Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 119 **2023**

p-ISBN:: 0209-3324

e-ISBN:: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2023.119.16

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Šarić, J., Vidović, A., Štimac, I., Abramović B. Potentials of Franjo Tudman airport in the development of intermodal transport. *Scientific Journal of Silesian University of Technology. Series Transport*. 2023, **119**, 267-278. ISSN: 0209-3324. DOI: https://doi.org/10.20858/sjsutst.2023.119.16.

Jure ŠARIĆ[1], Andrija VIDOVIĆ[2], Igor ŠTIMAC[3], Borna ABRAMOVIĆ[4]

POTENTIALS OF FRANJO TUDMAN AIRPORT IN THE DEVELOPMENT OF INTERMODAL TRANSPORT

Summary. In the territory of the Republic of Croatia, not a single airport is connected to the railway infrastructure, which is a limiting factor for the further development of air cargo transport. The traffic network within the catchment area of Franjo Tudman Airport in Zagreb is not sufficiently interconnected, and therefore the implementation of the rules of the single market within the transport sectors is uneven. This paper aims to investigate the factors of intermodality of air transport and other modes of transport, focusing on cases of infrastructure integration in order to improve transport connectivity. The research analysed several airports where increase in cargo traffic was influenced by the expanding capacities and connectivity at the airport. By calculating the coefficient of utilisation of the intermodal surfaces of the reference airports, it was determined that the increase of these capacities does not necessarily lead to a significant increase in air cargo transport. However, due to estimates of the global growth of air cargo transport, an adequate and modernised infrastructure gives an advantage

[1] Croatian Civil Aviation Agency, Ul. Grada Vukovara 284 Zagreb, Croatia. Email: jure.saric@ccaa.hr. ORCID: https://orcid.org/0000-0001-7688-4744
[2] University of Zagreb, Faculty of Transport and Traffic Sciences, Borongajska cesta 83a, Zagreb, Croatia. Email: avidovic@fpz.unizg.hr. ORCID: https://orcid.org/0000-0001-8430-6469
[3] Zagreb Airport Ltd. Rudolfa Fizira 1, p.p. 102, Velika Gorica, Croatia. Email: istimac@zagreb-airport.hr. ORCID: https://orcid.org/0000-0001-5615-5499
[4] University of Zagreb, Faculty of Transport and Traffic Sciences, Borongajska Cesta 83a, Zagreb, Croatia. Email: babramovic@fpz.unizg.hr. ORCID: https://orcid.org/0000-0001-8675-5778

of better positioning in the transport market compared to those airports that do not have such resources. Based on the obtained results and increased investment to improve rail speeds and intermodal accessibility, the modular approach of expanding the infrastructure, through monitoring of cargo transport utilisation coefficient, is considered sustainable.

Keywords: air-rail intermodality, air freight, cargo city, intermodal integration

1. INTRODUCTION

All airports have road access, which is the most developed and most important traffic access to the airport. Larger airports also have rail connections to the city or cities they serve, thereby solving bottlenecks near the airports by using more types of transport (multimodal transport). They are either connected to the railway network of the city, region, or country, or were built exclusively to connect the airport and the city centre. The European Union has over 400 airports with scheduled flights. Of the approximately 250 airports serving more than a million passengers a year in Europe, 68 are directly connected by rail [1]. Study [2] and report [3] have determined that in the future the transport of cargo on shorter distances will be carried out entirely by rail services. This is because the flight network is becoming increasingly congested, and the expected further growth of aircraft operations will have an additional negative impact on the environment. In addition to transporting passengers, most airlines also provide cargo and mail services. The role of air cargo is crucial for the trade of advanced industrial products, high-value goods and other sectors that rely on fast, reliable, and safe transport. Air freight represents less than 1% of global trade by tonnage, but air transport carries more than US$ 6 trillion in goods yearly, representing more than 35% of global trade by value [4]. Such a large difference between tonnage and value reflects the unique position of air transport in transporting goods, which often requires a high level of speed, reliability, and safety. This research proposes findings and strategies for promoting the development and operation of airports through the development of intermodal infrastructure and capacity for air cargo transport. We have used six steps in our research methodology. The first step was a literature review, focused on papers indexed in different scientific databases. We find out that the number of papers that cover our research goal is humble and do not cover the research topic of intermodal transport between air and rail cargo transport. According to findings in the literature, we have defined our research goal. The next step, the second one, was to define intermodal transport within the European transport sector and connect to a green policy of the European Union. Afterwards, follows the identification of interoperability between air and rail cargo transport. The fourth step was to introduce Indicators of capacity utilisation with which the development model of the cargo terminal can be established. After that, analysis of the results was made. To verify our research approach, we have made a case study to develop Franjo Tudman airport in Zagreb.

