Simulation Analysis of Seaport Rijeka Operations with Established Dry Port

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ABSTRACT

Seaport Rijeka is the largest seaport in Croatia. It specializes in transport of cargo, with the primary activities of loading, unloading, storage and transport of general cargo, timber, bulk cargo, livestock, containers, and other cargo at five specialized terminals. It is focused on increasing the quality of services and the competitiveness of the transport routes in Croatia. Due to its favourable position on the TEN-T network, Seaport Rijeka provides the shortest maritime connection between the countries of Central and Eastern Europe as well as the overseas countries. In the past 20 years Seaport Rijeka keeps record of continuous growth in container traffic. Due to increasing demand in container traffic, it seeks for the solutions to expand. One of the possible solutions that would satisfy the increasing demand in container traffic is establishing a dry port. Dry port is an inland intermodal terminal which has direct connection to the seaport by road or rail and its main purpose is to provide logistic activities and transport to inland destinations. Dry ports have many advantages, faster transport of cargo from seaports, use of more efficient modes of transport, providing facilities for the storage and consolidation of goods, the maintenance of road or rail freight carriers, customs services, etc. In the case of container transport, dry ports can be used to outsource the logistic activities of transport process, away from congested area of seaports. Due to the fact that Seaport Rijeka is reaching the limits of its capacity, one of possible solutions of its expansion is establishing a dry port. The focus of this paper is to prove that establishing a dry port would speed up the transport process of containers between Seaport Rijeka and its destinations. Due to this hypothesis, four simulations were made. First simulation shows the transport process in the existing set-up of the Seaport Rijeka. Second, third and fourth simulation shows the transport process in the future possible set-up of the Seaport Rijeka with established dry port in Miklavje, Zagreb or Vinkovci.

1 Introduction

Seaport Rijeka is located on the strategic EU TEN-T Mediterranean Corridor and is also connected to the Baltic-Adriatic Corridor. [11] Due to its favourable position, Seaport Rijeka provides the shortest maritime connection between the countries of Central and Eastern Europe as well as the overseas countries.

The EU and Croatia are strategically and operationally supporting investments in port and railway infrastructure that raise the traffic capacity of this traffic route and eliminate bottlenecks.

Figure 1 shows the position of Seaport Rijeka in EU TEN-T and potential strategic transport directions.

Seaport Rijeka specializes in transhipment of cargo, with the primary activities of loading, unloading, storage and transport of general cargo, timber, bulk cargo, livestock, tropical and other cargo. Port of Rijeka j.s.c. with a share of 49% also manages Adriatic Gate Container Terminal, a container terminal with a concession agreement until 2041. The annual capacity of the AGCT is currently 450,000 TEUs, with a plan to expand to 600,000 TEUs. [23]

Seaport Rijeka keeps the record of continuous growth in container traffic from 1999 to 2019, although there were certain periods when several factors such as the global crisis, declining purchasing power of users, exceptional growth of competing ports or systematic neglect of
transport and logistics strategy of the Republic of Croatia caused a drop in container traffic of the Seaport Rijeka. [23] Table 1 and Graph 1 show the increase in Seaport Rijeka container traffic.

Table 1 Increase in Container Traffic of Seaport Rijeka from 1999 to 2019

| Year | Total Number of TEU Units | Increase/Decrease in Percentage (%) |
|------|---------------------------|-------------------------------------|
| 1999 | 6.866                     | /                                   |
| 2000 | 9.722                     | 42                                  |
| 2001 | 13.172                    | 35                                  |
| 2002 | 16.681                    | 27                                  |
| 2003 | 28.298                    | 70                                  |
| 2004 | 60.864                    | 115                                 |
| 2005 | 76.258                    | 25                                  |
| 2006 | 94.390                    | 24                                  |
| 2007 | 145.040                   | 54                                  |
| 2008 | 168.761                   | 16                                  |
| 2009 | 130.740                   | -23                                 |
| 2010 | 137.048                   | 5                                   |
| 2011 | 150.677                   | 10                                  |
| 2012 | 171.945                   | 14                                  |
| 2013 | 169.943                   | -1                                  |
| 2014 | 192.004                   | 13                                  |
| 2015 | 200.102                   | 4                                   |
| 2016 | 214.348                   | 7                                   |
| 2017 | 249.975                   | 17                                  |
| 2018 | 260.375                   | 4                                   |
| 2019 | 271.817                   | 4                                   |

Source: Authors according to annual reports of Seaport Rijeka container traffic [23]

For the Rijeka Seaport to increase its capacity, which will be necessary due to the increase of container traffic in past 20 years [23], and without large investments, one of the possible solutions is the construction of a dry port terminal.

