of the tunnel, rerouting of the existing track in the tunnel, and a contact network for this phase.

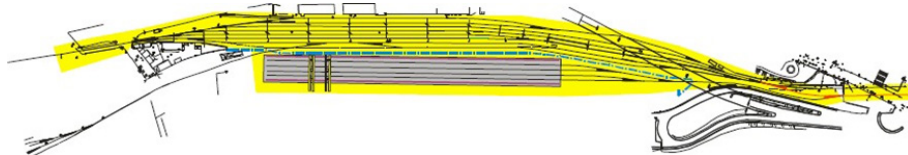


Figure 4 - Stage 2 [28]

Reconstruction of the uppermost and lowermost of the eight tracks, contact networks, and the station lighting renewal, and facilities were built for the signal-safety device, the telecommunication device, and the diesel generator. In addition, 4 new tracks, crane tracks, a parking zone, and a rainwater separator were built on the premises of the port of Rijeka [27].

4.2. Construction of a new high-efficiency railway Rijeka - Zagreb

The Kupa and Drežnica variants were considered for the construction of a new high efficiency railway route between Rijeka and Zagreb. According to the Kupa variant, the route would run over the existing railway route. Taking advantage of the course of the Kupa River, the route would come closest to the Kvarner Bay at a low altitude and would be the shortest connection between Zagreb and Rijeka.

The Drežnica variant of the route is 23 km longer than the Kupa variant. Additionally, the highest point is at an altitude of 460.00 m, 195 m higher than the Kupa variant. Although the Drežnica variant has shortcomings in terms of traffic operation and maintenance, the advantage of this variant is that the route partially (about 50 km) coincides with the route of the new Adriatic railway and allow for a more convenient connection with the station on Krasica. The main reason for choosing this route is that the route of the railway shares a section of about 50 kilometers with the route of the new Adriatic railway, allowing for a more convenient connection with the Krasica station. Also, this railway route offers the possibility of developing a network of high-speed lines, as the future railway to Dalmatia would run from Drežnica.

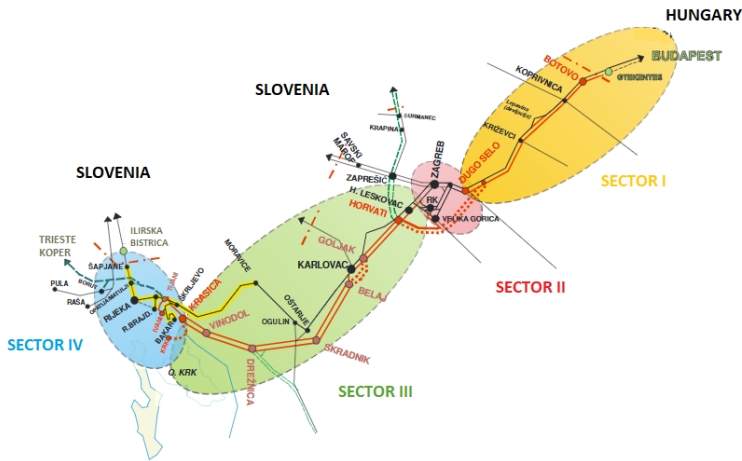


Figure 5 - High efficiency Rijeka-Zagreb railway line [29]

This route bypasses the Alps on the eastern side and is an effective transit link that is 60 km longer toward Central Europe. Accordingly, this corridor provides a practical alternative route between the Northern Adriatic and Central Europe. The use of a new railway route with effective technical aspects would double the transport capacity of the studied corridor while reducing transport costs. The annual freight capacity of the new railway route will be about 32 million tons.

