Feasibility Study of the Organisation of Intercity Fast Ship Lines – the Case of Croatia's Maritime Passenger Transport

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This study explores the scientifically based possibilities and potential effects of connecting cities in the Republic of Croatia through the organisation of intercity fast ship lines in maritime passenger transport. Through a meticulous analysis a model of an abstract type of transport has been chosen in order to estimate the possible contribution of intercity lines in maritime passenger transport towards the development of the transport system of the Republic of Croatia, and also to determine the feasibility of introducing these lines with the aim of achieving balance among certain forms of transport. The results of this research indicate the economic, environmental, and energy justification of the organisation of intercity fast ship lines and their competitiveness in comparison with other forms of transport.

KEY WORDS

~ Maritime passenger transport
~ Intercity fast ship lines
~ Abstract mode model

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1. INTRODUCTION

The Mediterranean Sea is the largest of Europe's semi-enclosed seas, covering almost 2.6 million km^2 and one of the world's busiest seas, accounting for 20% of all seaborne trade, 10% of global container traffic, and over 200 million passengers (Maritime Transport, 2022). Europe (European port calls) is by far the most important shipping connection for the Mediterranean, receiving roughly 40-50 percent of all extra-Mediterranean trade (from ports outside the Mediterranean) The share of intra-Mediterranean travel in overall Mediterranean traffic increased from 49% in 2009 to roughly 58% in 2016. The growth of either trans-shipment or coastal or short-sea shipping was responsible for this increase (Maritime Transport, 2022).

Ports on the Adriatic Sea coast are gradually gaining in importance for the growth of Central and West European economies. These ports offer enough depth to serve large-capacity ships. If these ports are swiftly connected to effective rail freight lines, the time it takes for commodities to travel from Asia to Europe will be greatly reduced (Kolar, 2017).

Promotion of balance among modes of transportation entails considering the disadvantages of each mode and ensuring mutual benefits, interaction, and integrated functioning (Transportation Modes, 2022). For millennia, commercial transportation in Europe has been dominated by sea and river travel. Large cities were built on rivers or at river mouths, and major trade fairs were always held in river or sea ports during the Middle Ages. However, despite a slight revival, inland waterway transportation has the worst interaction with other modes of transportation, despite the fact that it is a less expensive and more environmentally friendly mode of transportation than road transport.

Due to international trade and the import and export of goods, the short sea shipping is growing worldwide. In contrary to transcontinental cross-ocean deep sea shipping, short sea shipping (abbreviated as SSS) is the maritime delivery of products across relatively short distances (Short sea shipping, 2022). The Marco Polo Concept, which attempts to alleviate traffic congestion and promote sustainability, is an important aspect of the short sea shipping programme. Short sea shipping has a number of advantages, including increased fuel efficiency and overall reductions in greenhouse gas (GHG) emissions, air contaminant (CAC) emissions, traffic congestion, and noise from transportation.

Within the Union, maritime transport and inland waterway transport are two major components of intermodality that must address concerns, such as increasing congestion on roads and railway infrastructure, while also lowering air pollution. More in-depth discussions about the introduction of intercoastal navigation began in 2005 in Croatia. On the initiative of the Ministry of the Sea, Tourism, Transportation, and Development, the Short Sea Shipping Promotion Centre was established in Rijeka, one of the most important objectives being the promotion of short sea shipping along the Italian and Croatian coasts. The primary targets for the promotion of short marine shipping were named as Ravenna and Bakar, Ancona, Zadar, and Ploče. Croatian Shortsea Promotion Centre and Pro-Rail Alliance, Association of Ship Brokers and Agents of Croatia, Inland Navigation Development Centre Ltd., and Association of Croatian Road Hauliers formed the Intermodal Transport Cluster as a non-profit organisation after signing a Cooperation Agreement. The Croatian Ministry of Sea, Transport, and Infrastructure founded the Cluster, and its members include all marine port authorities, operators, Croatian railways, larger agencies and carriers, as well as other interested businesses (Rathman et al., 2016).

Primarily, the short-sea shipping is based on cargo transport; however, the Croatian transportation market might be ready to consider an alternative technology capable of providing faster, affordable intercity passenger transportation services between Croatian coastal cities. The organisation of inter-city fast ship lines contributes towards the achievement of traffic and maritime policy goals, as well as the enhancement of the entire traffic system and the stabilisation of various traffic branches (Rathman et al., 2016; Krčum et al., 2018). The proposed model for the organisation of inter-city fast ship lines in Croatian maritime passenger traffic highlights various advantages of maritime passenger traffic (more environmentally friendly, faster, more reliable, more economical, and safer traffic) and demonstrates the importance of short coastal navigation in the function of greater value and exploitation of the sea as a traffic route (Plazibat, 2014).

