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# Proposed solutions for increasing the capacity of the Mediterranean Corridor on section Zagreb - Rijeka

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**Abstract**

This paper analyzes all the bottlenecks on the railway line M 202 along the section of the European Mediterranean Corridor, which is a part of the corridor located in the Republic of Croatia. Upon the identification and analysis of these bottlenecks, new technical and technological solutions will be put forward for increasing the capacity of the railway line, i.e. the sections with bottlenecks. The researched bottlenecks on the observed section will be quantified according to the technological indicators of timetable quality and several other parameters (travel time, the manner in which trains depart in certain directions and the maximum utilization of the existing capacity). The potential solutions will be assessed by determining the railway infrastructure fees. A simulation software tool OpenTrack will be used for potential technological solutions.



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*Keywords:* Mediterranean corridor RH2; bottlenecks; utilizing railway track capacity; simulation of technological process; simulation analysis; Opentrack.

## Introduction

The railway line M202 Zagreb – Rijeka was built in 1873 and is still a highly significant railway link for the Republic of Croatia. As an international traffic corridor, it connects the Adriatic Sea, which is the Adriatic gateway to Central Europe. The line is of crucial importance for connecting the international port of Rijeka, as the port with the

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most favorable geographic and transport location in the Northern Adriatic. At the same time, the capital Zagreb with its capacities on the marshalling yard may support the port of Rijeka as a dry port, i.e, a background terminal of the port. Because of the railway line's significant exploitation importance for the Republic of Croatia, i.e. merging the traffic junction Zagreb-Rijeka, it is essential to maximize its capacity before the construction of a completely new line with high efficiency and transport capacity. For such a construction to be justified, there would need to be substantial financial investments and a large quantity of goods waiting to be transported.

## 1. The Analysis of Railway Line M 202 Zagreb – Rijeka

The railway line Zagreb – Rijeka (CRF corridor 6) was built in 1873 during the reign of the Austro-Hungarian monarchy over Croatian territory. It stretches throughout the country from the Hungarian border, over the railway and traffic junction Zagreb and central Croatia, Gorski Kotar, the lowest point of transit in the Dinara mountain range (continuation of the Alps), ending in the railway traffic junction and the port of Rijeka. Table 1 outlines the distances of major ports over the Northern Sea or the Northern Adriatic to Central Europe. [2], [3]

Table 1. The comparison of distances of Northern Adriatic and North Sea regions

| Port | Northern Adriatic (Nm) | North Sea (Nm) |
|---|---|---|
| Port Said | 1.294 | 3.564 |
| Bombay | 4.340 | 6.610 |
| Singapore | 6.308 | 8.578 |
| Hong Kong | 7.767 | 10.037 |
| Pusan | 9.169 | 11.466 |

Source: Port of Rijeka authority

### *2.1 The Features of M 202 Zagreb – Rijeka*

The railway line Zagreb – Rijeka, its construction, available funding and the technical achievements back then ensured a 230 kilometers route. A larger part of it passes through a demanding terrain as shown in Figure 1, together with the altitudes of the train stations. some sections of the track have reached their maximum transport capacity. Table 2 shows the sections and capacity usage calculations based on UIC 406. The railway track Zagreb – Rijeka is a single-track with the following inclination (slopes and downfalls) and the curve radius of the finished level:

1st section Zagreb GK. Karlovac up to 7 per mil, curve radius higher than 500 meters. 2nd section Karlovac – Moravice up to 9 per mil, curve radius between 300-500 meters, 3th section Moravice – Lokve up to 17 per mil, curve radius lower than 300 meters, 4th section Lokve – Rijeka up to 17 per mil, curve radius lower than 300 meters. [5]