Dry port is an inland intermodal terminal which has direct connection to the seaport by road or rail and its main purpose is to provide logistic activities and transport to inland destinations. [1, 3, 17, 19, 20, 21]

A well-designed dry port concept can shift cargo from the road to more energy efficient modes of transport that are less harmful to the environment, reduce congestion in cities, make handling of goods in seaports more efficient and make it easier for carriers to improve logistics solutions in seaport hinterland. [2, 6, 22, 24, 26, 27, 28]

In addition to their role in cargo transhipment, dry ports may also contain facilities for the storage and consolidation of goods, the maintenance of road or rail freight carriers and customs services. The location of these facilities on a dry port frees up storage and customs space on the seaport itself. [4, 8, 12, 18]

A dry port can speed up the flow of cargo between ships and major transport networks, creating a central distribution point. Dry ports can improve the movement of cargo, in this case containers, by moving sorting and processing of containers to dry port facilities, far away from congested seaports. [5, 7, 9, 10, 14]

Zagreb, Miklavlj and Vinkovci were chosen as possible locations, because of their geographical positions and existing infrastructure features. [13, 15, 25] Simulations were made for all three possible solutions to find the optimal solution and to see if it would speed up the transport process of cargo, specifically containers, and consequently increase the capacity of the Rijeka Seaport and eliminate bottlenecks and congestion at the Seaport Rijeka.

Four simulations of the operation of Rijeka Seaport were made. One simulation shows the operations of Rijeka Seaport in the existing set-up without established dry port and three simulations show the operations of Rijeka Seaport with the established dry port in Miklavlj,
Zagreb and Vinkovci. Simulations are made using Arena Simulation Software. Analysis of simulation results is conducted using Microsoft Excel.

Given the limitations of the simulation software, and with the purpose to obtain the most accurate results, the arrival of one ship with 130 TEU was simulated for each seaport set-up, and the simulation was repeated 30 times. For simplicity, it is assumed that each container is equal to 1 TEU. The input parameters are set up based on triangular distribution, i.e. three values: minimum, most likely, and maximum. The input parameters values are estimated for each required activity of the process based on real-life time frames, e.g. input parameters for road transport to Zagreb are 2.5, 4.5, 5 hours respectively, to Vienna are 5.5, 6.5, 8 hours, to Budapest are 5.5, 6, 7.5 hours; time spent in Temporary Storage are 6, 10, 12 days, time spent in Storage 1 are 3, 5, 9 days, in Storage 2 are 2, 3, 6 days, in Open Depot 0, 2, 2.5 days, in Closed Depot are 1, 2, 3 days, etc. The simulation uses input parameters to calculate output parameters. The simulation diagram of each Seaport Rijeka operations set-up (simulation model) is shown in following figures. Relevant output parameters of the transport process such as time and number of units as well as transport time required to destination by road or rail are shown in the following tables for each model. As 30 simulations of each model were made, the minimum and maximum time averages within these simulations are shown as well.

2 Simulation Analysis of Seaport Rijeka Operations

The simulation diagram of Seaport Rijeka operations in the existing set-up (AS-IS simulation model) is shown in Figure 2.