2. AIR AND RAIL SECTOR INFRASTRUCTURE FOR THE FUTURE DEVELOPMENT OF INTERMODALITY

Airport congestion will become an increasing problem. Therefore, attention is focused on the possibilities of meeting the demand for short-haul travel with high-speed rail services, whether it is a passenger or air cargo. In the territory of the Republic of Croatia, not a single airport is connected to the railway infrastructure, which is a limiting factor for the further

development of cargo air traffic. However, their technical characteristics meet the highest traffic and safety standards of the International Civil Aviation Organization (ICAO) [5]. The increasing traffic intensity and the emerging disproportions in the development of individual modes of transport cause that the European transport system becomes overloaded. Therefore, an important premise for the development of transport are the requirements of environmental protection, which affect the preference of environmentally friendly branches and transport technologies like multimodal or intermodal transport systems [6]. The airport's connection with the surrounding cities through a branched network of national roads and highways represents the potential for good traffic connections. Continued improvement of existing road and rail connections directly favours further development of air cargo transport and intermodal transport because they are located in the immediate vicinity of the airport. Despite the fact that in terms of the amount of transported cargo, Franjo Tudman Airport is far below the established EU airports, the situation could change with a more dynamic approach to the strategy of cargo transport development. This primarily refers to the emphasis on quality of service, building a reliable infrastructure, developing a network of routes, better utilising traffic connections with the railway network, implementing new technology and consistent monitoring of European standards and integrated management systems. Figure 1 [7] shows the airports in Europe with the most loaded and unloaded cargo in 2021 and the comparison with cargo traffic at Franjo Tudman Airport.

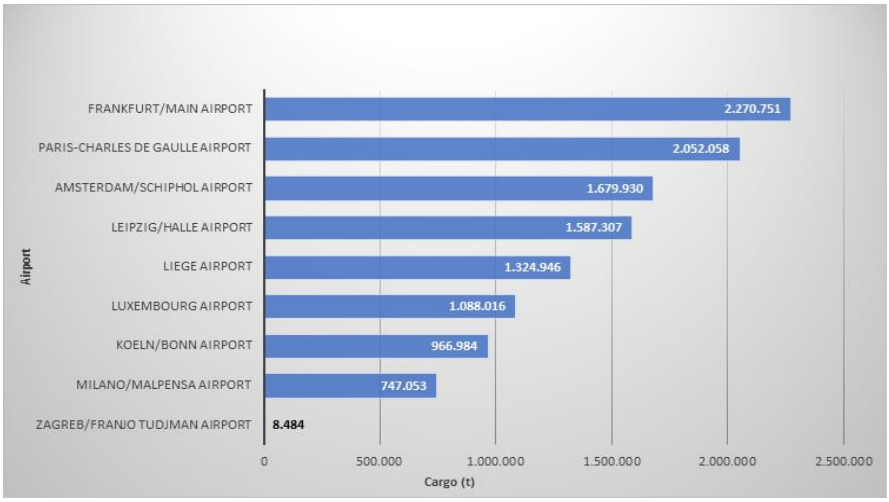

Fig. 1. Comparison of transshipped cargo of the busiest airports in Europe in 2021 compared to Franjo Tudman Airport

Authors emphasize the importance of specifically identifying the critical infrastructure of an integrated intermodal network, which consists of three modes of land transportation: highway, rail, and waterway [8]. The success of airport rail links depends on many factors and local circumstances, but some key elements need to be considered when planning airport rail connectivity. According to the Global AirRail Alliance, an international organisation that promotes rail access to airports, the following should be considered as best practices for rail-airport connectivity: (1) location, (2) frequency, (3) time of travel, (4) cost of travel, (5) ticket integration and (6) city check-in [9]. The same source emphasises the importance of accessibility to the land side of the airport through multimodal, intelligent and environmentally friendly integration with the systems of Central Europe. The cargo capacity of passenger aircraft usually accounts for 54% of the world's air cargo. Regarding Revenue Tone Kilometre (RTK)