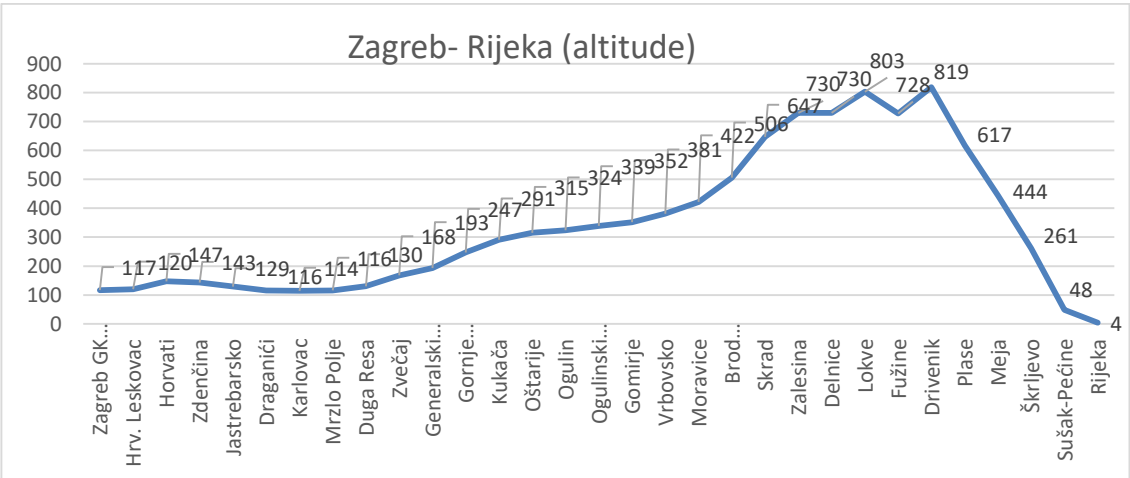


Fig. 1. The altitude of each train station along the M 202 railway line [6]

The service speeds at certain sections are listed in Table 2. The passenger and cargo trains on the M202 and analyzed sections travel at approximately same speeds: section Zagreb GK (or Zagreb marshalling yard) – Karlovac at about 85 km/h, Karlovac – Moravice at 65 km/h, Moravice – Lokve 70 km/h on average and section Lokve – Rijeka at about 55 km/h. [4], [5], [6]

Table 2. The list of train stations along the railway line with the number of tracks, speeds and the section capacity [5], [6], [8]

| Train station | Rail tracks | Usable length | Maximum speed allowed [km/h] | Driving speed – cargo train [km/h] | Driving speed – passenger train [km/h] | Speed in turning [km/h] | Utilized capacity based on UIC 406 |
|---|---|---|---|---|---|---|---|
| Zagreb GK (Zg marshalling yard) | 2* | 376 | 110 | 30 | 30 | 30 | |
| Hrv. Leskovac | 5 | 609 | 110 | 100 | 100 | 40 | |
| Horvati | 2 | 625 | 110 | 100 | 110 | 65 | 83,85% |
| Zdenčina | 3 | 504 | 110 | 100 | 110 | 50 | |
| Jastrebarsko | 3 | 519 | 140 | 80 | 90 | 40 | |
| Draganići | 4 | 484 | 100 | 100 | 100 | 50 | |
| Karlovac | 11 | 598 | 100 | 80 | 80 | 35 | |
| Mrzlo Polje | 2 | 557 | 80 | 75 | 80 | 20 | |
| Duga Resa | 3 | 517 | 80 | 80 | 80 | 40 | |
| Zvečaj | 2 | 713 | 80 | 80 | 80 | 20 | 99,85% |
| Generalski Stol | 3 | 592 | 80 | 60 | 60 | 20 | |
| Gornje Dubrave | 4 | 472 | 60 | 60 | 60 | 20 | |
| Kukača | 2 | 560 | 60 | 60 | 60 | 20 | |
| Oštarije | 4 | 549 | 60 | 60 | 60 | 40 | |
| Ogulin | 7 | 626 | 140 | 20 | 20 | 20 | |
| Ogulinski Hreljin | 2 | 642 | 70 | 75 | 75 | 50 | 56,99% |
| Gomirje | 2 | 588 | 70 | 70 | 70 | 20 | |
| Vrbovsko | 2 | 668 | 70 | 70 | 70 | 20 | |
| Moravice | 10 | 804 | 70 | 70 | 70 | 40 | |
| Brod Moravice | 2 | 444 | 70 | 70 | 70 | 40 | |
| Skrad | 3 | 388 | 70 | 70 | 70 | 40 | 65,69% |
| Zalesina | 2 | 423 | 75 | 70 | 70 | 40 | |
| Delnice | 3 | 394 | 75 | 65 | 65 | 40 | |
| Lokve | 4 | 397 | 75 | 75 | 75 | 40 | |
| Fužine | 4 | 348 | 75 | 75 | 75 | 40 | |
| Drivenik | 3 | 415 | 75 | 70 | 70 | 40 | 88,56% |
| Plase | 3 | 414 | 70 | 65 | 65 | 40 | |
| Meja | 3 | 362 | 70 | 65 | 65 | 40 | |
| Škrljevo | 5 | 406 | 70 | 70 | 70 | 35 | |
| Sušak-Pećine | 3 | 431 | 70 | 40 | 70 | 35 | 89,76% |
| Rijeka | 10 | 371 | 80 | 20 | 20 | 20 | |

*GK passenger train station – the number of rail tracks intended for arriving and departing cargo trains.