Table 2 shows the results of the AS-IS simulation model. As it is shown in the table, the number of containers that entered and exited the system is equal to 130 containers. The average time the container spent in the system from

| Time/Number of units (hrs/TEU) | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|-------------------------------|--------------|------------|-----------------------|-----------------------|---------------------|---------------------|
| Value Added Time              | 121.53       | 2.12       | 107.64                | 130.91                | 2.7577              | 289.86              |
| Wait Time                     | 0.1043       | 0.05       | 0.0288917             | 0.7285                | 0.00                | 13.1624             |
| Total Time                    | 121.64       | 2.12       | 107.78                | 130.94                | 2.9804              | 289.86              |
| Number In (TEU)               | 130.00       | 0.00       | 130.00                | 130.00                | /                   | /                   |
| Number Out (TEU)              | 130.00       | 0.00       | 130.00                | 130.00                | /                   | /                   |
| Number TEU in Process         | 58.2106      | 1.09       | 52.1870               | 62.1383               | 0.00                | 130.00              |

Source: Authors
unloading from the ship to arriving at the final destination is 121.46 hours. The longest time container spent in the system is 289.86 hours, while the least time container spent in the system is 2.9224 hours. Total time spent in the system is divided between the time the container spent in the process, and the time it spent waiting for the process to take place, i.e. in line. Average number of containers is 58.2106 containers, while the minimum average number of containers in the system is 52.1870 and the maximum average number of containers is 62.1383.

Table 3 shows the times required for one container to be transported from Rijeka to its destination, depending on whether it is transported by road or rail. In addition to the average times, the maximum and minimum values are also displayed. Minimum average values are slightly larger due to larger number of TEU units (a number arbitrarily chosen by simulation) that were directed to Zagreb by road and longer time required to process them in the depot.

Table 3 clearly shows that according to the existing set-up, road transport is the fastest mode, and if rail transport is not set as a competitive mode of transport, freight will continue to be transported by road, which is not in line with EU guidelines, which encourages the development of rail transport as the “backbone” of freight transport within the European Union.

3 Simulation Analysis of Seaport Rijeka Operations with Established Dry Port in Miklavlje

Miklavlje is one of the three possible solutions for the location of the dry port terminal. Miklavlje was chosen because of its location near the Rijeka Seaport. The idea is to connect the Rijeka Seaport by rail with the dry port. The Miklavlje Logistics Centre is located in the Municipality of Matulji, about 17 km west of the city of Rijeka, next to the Rijeka-Rupa motorway (on the Croatian-Slovenian border), the state road in the same direction and along the Rijeka-Ljubljana railway. The development of the logistics centre is planned on an area of 158.5 hectares, with the possibility of further expansion, depending on future requirements. [15] Thanks to this position, spatial potential and direct connection to European transport routes, the logistics centre provides the opportunity to develop various entrepreneurial projects (logistics and distribution centres, production facilities, business, services, transport, etc.) to a wide range of investors, especially those coming from areas of southern Germany, Austria, Switzerland, Italy, Czech Republic, Slovakia, Hungary, Slovenia, Serbia, Bosnia and Herzegovina, which gravitate around Rijeka Seaport and use the Rijeka traffic route.

The simulation diagram of Seaport Rijeka operations with dry port established in Miklavlje (TO-BE Miklavlje simulation model) is shown in Figure 3.

Table 4 shows the results of the TO-BE simulation model with a dry port in the immediate vicinity of Rijeka Seaport, in Miklavlje. As in the AS-IS model, the number of containers that entered and exited the system is equal to 130 containers and the simulation was run 30 times. The average time the container spent in the system from unloading from the ship to arriving at the final destination is 80.3701 hours. The longest time container spent in the system is 289.29 hours, while the least time container spent in the system is 2.9224 hours. Total time spent in the system is divided between the time the container spent in the process, and the time it spent waiting for the process to take place, i.e. in line. Average number of containers is 39.6245 containers, while the minimum average number of containers in the system is 33.8458 and the maximum average number of containers is 46.1689.

Table 5 shows the times required for one container to be transported from Rijeka to its destination, depending on whether it is transported by road or rail if a dry port is to be established in the Miklavlje area. In addition to the average times, the maximum and minimum values are also displayed. Minimum average values are slightly larger due to larger number of TEU units (a number arbitrarily chosen by simulation) that were directed to Zagreb by road and longer time required to process them in the depot.