In order to design an appropriate model that will justify the organisation of intercity fast ship lines in maritime passenger transport, it is necessary to include all relevant variables into the model. In addition, the designed model should also consider some basic facts, such as the non-existence of intercity fast ship lines and the organisation of an entirely new type of transport. Along Croatia's shores of the Adriatic Sea, fast passenger transport has been performed only between the mainland and the islands, but not in coastal shipping, i.e. among larger coastal towns. Furthermore, according to data available to the authors, such experiences do not exist in other countries and represent a unique and original proposal. It is also essential to take into account the basic postulates of the theory of the system, or to accept the fact that maritime passenger transport cannot be observed as isolated from other types of transport that provide the same or similar service. Having this in mind, the mutual competitive effects of certain types of transport, as well as the effects, competitiveness and survival of the organisation of intercity lines in maritime passenger traffic can be best evaluated. The third important fact is that maritime passenger traffic in the Republic of Croatia is primarily dependent on tourist demand. Namely, during the summer season, the number of tourist destinations in the Republic of Croatia often increases several times, and this is a fact that requires consideration.

In the light of the foregoing, the feasibility study starts with the model for an abstract type of transport. Accordingly, the fundamental variables that determine the type of transport are the economic exploitation features of the transport. In this regard, indispensable variables include the ability to manufacture transport services in maritime passenger transport (which is primarily reflected in the number of departures), the duration of transport, and the individual travel costs.

These variables are essential, not only for creating the model for intercity lines in maritime passenger transport, but also for justifying the organisation of such lines. Furthermore, it seems appropriate that the model also adheres to the requirements of the gravitational model, as the demand for passenger transport depends on a number of economic elements. The latter include the size and configuration of the country, the size and spatial distribution of shopping centres (which exist in all cities included in the model), the number of inhabitants, gross domestic product, infrastructural connectivity, demographic factors, living standard, and institutional features of individual cities. Analogously to Newton's law of gravity, the transport gravitational model starts from the fact that the volume of transport between two towns is proportional to the volume of generated and attracted transport, and inversely proportional to some measure of resistance between these two towns (distance, travel costs, travel time).

The present economic structure is built on the usage of vessels for the transportation of passengers, primary, intermediate, and final products. A boat delivers its services in this manner, and while it earns revenue for the owner, it also has environmental consequences, such as pollutants from burning and fuel leftovers disposed in the environment. Furthermore, there are major repercussions on the environment and the people involved in the final phase of use, i.e., dismantling. Boats using electric propulsion systems, on the other hand, have seen significant technological advancements in recent years (Moya et al., 2022). In the context of zero-emission shipping, the Keep It Sustainable and Smart (KISS) programme focuses on a review of battery-powered small boats. The KISS programme's initial stage is to design and build a prototype of a zero-emission small ship, suited to both pleasure and passenger transportation. This project is backed by EU co-funding and provides a fantastic chance for small marine businesses to update their own brands with sustainable elements that reflect the most common market requests (Begovic et al., 2021). Overall, electric machines, power electronics, control and optimisation methodologies, and energy storage systems, have become significant actors in the development of zero emission ships based on an electric ship architecture. The shipping industry, which is governed by the International Maritime Organisation (IMO), has a well-structured framework in place to attain a zero emission fleet in the long run and as a transitional phase (Reusser et al., 2021). Involving local governments in enforcing policies that encourage ship owners and port authorities to implement and develop strategies and technologies in order to achieve true zero-emission shipping is of utmost importance, but until this is accomplished connecting cities through fast intercity ship lines helps in minimising the carbon impact.

2. THE THEORY OF AN ABSTRACT TYPE OF TRANSPORT AND THE PROBLEM OF RESEARCH

When discussing the possible contribution of intercity fast ship lines to the quality of maritime passenger service and the development of the traffic system, the theoretical analysis of the demand for the abstract type of traffic starts from the point of view of the users of the transport service, not from the point of view of the bidders (Andreasson et al., 2010). Accordingly, the following economic and exploitative features are selected as the fundamental variables that influence the choice of a specific type of transport: the speed of transport, the frequency of service delivery, the comfort of transport, and the cost of transport.

For the presentation of the abstract type of transport analysis (Bukša, 2005) a hypothetical example with the economic-exploitation features of each type of traffic is used (Table 1).

Type of transport	Duration of journey (h)	Travel cost (EUR)	Number of daily departures
A – transport by bus	6.30	15,26	32
B- air transport	3.30	79,63	5
C- railway transport	7.30	19,91	2
D – car transport	4.0	106,18	Not Applicable

Table **1.** Duration of journey, travel cost and number of daily departures of certain means of transport between the departure point and destination (Source: authors).