growth, air cargo, including express traffic, is forecast to grow 4.1%, while air mail will grow at a slower pace, averaging 1.7% in 2039. Overall, world air cargo traffic will more than double in the next 20 years, from 264 billion RTK in 2019 to 578 billion RTK in 2039 [10]. Among the fastest growing types of cargo are e-commerce products, which, according to the International Air Transport Association (IATA) estimate, represent 15% of the total amount of air cargo in 2019. The e-commerce trend experienced even greater growth in 2020, driven by the COVID-19 pandemic, when an additional 18% growth was recorded. The significant development of the airport is therefore not possible without adequate infrastructure, with the infrastructure being planned in a modular manner regarding the projections of traffic and economic growth. Many major airports actively promote cargo because it creates additional jobs and revenue for the airports. As stated earlier, more than half of all air cargo is carried in the cargo compartment of scheduled airlines, and in most circumstances, it would be challenging and ineffective to isolate cargo from passenger operations. The study proposes a general framework for assessing airport expansion and new development projects, as well as a methodology for analysing the impact of one of the least understood and often neglected elements of such a framework - connectivity [11]. Improved air connectivity is a key element of economic growth and development through air cargo transport.

ICAO actively contributes to improving connectivity in several areas by encouraging various initiatives within this framework, as well as strengthening standards and recommended practices. In order to optimise connectivity, a strong support framework is needed. Among other elements, this framework includes market access and liberalisation, optimal use of air navigation services, aircraft, and airport systems, as well as improved facilitation procedures and security. The above is essential for the full benefit of air connectivity and the realisation of intermodal connections and the efficient operation of air carriers [12]. The development of flight schedules and the offer of Franjo Tudman Airport for different destinations in scheduled or charter traffic, as well as the development of infrastructure and capacity, will determine the strategic position in attracting passenger and cargo traffic in the future. Franjo Tudman Airport is located at the intersection of the main road and rail corridors in the territory of the Republic of Croatia, which together with air synergy create all the preconditions for the development of a high-quality intermodal transport system. The study [13] points out that the effects of traffic improvement are broad, especially for large projects.

According to the EU document "White Paper on transport 2011", all major airports in Europe should be connected to the railway infrastructure by 2050. In the list of initiatives, in the section related to airports, the document points to solving future capacity problems, including better integration with the rail network. Zagreb is the hub of European transport corridors. As mentioned earlier, Zagreb is located at the intersection of the TEN-T core and comprehensive corridors, which form crosses in west-east and north-south directions. The Study of the development of the Zagreb railway junction, emphasizes the importance of the position of the Zagreb railway hub, which is located at the traffic hub of Western, Central and Southeastern European routes and the Adriatic Sea (Figure 2) [14]. Therefore, the Zagreb railway junction plays an extremely important role because it is located at the intersection of corridors RH1 (DG - Savski Marof - Zagreb - Dugo Selo - Novska - Vinkovci - Tovarnik - DG) and RH2 (DG - Botovo - Koprivnica - Dugo Selo - Zagreb - Karlovac - Rijeka - Šapjane - DG), but in addition to these corridors, railways from Split, Sisak (Sunje, Bosnia and Herzegovina), Bjelovar (Osijek), Varaždin (Čakovec, Hungary) and Krapina intersect in it. The Zagreb railway junction is connected to the TEN-T Mediterranean Corridor via RH1 and RH2 corridors. Franjo Tudman Airport in Zagreb is located next to the A3 highway (European route E65), which continues to the TEN-T Mediterranean Corridor. At the distance of 1 kilometre from the airport, the railway

route M502 Zagreb Main Station - Sisak - Novska passes, but a railway track does not connect the airport. At the distance of 4.6 km from the airport, there is the Zagreb marshalling yard (Zagreb Ranžirni kolodvor), which, along with the existing highway network, represents one of the potentials for the development of intermodality at the airport. National and international highway routes originate at the Zagreb ring road: A1 Zagreb - Split, A2 Zagreb - Macelj, A3 Bregana - Zagreb - Lipovac, A4 Zagreb - Goričan, A6 Zagreb - Rijeka and A11 Zagreb - Sisak (under construction). Franjo Tudman Airport provides access not only to the city of Zagreb, but also to other cities located in the functional region of Central Croatia. The highway network in the Republic of Croatia in relation to the airport (Figure 3) [15]. In addition to domestic and international passenger traffic, regional passenger and freight traffic, the Zagreb railway junction plays a very significant role in the urban and suburban traffic of the City of Zagreb, but its potential role is far greater. The city of Zagreb has almost 770,000 inhabitants, and together with the greater area (Zagreb County - 301,206), about 1.1 million.