## 3. Bottlenecks on M 202 Zagreb – Rijeka

Bottlenecks are defined as places of limited train traffic due to a certain technical or technological issue. Such places are usually train stations, open tracks or the entire section of a railway line. The bottlenecks can occur during the planning phrase due to the configuration of the terrain, i.e. the area of the railway section. The only steps to avoid these situations are financially demanding and complex technological and construction solutions, e.g. tunnels, viaducts, or giant dams. Another type of bottlenecks occurs in cases of certain organizational lapses and these become evident during the exploitation phase due to the inadequate planning and elaboration of technology in the process of railway and station planning and construction, that is, the defining of the purpose of certain official places. [1]

### *3.1. Potential Solutions of Bottlenecks*

There are certain organizational and restorative or investment measures that can be taken to remediate the bottlenecks.

#### *3.1.1. Organizational Measures for Solving Bottlenecks*

Some of the organizational measures that can be taken in order to fix the issue of bottlenecks include an increase of cargo train weight, using kinetic energy of cargo trains, using multiple haul types (pusher locomotives, banking engine and double heading), connecting trains, pusher-rack train station intervals, increasing train speed, changing the chart type, central regulation of train traffic, fitting a single track on a double-track railway with safety devices that enable two-way traffic, block train traffic movement, train traffic in time intervals, a better use of wagon deadweight and the allowed axle weight. [1]

#### *3.1.2 The Reconstruction Measures for Solving Bottlenecks*

Some measures of reconstructions or investments that can be taken to solve bottlenecks, i.e. the permeability and transport capacity of the railway include: implementing signaling and safety devices in order to reduce train station intervals, introducing a modern information management system, fitting the track with a system of automatic block signaling, equipping train stations for junctions or overtaking without halting, increasing the number of train stations for train level junctions, extending the train station tracks, a partial construction of a double-track line, introducing modern train haul types (multi-system locomotive, locomotives specialized for heavy cargo train haul), railway electrification, changing the longitudinal section, increasing the axle weight capacity of the track and the traffic capacity of train stations (through reconstruction and appendage). [1] This paper will attempt to offer solutions to the aforementioned steps, first and foremost through specific organizational measures that will be simulated within this model. There are some sections along the M202 that will be described here as well.

### *3.2. Potential Solutions to Bottlenecks on M202 Zagreb – Rijeka*

The bottlenecks are identified by calculating the existing utilized capacity at certain sections. The sections that will be analyzed are Generalski Stol – Gornje Dubrave, Drvenik – Plase and Škrljevo – Sušak Pečine illustrated in Figure 2. Since the capacity of the first section can be increased by increasing the speed at which trains arrive at the station (when turning), this section will not by further analyzed. [3] At station Škrljevo the track separates into Škrljevo – Bakar where there are bulk cargo terminals, or towards Šioći, with liquid cargo terminals. Therefore, the section that will be analyzed is Drvenik – Plase which is operating at highest capacity due to its geographic position and altitude.

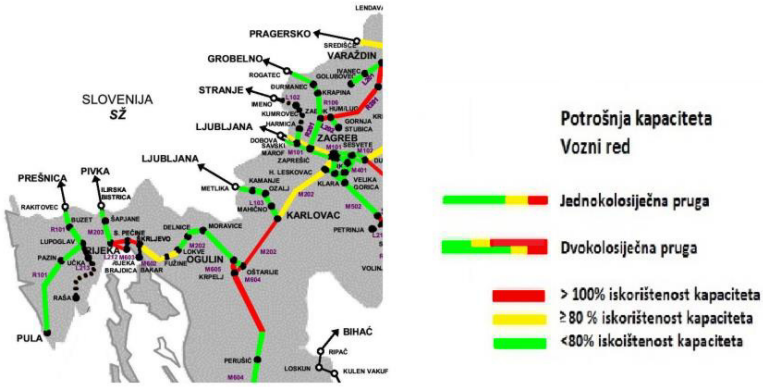


Fig. 2. Capacity utilization on railway line M202

## 4. A List of Solutions and Simulations of the Proposed Steps

According to the existing timetable of the railway line Zagreb – Rijeka, the maximum weight of trains operating on section Zagreb – Moravice amounts to 1600 tons, whereas the Moravice – Rijeka section is operated by trains weighing 1204 tons. In the direction Rijeka – Zagreb, the train weight is 860 tons on section Rijeka – Lokve, and 1702 tons on section Lokve – Zagreb. The units used for hauling trains on sections Moravice – Rijeka and Rijeka – Lokve are mainly class 1141 (banking and haul), while the section Zagreb – Moravice and Lokve – Zagreb is operated only by the haul locomotive class 1141. [7] The foreseen solutions include the following initial parameters. Cargo trains from Zagreb to Rijeka would weigh 2800 tons until they reach Moravica station, hauled by two locomotive units class 1141. From Moravice to Rijeka, four locomotives would haul two trains, each train weighing 1204 tons, and an additional train with a locomotive weighing 400 tons. The two trains traveling in the opposite direction would weigh 860 tons hauled by two 1141 class locomotives, due to the technical condition of the track. These would then join at station Lokve into a single train weighing 1780 tons hauled by a single 1141 series locomotive all the way to Zagreb. The remaining three locomotives would be transferred to station Moravice from where the cargo would depart for Rijeka. This simulation was carried out in such a way that passenger trains operating on this section would not need to be moved nor would their timetable have to be altered. The situation is show in a timetable chart in Figure 3.