### Table 3 Transport Time Required to Destination by Road/Rail

| AS-IS model – Seaport Rijeka | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|-----------------------------|--------------|------------|-----------------------|-----------------------|--------------------|--------------------|
| Transport Time to Vienna by Road | 119.17       | 14.70      | 63.222                | 212.66                | 5.9484             | 285.36             |
| Transport Time to Budapest by Road | 125.69       | 11.31      | 55.2889               | 207.86                | 5.8647             | 289.86             |
| Transport Time to Zagreb by Road | 110.87       | 6.65       | 73.443                | 147.49                | 2.9804             | 282.49             |
| Transport Time to Vienna by Rail | 127.11       | 3.67       | 106.09                | 142.83                | 25.7914            | 236.13             |
| Transport Time to Budapest by Rail | 125.26       | 3.72       | 108.11                | 144.65                | 16.5369            | 234                |
| Transport Time to Zagreb by Rail | 102.38       | 6.44       | 56.7486               | 133.04                | 6.8994             | 211.15             |

Source: Authors
Figure 3 Simulation of Seaport Rijeka with Established Dry Port (TO-BE Model – Miklavlje)

Source: Authors

Table 4 Relevant Parameters of the Transport Process

| Time/Number of units (hrs/TEU) | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|-------------------------------|--------------|------------|-----------------------|-----------------------|---------------------|---------------------|
| Value Added Time              | 77.1141      | 1.45       | 71.7396               | 84.8720               | 2.8502              | 289.29              |
| Wait Time                     | 3.2560       | 0.57       | 0.7569                | 6.2510                | 0.00                | 43.1403             |
| Total Time                    | 80.3701      | 1.54       | 73.7924               | 88.7974               | 2.9224              | 289.29              |
| Number In (TEU)               | 130.00       | 0.00       | 130.00                | 130.00                | /                   | /                   |
| Number Out (TEU)              | 130.00       | 0.00       | 130.00                | 130.00                | /                   | /                   |
| Number TEU in Process         | 39.6245      | 1.16       | 33.8458               | 46.1689               | 0.00                | 130.00              |

Source: Authors

Table 5 Transport Time Required to Destination by Road/Rail

| TO-BE model – Miklavlje       | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|-------------------------------|--------------|------------|-----------------------|-----------------------|---------------------|---------------------|
| Transport Time to Vienna by Road | 125.63      | 11.94      | 66.8306               | 203.54                | 6.0756              | 283.43              |
| Transport Time to Budapest by Road | 121.24      | 10.79      | 59.6551               | 171.79                | 5.8436              | 279.37              |
| Transport Time to Zagreb by Road | 113.44      | 6.00       | 80.4975               | 155.03                | 2.9224              | 289.29              |
| Transport Time to Vienna by Rail | 77.9494     | 1.71       | 69.8824               | 86.7704               | 30.5267             | 131.05              |
| Transport Time to Budapest by Rail | 61.2347     | 0.77       | 56.9419               | 65.5463               | 22.6463             | 92.4907             |
| Transport Time to Zagreb by Rail | 47.3934     | 1.90       | 36.3356               | 58.0630               | 9.1995              | 72.0059             |

Source: Authors
4 Simulation Analysis of Seaport Rijeka Operations with Established Dry Port in Zagreb

One of the possible locations for the construction of a dry port terminal is in Zagreb. The advantage of Zagreb is definitely its geostrategic position and the fact that it is located on two rail freight corridors, the Mediterranean and the Alpine-Western Balkan. [16, 25] Most of the cargo that has a destination in the countries of the European Union and is brought to the Rijeka Seaport by ship, passes through Zagreb on its way.

The role of the dry port is to avoid unnecessary storage of containers on the seaport itself. The containers are loaded directly on the train, transported to Zagreb, and are furtherly handled/processed at the dry port. Since operations in a dry port are performed much faster than on the seaport itself, the cargo is kept at the dry port much shorter and it reaches the destination much faster, which can be seen from the simulation results shown in the tables below.

The simulation diagram of Seaport Rijeka operations with dry port established in Zagreb (TO-BE Zagreb simulation model) is shown in Figure 4.