With the construction of a high-capacity railway, the route would run from Zagreb via Jastrebarsko to Karlovac and then via Duga Resa and Ogulin to Josipdol. From Josipdol it would run through Velika Kapela to Novi Vinodolski. This would be the most challenging section because of the planned construction of three tunnels with a total length of 33 km. In addition, the railway route would pass Crikvenica and Kraljevica and run via Bakar to Rijeka. The shortening of the route and the introduction of high speeds would reduce travel time. Therefore, it is expected that the journey from Zagreb to Rijeka would take about one hour, compared to the current 3 hours and 45 minutes, and that the transport of goods from the port of Rijeka to Budapest would take 5 hours, which is 5.5 hours less than the current travel time.

The high efficiency Rijeka-Zagreb railway route would be a modern double-track multipurpose railway. The route of the new railway is characterized by features of a lowland railway. The railway route will not run at high altitude (Figure 6), therefore, it will also run with improved radii and less resistance. The construction of the Zagreb-Rijeka railway route would provide access to Europe and the gravitational area of the port of Rijeka on the north-eastern side.

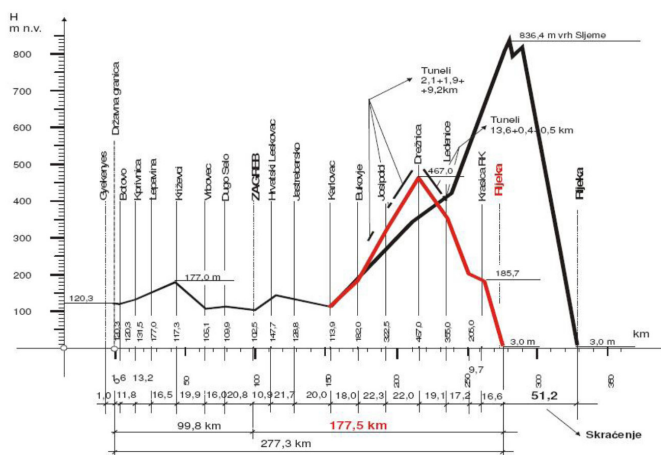


Figure 6 - Longitudinal profile of the high efficient railway line Rijeka-Zagreb [30]

Passenger trains will travel between 160 and 200 kilometers per hour, while freight trains will travel between 100 and 120 kilometers per hour. The smallest radii will be 3.5 km in the open field and 6.5 km in the tunnels. In addition, most of the route will be straight, which will shorten the distance and travel time. The finished railway route will have a gradient of up to 12.5 millimeters per meter in the open field and 8 millimeters per meter in the tunnels, which will allow for enormous transport capacity. It will also significantly reduce energy consumption and increase transport efficiency and profitability. The new railway route will have a usable length of main tracks 750 meters and the maximum permissible weight of train will be 26 t/a. In addition, a single-phase AC power operating at kV/50 AC 25 Hz will be utilized, as well as sophisticated signaling, security, and telecommunications systems following European criteria.

The current railway route State border - Botovo - Zagreb - Rijeka is 328.7 kilometers long. The new project of the lowland railway will shorten the railway route between Zagreb and Rijeka by 57 kilometers. This shortening of the route will take place in the northern section of the former Corridor V, Branch B, Dugo Selo - Botovo, due to the construction of a detour near Lepavina to prevent landslides.

5. Impact of railway infrastructure modernization on development of the port of Rijeka AGCT

The capacity and efficiency of technical equipment of ports and loading/unloading facilities are among the parameters that determine the expected cargo turnover. The modernization of land transport connections between the hinterland and the port is a

prerequisite for a continued successful operation of Rijeka as a transit port for Central European countries. The existing A6 and A7 motorways make a great contribution to the Port of Rijeka, but for greater competitiveness, a high-quality railway is necessary. The existing railway line Rijeka-Zagreb does not meet today's standards in terms of technology and infrastructure.