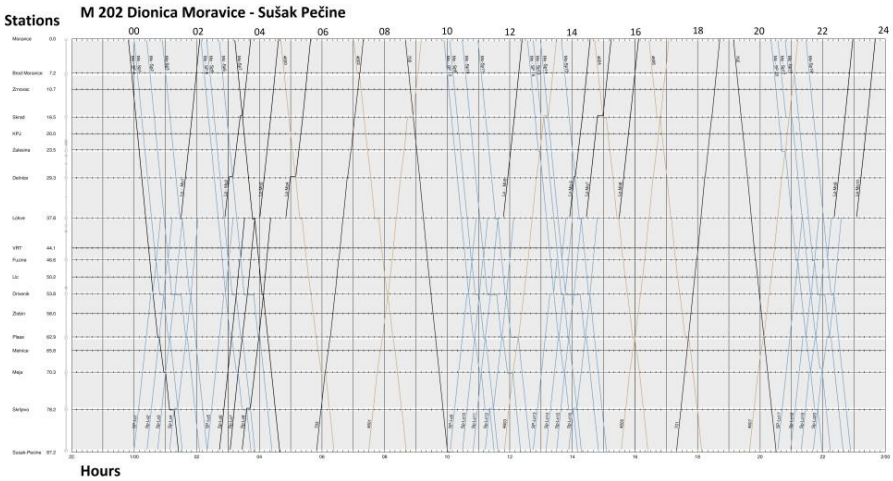


Fig.3. An illustration of train operation between stations Moravice and Rijeka

Naturally, in order to obtain more precise data, there would have to be additional intersection tracks in stations

Zagreb, Lokve, Drvenik, Plase and Meja for trains with turning speeds of minimum 40 km/h. The current railway track situation has not been altered or simulated in this paper.

## 5. Quantitative Indicators of the Quality of Timetable

The current organization utilizes 88,56 % of the capacity, which means 9 more cargo train routes may be added for it to operate at full capacity. [8] The suggested new organization structure of cargo trains reduce the capacity to 65,40 %. Passenger trains operate according to the valid timetable and real-time journey and stopping times. Since the calculation of the railway infrastructure free is prescribed separately, the average railway fee for both directions on the section Drivenik – Rijeka amounts to 673,95 HRK. The power service fee on this section is charged according to different tariffs. The higher tariff rates were used in calculations, as well as the tariff increase for the hilly areas of the railway line, which rounds up to 436,69 HRK for section and direction Drivenik – Rijeka, and 1258,25 HRK in direction Rijeka – Drvenik. [5], [7] This new structure primarily ensures greater efficiency for the infrastructure manager. The greater traffic and a better capacity utilization would yield higher profit. This could be used to modernize and reconstruct the infrastructure, solve certain bottlenecks along the track or perhaps build additional tracks or parts of the railway line which would minimize the number of bottlenecks. At the same time, the deadline for the construction of a brand new modern railway with a high transport capacity and exploitation efficiency would be extended. Another benefit that might be gained for the terminal managers and logistics companies through potential merging of the Rijeka and Zagreb traffic junction is the utilization of capacity of Zagreb marshalling yard as a dry port or background terminal of the port of Rijeka, which would offer additional logistical services and distribute goods into Central Europe.

## 6. Conclusion

The railway line Zagreb – Rijeka is of great significance for the Republic of Croatia which is why all possibilities have to be explored in order to utilize its maximum capacity, primarily in the existing organizational structure. Since the construction of a new railway line is a considerable financial undertaking, there is a need for solving certain bottlenecks in a way to change the parameters of train traffic, move train intersections and other steps. It was previously determined that the method of simulation on a real-time model various situations and changes at a train station can be simulated, which has determined that raising the curve train speed from 20 to 40 km/h increases the capacity by roughly 10 %. [3] Certain benefits can be gained in terms of higher capacity utilization by changing the organization of train movement, i.e. the manner and location of train intersections at this section of the railway, which is generally unfavorable for exploitation. Additional advantage for the infrastructure and terminal managers and logistical companies is the merging of Rijeka and Zagreb traffic junction, which means utilization the capacity of Zagreb marshalling yard as a dry port or a background terminal of the port of Rijeka. These organizational measures that can be taken might provide greater benefit for the carriers, which could become more competitive on this railway line, and with it make the port of Rijeka more competitive for new types and amounts of cargo. Through a higher capacity utilization, the financially demanding mega-project of constructing a new railway line - which would demand enormous financial means and amounts of cargo - would be postponed.

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