Table 6 shows the results of the TO-BE simulation model with a dry port in the vicinity of City of Zagreb, possibly in Velika Gorica. As in the AS-IS model, the number of containers that entered and exited the system is equal to 130 containers and the simulation was run 30 times. The average time the container spent in the system from unloading from the ship to arriving at the final destination is 72.3399 hours. The longest time container spent in the system is 289.47 hours, while the least time

![Figure 4 Simulation of Seaport Rijeka with Established Dry Port (TO-BE Model – Zagreb)](image)

*Source: Authors*

| Time/Number of units (hrs/TEU) | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|-------------------------------|---------------|------------|-----------------------|-----------------------|--------------------|--------------------|
| Value Added Time              | 70.7244       | 1.66       | 61.8250               | 78.3930               | 2.7556             | 289.47             |
| Wait Time                     | 1.6155        | 0.14       | 0.7748                | 2.2947                | 0.00               | 12.8458            |
| Total Time                    | 72.3399       | 1.61       | 64.1197               | 79.8556               | 2.9224             | 289.47             |
| Number In (TEU)               | 130.00        | 0.00       | 130.00                | 130.00                | /                  | /                  |
| Number Out (TEU)              | 130.00        | 0.00       | 130.00                | 130.00                | /                  | /                  |
| Number TEU in Process         | 35.6631       | 0.91       | 31.4582               | 42.5818               | 0.00               | 130.00             |

*Source: Authors*
container spent in the system is 2.9224 hours. Total time spent in the system is divided between the time the container spent in the process, and the time it spent waiting for the process to take place, i.e. in line. Average number of containers is 35.6632 containers, while the minimum average number of containers in the system is 31.4582 and the maximum average number of containers is 42.5818.

Table 7 shows the times required for one container to be transported from Rijeka to its destination, depending on whether it is transported by road or rail if a dry port is to be established in the Zagreb area. In addition to the average times, the maximum and minimum values are also displayed. Minimum average values are slightly larger due to larger number of TEU units (a number arbitrarily chosen by simulation) that were directed to Budapest by road and longer time required to process them in the depot.

| TO-BE model – Zagreb | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|----------------------|--------------|------------|-----------------------|-----------------------|---------------------|---------------------|
| Transport Time to Vienna by Road | 122.25 | 12.08 | 75.7028 | 202.24 | 6.1454 | 280.11 |
| Transport Time to Budapest by Road | 124.14 | 9.03 | 88.8765 | 186.27 | 5.8435 | 287.16 |
| Transport Time to Zagreb by Road | 113.47 | 6.71 | 63.5515 | 140.15 | 2.9224 | 289.47 |
| Transport Time to Vienna by Rail | 65.2477 | 1.02 | 60.3022 | 72.613 | 20.3167 | 100.19 |
| Transport Time to Budapest by Rail | 59.1304 | 0.56 | 54.8758 | 62.01 | 20.7279 | 92.5141 |
| Transport Time to Zagreb by Rail | 11.9081 | 0.50 | 9.5746 | 15.102 | 5.2669 | 23.3067 |

Source: Authors

5 Simulation Analysis of Seaport Rijeka Operations with Established Dry Port in Vinkovci

As a third possible solution, a dry port was proposed to be located in Vinkovci. The position of the city of Vinkovci which is in the zone between significant transport corridors of European and national importance also influenced the formation of the transport system of the city itself. The former X Pan-European Railway Corridor, today’s Alpine-Western Balkan Rail Freight Corridor, runs through the city. The proximity of the Danube (TEN-T corridor Rhine-Danube) and the route of the state road D2 along with it, and the highway Zagreb-Lipovac (former X pan-European corridor) influenced the formation of a significant transversal road connection that passes through the city of Vinkovci. [11, 16]

One of the largest railway hubs on the Croatian railways network is located in Vinkovci. The railway hub consists of a passenger and a freight terminal. The freight terminal consists of 50 tracks classified into four groups. Nowadays, traffic through the freight terminal has been significantly reduced, and its future depends on the development of the multi-purpose canal project, where part of the existing freight terminal capacity could be used for new dry port.

The advantage of the city of Vinkovci is that its traffic routes, unlike Zagreb and Miklavje, are not oriented to the directions of Western Europe, but also to the directions of Eastern and South-Eastern Europe, which are also used to transport goods unloaded in the Rijeka Seaport, primarily direction of Orient – East Med Corridor via Vukovar and RFC 10 to Thessaloniki. [13]

The simulation diagram of Seaport Rijeka operations with dry port established in Vinkovci (TO-BE Vinkovci simulation model) is shown in Figure 5.