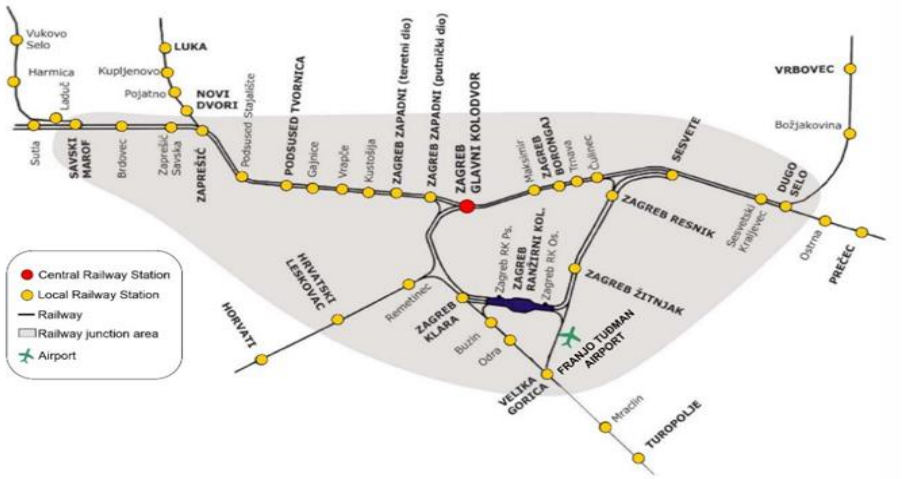

Fig. 2. Zagreb railway junction

Fig. 3. The highway network in the Republic of Croatia in relation to the airport

3. METHODS FOR ASSESSING INFRASTRUCTURE CAPACITIES FOR THE DEVELOPMENT OF AIRPORT FREIGHT TRAFFIC

The fundamental components of any airport are its runway system, technical facilities, terminal buildings and buildings for supporting services such as maintenance, warehouses, security, land access system of roads, railways and parking, which together form a strategic infrastructure for regional development. It is considered that international transport links are a key factor when choosing the location of a company's headquarters in Europe, as well as that the lack of good transport connections (road, rail, …) significantly influenced the investment decisions of companies in many countries [16].

3.1. Franjo Tudman Airport in the function of intermodal connectivity

The Franjo Tudman Airport is currently not connected to the railway network. However, the proximity of the railway enables the quick connection of part of the land planned by the spatial plan for the expansion of the airport's activities. Determining a suitable location for an intermodal terminal is a critical element of the terminal establishment process, a decision on which the functionality of the entire intermodal freight distribution chain depends [17]. The development of infrastructure through the implementation of the Zagreb Airport Cargo City project involves the construction of modern infrastructure for reloading cargo, runways, apron for cargo planes, parking lots for trucks and cars, access roads, industrial railway tracks and other facilities for efficient cargo ground handling. After the growth phase, terminals primarily competed by expanding their capacity by offering value-added services (VAS). The impact of the VAS offer on the terminal operational performance was analysed using a generic System Dynamics model [18]. The main infrastructural elements for cargo ground handling at airports are the technical and technological equipment of the cargo terminal, adequate aircraft equipment for cargo handling and equipment for loading and unloading trucks. The Franjo Tudman Airport does not record major investments in the renewal of mechanisation or the introduction of new technologies for cargo handling, and it can be concluded that it is a low level of investment in the modernisation of freight transport technology. The Franjo Tudman airport cargo terminal consists of a warehouse which is divided into a departure area of 960 m^2 and an arrival area of 1,200 m^2. The Liszt Ferenc International Airport in Budapest is an example of how a cargo transport development plan and associated infrastructure should look like. According to the airport's official website, it has a newly built cargo terminal of 21,600 m^2 with a high degree of automation and a warehouse with offices for freight forwarders and logistics companies of 11,200 m^2 surface area. When comparing the Franjo Tudman Airport with the previously mentioned airport, it is clear that without a serious strategy for the development of freight transport and for strengthening the infrastructure and intermodal characteristics, the airport cannot be competitive in the environment of the cargo handling market. In order to position Franjo Tudman Airport as a competitive regional centre for the realisation of the Zagreb Airport Cargo City project, it is necessary to invest significant funds in infrastructure and supra infrastructure. The development of infrastructure through implementation of the Zagreb Airport Cargo City project, which is planned for the north-western part of the airport, in the triangle formed by the Zagreb ring road, the railway from the marshalling yard and the airport's runway, implies the construction of a modern cargo infrastructure [19]. The term infrastructure here means the construction of a high-tech, fully computerised, complex centralised system of cargo handling terminals (minimum semi-automatic, preferably fully automatic) that will be able to handle special and dangerous goods.