Construction of the Zagreb-Rijeka railway route would provide access to Europe and to the gravitational area of the port of Rijeka on the north-eastern side. In addition, reconstruction of the "Brajdica" railway station has shown a positive effect on rail transport. Before the reconstruction of the rail terminal in 2019, the share of rail transport in the total container throughput was 28%, which was below the desired share of the port operator [28]. In the same year, about 103 000 TEUs were transported by rail from the "Brajdica" station, which corresponds to 38% of the total transport. In the year 2023, 177 881 TEUs were delivered/dispatched by rail or 47% of the total throughput.

In view of the growing share of rail transport, the "Brajdica" station has started to approach the given strategic decision of the port operator to increase the share of rail transport to 60% in the total container throughput [28]. Supposing that the projection for the past year had been calculated according to the targets for the share of rail transport to be achieved in the future, the estimated number of dispatched/delivered TEUs will reach around 233 000 TEUs.

The reconstruction was completed in 2020 and the terminal was put into operation in September the same year. With the reconstruction of the terminal, the capacity of the railway was increased by 25% i.e., the maximum dispatch/delivery capacity was 12 trains per day and now it is 15 trains per day. In analyzing the capacity for potential number of containers that can be transported from the container terminal to the railway station, it was assumed that a four-axle wagon can hold a maximum of 3 TEU, while in this article 2 TEU were used for the analysis.

Concerning the dispatch/delivery of rail wagons in the port of Rijeka, the capacity is 48 TEU/train or 70 TEU/train per block train. By comparison, the European standard is 100 TEU per block train. Construction of the new Rijeka-Zagreb railway will ensure long-term transport with an average of 70 TEU/train.

Analyzing the railway statistics of the port, the average number of dispatched/delivered trains in 2023 was 9 or 43 TEU/train. The difference of 5 TEU per each train in relation to the maximum train capacity occurs as a result of wagons conjunction at the rail station, thus enabling proper train composition. That means that a distinct number of trains are dispatched and delivered from/to customers with reduced capacity.

The expansion of the Rijeka railway junction is linked to the growth of the port of Rijeka. The planned expansion strategy of the port of Rijeka cannot be implemented without adequate railway modernization and track construction. Efforts to build an efficient railway network are also useless if they are not coordinated with plans for modernization of the port [2].

6. Conclusion

Inclusion of the port of Rijeka in the Mediterranean corridor is important for the development of the port itself and for strengthening its connections with the hinterland. Development of the port of Rijeka should be seen in the context of development of the port infrastructure. The importance of the reconstruction of the container terminal “Brajdica”, Adriatic Gate Container Terminal, as well as the railway station, is emphasized by the increase in maritime transport and delivery of containers. Furthermore, the reconstruction of the “Brajdica” terminal has improved transport services and infrastructure. In addition to the basic rail network, Croatian and European connectivity has been improved and transport of containers to and from ships has been facilitated using railways. In line with interoperability and intermodality requirements, the capacity of the railway station and container terminal at Brajdica was also significantly increased. This supports the development of the port of Rijeka into an efficient and sustainable entry and exit point for container and other freight traffic, better connected to the Mediterranean Corridor, the Rhine-Danube Corridor and the Baltic-Adriatic Corridor.

This study found that the reconstruction of the “Brajdica” railway station had a positive impact on the increase in maritime transport and delivery of containers by rail. In 2015, there were 50% more containers transported by road than by rail. In 2023, this percentage was decreased and only 20% more containers were transported by road than by rail. Although shipment and delivery of container freight by road is still represented, it can be concluded that this representation is gradually weakening, and rail transport is gradually becoming stronger. With further development of the transport infrastructure, i.e. the construction of the new, high-efficiency Rijeka-Zagreb railway line, an increase in rail freight is expected.

One of the objectives is to support the shift of container transport from road to rail, which is certainly in line with the European Union’s efforts to transport as much freight as possible by rail instead of road for environmental reasons. In addition, the modernization and reconstruction of traffic routes between the Rijeka hinterland and the port will promote further growth of Rijeka as a transit port for Central European countries as well as growth and development of the hinterland region.

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