Table 8 shows the results of the TO-BE simulation model with a dry port in the railway hub of city of Vinkovci. As in the AS-IS model, the number of containers that entered and exited the system is equal to 130 containers and the simulation was run 30 times. The average time the container spent in the system from unloading from the ship to arriving at the final destination is 844.02 hours. The longest time container spent in the system is 2420.74 hours, while the least time container spent in the system is 3.1756 hours. Total time spent in the system is divided between the time the container spent in the process, and the time it spent waiting for the process to take place, i.e. in line. Average number of containers is 51.3340 containers, while the minimum average number of containers in the system is 45.5522 and the maximum average number of containers is 56.7295.

Table 9 shows the times required for one container to be transported from Rijeka to its destination, depending on whether it is transported by road or rail if a dry port is to be established in the area of city of Vinkovci. In addition to the average times, the maximum and minimum values are also displayed. Minimum average values are slightly larger due to larger number of TEU units (a number arbitrarily chosen by simulation) that were directed to Zagreb by road and longer time required to process them in the depot.
**Figure 5** Simulation of Seaport Rijeka with Established Dry Port (TO-BE Model – Vinkovci)

*Source: Authors*

**Table 8** Relevant Parameters of the Transport Process

| Time/Number of units (hrs/TEU) | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|--------------------------------|---------------|------------|-----------------------|-----------------------|--------------------|--------------------|
| Value Added Time               | 93.3898       | 1.42       | 88.1777               | 103.18                | 2.7814             | 282.90             |
| Wait Time                      | 750.63        | 38.48      | 541.45                | 956.69                | 0.00               | 2336.86            |
| Total Time                     | 844.02        | 38.04      | 639.40                | 1045.50               | 3.1756             | 2420.74            |
| Number In (TEU)                | 130.00        | 0.00       | 130.00                | 130.00                | /                  | /                  |
| Number Out (TEU)               | 130.00        | 0.00       | 130.00                | 130.00                | /                  | /                  |
| Number TEU in Process          | 51.3340       | 1.01       | 45.5522               | 56.7295               | 0.00               | 130.00             |

*Source: Authors*

**Table 9** Transport Time Required to Destination by Road/Rail

| TO-BE model – Vinkovci          | Average (hrs) | Tolerances | Minimum Average (hrs) | Maximum Average (hrs) | Minimum Value (hrs) | Maximum Value (hrs) |
|--------------------------------|---------------|------------|-----------------------|-----------------------|--------------------|--------------------|
| Transport Time to Vienna by Road| 120.02        | 11.19      | 53.1790               | 182.28                | 6.2756             | 282.90             |
| Transport Time to Budapest by Road| 119.72        | 9.21       | 67.2319               | 167.12                | 5.8951             | 273.98             |
| Transport Time to Zagreb by Road| 120.57        | 6.30       | 78.6195               | 156.13                | 3.1756             | 281.99             |
| Transport Time to Vienna by Rail| 1121.48       | 46.50      | 876.19                | 1313.47               | 70.2195            | 2420.74            |
| Transport Time to Budapest by Rail| 1099.72       | 31.94      | 973.06                | 1306.12               | 53.6797            | 2380.55            |
| Transport Time to Zagreb by Rail| 1072.16       | 81.69      | 706.94                | 1582.46               | 43.7273            | 2319.69            |

*Source: Authors*
6 Analysis of simulation results and discussion

By comparing the obtained results, simulations of possible locations of the dry port terminal, the best solution for dry port location is in the area of City of Zagreb. As stated, Zagreb has the most favourable geostategic position and the best connection with the cities of Central and Western Europe. Further research and analyses are needed to determine the optimal location for the construction of the dry port terminal. Also, the other two proposed locations should not be rejected, as each of them has its own advantages, which in more detailed analysis, can prove to be crucial for the construction of a dry port.

The conclusions of the results obtained by simulations are presented in graphs below. Two parameters are presented in the following graphs: *Average Total Time and Number of Units Operated at the Existing Seaport Set-up and Seaport with Established Dry Port* and *Average Time Required to Destination by Road/Rail at the Existing Seaport Set-up and Seaport with Established Dry Port* for each selected location (Miklavlje, Zagreb, Vinkovci).