Also, it is necessary to build a railway for intermodal connection, which will connect the main railway route M502 Zagreb Main Station - Sisak - Novska and the Franjo Tudman Airport zone itself (including Zagreb Airport Cargo City) and to build a connection of Zagreb Airport Cargo City to highway A3 (European route E65). From the aspect of the supra infrastructure, and with the goal of competitiveness, it is necessary to modernise the existing capacities of the cargo terminal (systems for consolidation and deconsolidation of shipments, systems for palletising shipments and a new X-ray device in line with the latest standards), as well as introduce RFID (Radio-Frequency Identification) technology in order to increase the level of service quality. Spatial plans of the cities located in the narrow gravitation area of the Franjo Tudman Airport in Zagreb (Zagreb, Velika Gorica, Zaprešić, Dugo Selo, Sv. Nedjelja and Samobor) envisage concrete measures to improve the railway infrastructure. This primarily refers to the reconstruction and upgrading of the existing infrastructure, which includes the construction of additional tracks, stops, stations and sections with the aim of connecting the airport to the rail transport system (Zagreb and Velika Gorica), which directly contributes to intermodal connectivity. Intermodality, i.e. the integrated transport system in the City of Zagreb and its greater area, will provide for a more efficient, high-quality service. In terms of environment, energy and safety, such a service will be much more acceptable than the current service, ensuring full integration of different transport modes in the railway node. An important driver of air cargo traffic is the industry located near airports.

3.2. Analysis of the intermodal infrastructure and cargo of the main airports in the area

Franjo Tudman Airport is located in Zagreb, in the vicinity of a significant number of manufacturers of electrical components, special vehicles and industrial equipment, pharmaceutical companies, textile production companies and large distribution companies that would also use air transport. In the last few years (2015-2021), more than 63,583 tons of cargo (freight and mail) were transported by air in the Republic of Croatia, of which more than 90% relate to the loading and unloading of cargo at Franjo Tudman Airport. In 2021 alone, 8,484 tons of cargo were transported, which is almost 98% of the total transported cargo compared to other airports in that year [7]. In the mentioned period, the airport did not have significant cargo transport, except in relation to other airports in the Republic of Croatia. Considering the airport's connection with the surrounding cities, the branching of roads within the gravitation area, especially the highways located on international corridors, and the continuity of traffic throughout the year, the airport has positioned itself as the centre of air cargo transport compared to other airports in the Republic of Croatia.

Despite different motivations, all airports that participated in the study (2011) [20] support the idea that intermodal concepts represent an important competitive advantage for an airport. According to available traffic forecasts for Europe, the growth rate of air cargo from 2020 to 2039 is estimated at an annual rate of 2.3% [21]. Flows of goods (annual volumes, frequencies, goods characteristics, etc.) that can potentially be served as air cargo within the gravitation area of the airport are the only realistic indicator for the positioning of Franjo Tudman Airport in the air cargo market through the construction of the necessary infrastructure for cargo ground handling (Zagreb Airport Cargo City). In the following, several factors are analysed that are considered significant indicators, which will determine the direction of the infrastructure capacity development in relation to the targeted airports. The reference period for observations and analysis of air cargo handling area factors, cargo volume and utilisation indicators of tons per square meter (t/m²) is from 2015 to 2019 (no impact of COVID).

According to Eurostat, Franjo Tudman Airport is far below the stated capacity for cargo transport of the observed airports from Table 1 [7]. Throughout the entire observed period, there was no increase in the area for handling air cargo. None of the other airports, except Liszt Ferenc Airport in Budapest, and to a lesser extent Vienna Airport, had an increase in surface areas in the observed period, but their existing capacities are significantly larger than those of Franjo Tudman Airport.

Tab. 1

Capacities of airports for intermodal freight transport (m^2)

Airport	2015	2016	2017	2018	2019	2020	2021
PRAHA/RUZYNE	27,973	27,973	27,973	27,973	27,973	29,973	29,973
ZAGREB/FRANJO TUDMAN	2,100	2,100	2,100	2,100	2,100	2,100	2,100
BUDAPEST/LISZT FERENC	26,000	26,000	26,000	53,000	54,500	54,500	54,500
WIEN-SCHWECHAT	23,116	23,116	25,807	25,807	25,807	25,807	25,807
BERGAMO/ORIO AL SERIO	22,000	22,000	22,000	22,000	22,000	22,000	22,000

Franjo Tudman Airport has by far the fewest tons of freight transhipment throughout the reference period, which is not enough for a more serious positioning in the air freight transport market, as summarized in Table 2 [7]. This situation points to the fact that the airport does not have sufficient infrastructure for cargo ground handling, i.e., capacities, level equipment and an insufficiently developed network of long-distance routes. Global trade is seen growing at 4.7% from 2020 to 2025 and 2.8% on average over the 20-year forecast period, with many of the longer-term economic drivers reestablished after the near-term disruptions from the pandemic subside [10].

Tab. 2

Air cargo transport at selected airports (t)

Airport	2015	2016	2017	2018	2019	2020	2021
PRAHA/RUZYNE	50,521	71,029	81,750	82,460	85,397	52,641	62,447
ZAGREB/FRANJO TUDMAN	7,113	7,651	9,487	11,894	10,833	7,646	8,484
BUDAPEST/LISZT FERENC	65,783	77,535	87,277	101,411	95,590	88,872	125,823
WIEN-SCHWECHAT	209,053	216,383	220,790	229,607	220,831	154,669	176,154
BERGAMO/ORIO AL SERIO	120,952	117,660	125,857	122,026	119,041	51,505	26,024

3.3. Analysis of indicators of capacity utilisation for cargo transport

In order to get a realistic picture of the capacity utilisation of airports for cargo transport, according to the above data, capacity utilisation indicators (k_{ef}) were calculated in tons per square meter (t/m²) which is shown in formula 1.

$$k_{ef} = \frac{amount\ of\ goods\ [t]}{surface\ capacity\ [m^2]} \quad (1)$$

The average capacity utilisation in 2019 for all observed airports is 4.78 t/m². According to the analysis, the Zagreb airport does not have such a bad utilisation coefficient of tons per square meter (t/m²), considering the capacities for intermodal cargo transport. The average value in 2019 is 5.16 t/m², thus positioning the airport by 0.37 t/m² above the average of the surrounding airports (although in 2019, a slight decrease in the coefficient was recorded compared to 2018). The comparison of the coefficient of Franjo Tudman Airport with the coefficient of Bergamo Airport shows that Franjo Tudman Airport has a very high utilisation coefficient based on the current state of infrastructure capacity, somewhere at the level of Bergamo Airport shown in Table 3, even though Bergamo Airport has ten times more infrastructure capacity shown in Table 1 [7].

Tab. 3

Utilization indicators t/m² in the period from 2015-2021 at selected airports

Airport	2015	2016	2017	2018	2019	2020	2021
PRAHA/RUZYNE	1.81	2.54	2.92	2.95	3.05	1.76	2.08
ZAGREB/FRANJO TUDMAN	3.39	3.64	4.52	5.66	5.16	3.64	4.04
BUDAPEST/LISZT FERENC	2.53	2.98	3.36	1.91	1.75	1.63	2.31
WIEN-SCHWECHAT	9.04	9.36	8.56	8.90	8.56	5.99	6.83
BERGAMO/ORIO AL SERIO	5.50	5.35	5.72	5.55	5.41	2.34	1.18

Despite the decline in cargo traffic in 2020 and 2021 shown in Table 2, Franjo Tudman Airport used its potential very well and remained within the framework of the increase in cargo traffic in the period shown. It is also important to note that Budapest Airport, after the capacity expansion, recorded a significant drop in the utilisation coefficient. The intermodal transport capacities of Budapest Airport in the period 2015-2019 increased by around 100%, while transported cargo increased by only 16%. Therefore, it is unrealistic to expect a very sharp increase in transported cargo in a year when surface capacities are increased. In order to rise to the coefficient from 2017, the expected total annual volume of cargo transport of Budapest Airport must be 183,120 tons. The increase is an average of 12,000 tons per year, so Budapest Airport needs less than 4 years for the usable coefficient to return to a level of the period before the increase. If the Budapest Airport model were applied to the Zagreb Airport Cargo City project, it would include building the additional 19,000 m² in the first phase, raising the airport's capacity to 21,100 m². With the coefficient from 2019 (5.16), that increase would maximise cargo traffic to 108,876 tons in the year. Considering the calculation of the reduction of

the coefficient as in Budapest, from 3.36 to 1.91 (-43%), if such a model is applied to the Franjo Tudman Airport, and the coefficient of 5.16 is reduced by 43%, a new utilisation coefficient of 2.94 would be obtained. If this coefficient is applied to the newly created area, an increase in freight traffic in the year after the opening of 62,034 tons is obtained compared to 2019, when it was 10,833 tons, which would amount to more than five times increase in freight traffic at the airport.