![Graph 2](image1.png)

**Graph 2** Comparison of Average Total Time and Number of Units Operated at the Existing Seaport Set-up and Seaport with Dry Port Established in Miklavlje

*Source:* Authors

![Graph 3](image2.png)

**Graph 3** Decrease/Increase in Average Total Time and Number of Units Operated – AS-IS/TO-BE Miklavlje, Expressed as a Percentage

*Source:* Authors

Conclusion of graphs 2 and 3: The average total time in the process with the established dry port in Miklavlje would decrease compared to the existing set-up without a dry port by 37 %, the waiting time would increase, while the total time would decrease by 34 %.
Conclusion of graphs 4 and 5: The average time required by road/rail with an established dry port in Miklavlje would be significantly reduced due to railway use, while in the terms of road transport, it would remain approximately the same, compared to the existing set-up without a dry port. Graphs 4 and 5 show the significant impact of the establishment of a dry port and significant time savings due to rail transport, compared to the existing set-up without a dry port.
Graph 6  Comparison of Average Total Time and Number of Units Operated at the Existing Seaport Set-up and Seaport with Dry Port Established in Zagreb

Source: Authors

Graph 7  Decrease/Increase in Average Total Time and Number of Units Operated – AS-IS/TO-BE Zagreb, Expressed as a Percentage

Source: Authors

Conclusion of graphs 6 and 7: The average total time in the process with an established dry port in Zagreb would decrease compared to the existing set-up without a dry port by 42 %, the waiting time would increase, while the total time would decrease by 41 %. 
Graph 8: Comparison of Average Time Required to Destination by Road/Rail at the Existing Seaport Set-up and Seaport with Dry Port Established in Zagreb

Source: Authors

Graph 9: Decrease/Increase in Average Time Required to Destination by Road/Rail – AS-IS/TO-BE Zagreb, Expressed as a Percentage

Source: Authors

Conclusion of graphs 8 and 9: The average time required by road/rail with an established dry port in Zagreb would be significantly reduced due to railway use, while in the terms of road transport, it would remain approximately the same, compared to the existing situation without a dry port. Graphs 8 and 9 show the significant impact of the establishment of a dry port and significant time savings due to rail transport, compared to the existing set-up without a dry port.
Graph 10 Comparison of Average Total Time and Number of Units Operated at the Existing Seaport Set-up and Seaport with Dry Port Established in Vinkovci

Source: Authors

Graph 11 Decrease/Increase in Average Total Time and Number of Units Operated – AS-IS/TO-BE Vinkovci, Expressed as a Percentage

Source: Authors

Conclusion of graphs 10, and 11: The average total time in the process with the established dry port in Vinkovci would decrease compared to the existing set-up without a dry port by 23 %, while the waiting time and total time would increase.
Conclusion of graphs 12, 13: The average time required by road/rail with an established dry port in Vinkovci would increase significantly in terms of railway use, while the road would remain approximately the same, compared to the existing set-up without a dry port. Graphs 12 and 13 show the increase in transport time due to the fact that the simulation uses Vienna and Budapest as destinations, where transport via Vinkovci would not be efficient, compared to the existing set-up without a dry port, but perhaps for some other destinations such as Thessaloniki, it would be very useful.
Table 10 Decrease/Increase Rate (%) of the Average Total Time and Number of Units Operated at Three Locations of Dry Port Establishment – Miklavje, Zagreb, Vinkovci

| Average Time/Number of Units (TEU) | Decrease/Increase Rate – Existing vs. Planned Set-up (Miklavje) | Decrease/Increase Rate – Existing vs. Planned Set-up (Zagreb) | Decrease/Increase Rate – Existing vs. Planned Set-up (Vinkovci) |
|-----------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Value Added Time                  | -37 %                                                        | -42 %                                                        | -23 %                                                        |
| Wait Time                         | 97 %                                                         | 94 %                                                         | 100 %                                                        |
| Total Time                        | -34 %                                                        | -41 %                                                        | 86 %                                                         |
| Number In (TEU)                   | 0 %                                                          | 0 %                                                          | 0 %                                                          |
| Number Out (TEU)                  | 0 %                                                          | 0 %                                                          | 0 %                                                          |
| Number TEU in Process             | -32 %                                                        | -39 %                                                        | -12 %                                                        |