The Zagreb Airport Cargo City project should apply a modular approach to cargo capacity expansion in four phases. Each phase of the project would consist of the construction of 5,000 m² for cargo capacity needs within a period of 5 years. With this approach, within a period of 20 years, the Zagreb Airport Cargo City project would reach the capacities described in the Strategic Business Plan Zagreb Airport Cargo City Project, Zagreb, February 2010 (update 2013) and return the investment in realistic time frames. Following the coefficient of capacity utilisation for cargo transport, through the increase in cargo transport by air transport, the set utilisation goals of Cargo City become realistic and sustainable. Of course, the cargo flow also depends on the type and size of the airport's route network and its expansion plan. As already stated earlier, the cargo capacity of passenger planes makes up more than 50% of the transported cargo, and in this sense, the number of transported passengers and the number of destinations has a great influence on the transport of cargo. In most cases, the cargo has higher value and smaller dimensions and is transported over a distance of more than 800 km. When it comes to combined passenger and cargo airlines, the cargo business accounts for an average of 9% of airline revenue, which is more than double the revenue from the first-class revenue segment [22]. However, with the construction of the new Franjo Tudman Airport passenger terminal and accompanying infrastructure (in 2013) and the planned modular development of capacity expansion, given the expected forecasted growth in the number of passengers, expectations in this regard are optimistic. In order to revitalize a certain dysfunctional intermodal transport terminal, the study proposes a methodology for connecting the terminal with the railway and road infrastructure, the necessary quantification of the traffic potential, which subsequently defines the operational need for transshipment equipment, and other parameters of the basic elements of the terminal [23].

4. CONCLUSIONS

In this paper, some of the international airports in the vicinity of Franjo Tudman Airport were analysed, which, due to their infrastructure of intermodal capacities and the amount of transported cargo and passengers, can serve as an example for the future development of the concept of intermodal transport. According to analysis, it can be concluded that the EU countries with the largest amounts of cargo transported by air are more developed than the average, compared to other EU countries, with strong IT industries, developed auto industry and pharmaceuticals. Also, the existing airports have a developed and modernised infrastructure and have a good and connected intermodal transport infrastructure. The available literature points to different approaches to the development of intermodal solutions in the development of cargo transport by air, depending on the size of the country, business and economic activity, and the condition and connectivity of the infrastructure. This paper also analysed the connection of the existing transport infrastructure with the TEN-T. It confirmed the continuity in the construction of the necessary roads and the integration of the national road networks of the Republic of Croatia into a single TEN-T network. Research shows - and this especially applies to the airports that are not connected by railways - that several factors should be considered

when evaluating the integration of airports into the railway network: primarily, a sufficient demand to justify adequate railway frequencies, as well as infrastructural integration and sufficient offer of long-haul flights from the airport to cover the demand and interest of operators to offer intermodal products. This paper provides a comprehensive overview of the problem of air cargo planning, which is seen in the lack of the necessary infrastructure related to the capacities and integration of different types of traffic. Therefore, the promotion of compatibility between different types of transport for the ground handling of express mail and cargo through the Zagreb Airport Cargo City project is of utmost importance for the economic growth of air transport. Without an appropriate strategy for developing the necessary infrastructure and modernizing the means of operation, there will be no impact on competitiveness in competing airports. Thus, the existing location in Zagreb combines air, road, rail, postal and long-term through the navigability of the Sava River and river traffic, which is ideal from the point of view of multimodality. It is expected that the results of this work will provide better insight for the stakeholders and the authorities when planning the development of the airport in terms of infrastructural and intermodal improvements.