Source: Authors

Graph 14 Comparison of Decrease/Increase Rate (%) of the Average Total Time and Number of Units Operated – AS-IS/TO-BE Miklavje, Zagreb, Vinkovci

Source: Authors

Conclusion of Table 10 and Graph 14: The average total time with an established dry port in three locations – Miklavje, Zagreb and Vinkovci shows a decrease, compared to the existing set-up without a dry port. The best result can be seen with the establishment of a dry port in the Zagreb area.
Table 11 Decrease/Increase Rate (%) of the Average Time Required to Destination by Road/Rail to Destination at Three Locations of Dry Port Establishment – Miklavlje, Zagreb, Vinkovci

| Average Time Required by Road/Rail | Decrease/Increase Rate – Existing vs. Planned Set-up (Miklavlje) | Decrease/Increase Rate – Existing vs. Planned Set-up (Zagreb) | Decrease/Increase Rate – Existing vs. Planned Set-up (Vinkovci) |
|------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Transport Time to Vienna by Road   | -5 %                                                          | 3 %                                                          | 1 %                                                          |
| Transport Time to Budapest by Road | -4 %                                                          | -1 %                                                         | -5 %                                                         |
| Transport Time to Zagreb by Road   | 2 %                                                           | 2 %                                                          | 8 %                                                          |
| Transport Time to Vienna by Rail   | -39 %                                                         | -49 %                                                        | 89 %                                                         |
| Transport Time to Budapest by Rail | -51 %                                                         | -53 %                                                        | 89 %                                                         |
| Transport Time to Zagreb by Rail   | -54 %                                                         | -88 %                                                        | 90 %                                                         |

Source: Authors

Graph 15 Comparison of Decrease/Increase Rate (%) of the Average Time Required to Destination by Road/Rail – AS-IS/TO-BE Miklavlje, Zagreb, Vinkovci

Source: Authors

Conclusion of Table 11 and Graph 15: Average time required by road/rail with established dry port in three locations – Miklavlje, Zagreb and Vinkovci shows a significant decrease in two locations, compared to the existing set-up without dry port. The best result can be seen with the establishment of a dry port in Zagreb.

7 Conclusion

Due to the fact that Seaport Rijeka is reaching the limits of its capacity, one of possible solutions of its expansion is establishing a dry port. The focus of this paper is to prove that establishing a dry port would speed up the transport of containers between Seaport Rijeka and its destinations. Three locations of dry port were chosen to show the transport process, due to time required to transport containers from seaport to its destinations. Chosen destinations are set up to be city of Vienna and city of Budapest, as those were already destinations Seaport Rijeka uses in existing set-up to transport containers. Dry port locations are chosen to be in Miklavlje, Zagreb and Vinkovci because of their geographical locations that are already placed on the significant routes of European TEN-T network, and some already have existing necessary infrastructure, as well as they fit in the concept of building dry ports, i.e. distant, mid-range and close dry ports. Miklavlje is chosen to be close dry port, Zagreb mid-range, and Vinkovci distant dry port. Due to this hypothesis, four simulations were made. First simulation shows the transport process in the existing set-up of the Seaport Rijeka. Second, third and fourth simulation shows the transport process in the future possible set-up of the Seaport Rijeka with established dry port in Miklavlje, Zagreb or Vinkovci. Simulations were made using Arena Simulation Software. Analysis of simulation...
results was conducted using Microsoft Excel. Comparing the results of simulations made with established dry port serving seaport against the simulation made to present existing transport operations without dry port, showed that transport process is improved, in the terms of reduced time required to reach the allocated destination by implementing rail transport and outsourcing logistic activities of seaport to its dry port. The simulations also showed that the best location for establishing dry port is in the area of Zagreb. Due to the results of this research, which shows that the transport process will be improved by establishing dry port to serve the Seaport Rijeka, the further analysis of other factors can be made in the future research.

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