References

1. Interreg Central Europe. *LAirA Project Report*. 2018. Supported by the European Union's – Regional Development Fund. Available at: https://www.interreg-central.eu/Content.Node/Action-Plan-1.pdf.
2. Reiter Vreni, Augusto Voltes Dorta, Pere Suau-Sanchez. 2022. "The Substitution Of Short-Haul Flights With Rail Services in German Air Travel Markets: A Quantitative Analysis". *Case Studies on Transport Policy* 10(4): 2025-2043. DOI: https://doi.org/10.1016/j.cstp.2022.09.001.
3. European Union, Agency for Railways. *Report 2021. Fostering Rail Through Green Deal – Part 2 Freight*. Valenciennes Cedex, France. 2021.
4. Industry High Level Group (IHLG) 2019. *Aviation Benefits Report*. Available at: https://www.icao.int/sustainability/Documents/AVIATION-BENEFITS-2019-web.pdf.
5. Annex 14. 2018. *Eighth Edition to the Convention on International Civil Aviation.* Aerodromes, Volume I. Design and Operations. Montreal, Canada. ICAO.
6. Cieśla Maria, Jerzy Margielewicz, Damian Gąska. 2020. "Intermodal Terminals Network Modelling". In: *Modelling of the Interaction of the Different Vehicles and Various Transport Modes*. Springer, Cham. P. 185-231.
7. Eurostat Data Browser. *Airport connections to other modes of transport.* Available at: https://ec.europa.eu/eurostat/databrowser/view/avia_if_arp_co/default/table?lang=en.
8. Hosseini Seyedmohsen, Abdullah Al Khaled. 2021. "Freight flow optimization to evaluate the criticality of intermodal surface transportation system infrastructures". *Computers & Industrial Engineering* 159: 107522.
9. Interreg Central Europe programme, supported by the European Union's. 2018. *Air-Rail Link- a Project Report LAirA*.
10. *World Air Cargo Forecast 2020-2039*. Boeing Commercial Airplanes, Boeing, Commercial Airplanes. Seattle, USA. Available at: https://www.utikad.org.tr/images/BilgiBankasi/worldaircargoforecast20202039-1988.pdf.
11. Smit Martine, Marnix Koopman, Jasper Faber. 2013. *Aviation Policy Development Framework*. CE Delft, Delft, Netherlands.

12. ICAO. *Information Paper, Impact of Air Cargo Service on Economic Development*. Available at: https://www.icao.int/Security/aircargo/Documents/AirCargo_EconomicDevelopment.pdf.
13. Venables Anthony J, James Laird, Henry Overman. 2014. *Transport Investment and Economic Performance: Implications for project appraisal*. UK Department for Transport, London, UK.
14. *Studija razvoja željezničkog čvora Zagreb*. 2016. Ministry of Maritime Affairs, Transport and Communications, Republic of Croatia. [In Croatian: *Study of the development of the Zagreb railway junction*].
15. Hrvatske autoceste d.o.o. Limited Liability Company for Operation, Construction and Maintenance of Motorways. Available at: https://www.hac.hr/en/traffic-and-security.
16. Air Transport Action Group (ATAG). 2008. *The economic & social benefits of air transport*. Air Transport Action Group. Geneva, Switzerland.
17. Roso Violeta, Nikolina Brnjac, Borna Abramovic. 2015. "Inland intermodal terminals location criteria evaluation: The case of Croatia". *Transportation Journal* 54(4): 496-515.
18. Russo Sonja, Manfred Gronalt. 2021. "Value added services at intermodal inland terminals and the importance of choosing a moderate innovation path". *Research in Transportation Business & Management* 41: 100694.
19. Master Plan Airport City. 2018. *Novi putnički terminal Franjo Tudman.* [In Croatian: The new Franjo Tudman passenger terminal]. Zagreb Airport Ltd.
20. Vespermann Jan, Andreas Wald. 2011. "Intermodal integration in air transportation: status quo, motives and future developments". *Journal of Transport Geography* 19(6): 1187-1197.
21. Statista. *Forecast of air cargo growth rates from 2020 to 2039*. Available at: https://www.statista.com/statistics/1189158/air-cargo-growth-rates-by-region/.
22. IATA. *White paper, Air cargo and e-commerce enabling global trade.* Available at: https://www.iata.org/contentassets/d22340c37e0c4cfd8fc05ca6ebf6cc9f/stb-cargo-white-paper-e-commerce.pdf.
23. Ližbetin Jan, Ondrej Stopka. 2020. "Application of specific mathematical methods in the context of revitalization of defunct intermodal transport terminal: A case study". *Sustainability* 12(6): 2295.

Received 19.12.2022; accepted in revised form 29.02.2023