Potential users of transport services in passenger traffic may opt for the following selection of transport types between two locations: a) the type of transport that is best by all criteria; b) the type of transport according to the performance of each transport alternative compared to the "best" alternative. Accordingly, Table 1 can be transformed as follows (Table 2).

Type of transport	Duration of journey	Travel cost (EUR)	Number of daily departures
A - transport by bus	1.91	0,13	1
B- air transport	1	0.69	0.15
C- railway transport	2.21	0,17	0.06
C- railway transport	1.21	0,92	-

Table **2.** Relative characteristics of some types of transport between departure point and destination (Source: authors).

Demand estimations (Tk) for the above mentioned abstract carriers are based on the above data, but for the sake of simplicity the first three types of transport (A, B, and C), with their economic exploitation characteristics, are taken into consideration. Upon processing the statistical data for a particular type of transport, a model for demand estimation is obtained:

$$Tk=1000000-40000\cdot Hb-1500\cdot Pb+2500\cdot Db-120000\cdot Hr-80000\cdot Pr+125000\cdot Dr-20000\cdot N \quad (1)$$

Hb - absolutely best travel time
Pb - cost of travel
b - number of daily departures for any type of transport
Hr - relative travel time
Pr - cost of travel
Dr - number of daily departures for the type of transport
N - number of types of transport on the specified route

Using this model, it is possible to estimate the demand for all three types of transport, namely (**T**ype of **T**ransport=TT):

TTA	=	541300
TTB	=	139650
TTC	=	353800
Total	=	1.034750

Based on the data obtained, it can be noted that transport A (52.31%) has the largest share, both absolute and relative, in the total passenger transport, followed by type B with 34.19%, and type C with 13.49%.

Now it is time to assume the introduction of a new type of transport. Its economic features on the above route are as follows: travel time of 5.5 hours, travel cost of 13.27 EUR, and number of daily departures = 2. At this point it is necessary to make a new estimation of the demand for certain types of transport, taking into account that now N = 4. The introduction of a new type of transport will not affect the best travel time Hb, the relative travel time Hr, the best number of departures Db, or the relative departure time of the Drb. However, it will change the best cost of travel Pb and the relative travel Pr.

In this case the following results have been obtained:

TTA	=	541800
TTB	=	156750
TTC	=	360300
TTD	=	473500
Total	=	1532350

Based on the data obtained, it is apparent that the turnover on this route has increased by as much as 48.08%, and that the bulk of the new traffic has been generated by the newly introduced mode of transport. It is significant that the relative share of TTA transport has significantly decreased from 52.31% to 35.35%, while the newly introduced form of transport has taken the second largest absolute and relative share. This is very encouraging if the new traffic service is intended to stop the expansion of undesirable growth in demand for environmentally unacceptable forms of transport. Accordingly, it is appropriate to elaborate the model of organising intercity fast ship lines in the maritime passenger traffic of the Republic of Croatia.

Connecting coastal towns in Croatia through establishing intercity fast ship lines has never been theoretically explored, despite the potential for the development of such a form of transport and the overall positive effects it might generate. The bibliographic units related to the subject of this paper prefer referring to freight traffic that is organised in the context of short sea shipping (coastal traffic linking), with the idea of redirecting this traffic from roads to sea routes. Here are some important works of Croatian researchers. The authors in (Hallocsk et al., 2009) analyses short sea shipping in terms of the benefits or impacts that have been determined by the research carried out at the level of the European Union. The author determined the significance of the Marco Polo project in the development of short sea shipping. A special contribution was made with the analysis of the potential of short sea shipping development in the Republic of Croatia. Authors in (Jugović et al., 2001) analysed coastal commuting (short sea shipping) in Europe as a factor for sustainable development of the transport system in the Republic of Croatia. The paper presented obstacles to the introduction of short sea shipping in the Republic of Croatia in the area of freight transport, which can be applied to some extent to maritime passenger transport. The author in (Kafuman, 2007) gave a brief overview of the short sea shipping in the context of the concept, development, and impacts of its introduction. Krčum et al. (2018) analysed the sustainability of short sea shipping, i.e., ecological aspects of short sea shipping, pointing out the need for higher fuel quality, higher speed and better quality of ships. Furthermore, the author also determined the social benefits of short sea shipping. A particularly important contribution was the description of Croatia's approach to the introduction of short sea shipping. The author in (Lutenberger, 2011) elaborated and evaluated the most important features of transport service in organising intercity fast ship lines in maritime passenger transport. They demonstrated that the greatest impact on the organization of intercity fast ship lines in maritime passenger transport would be the ability to produce transport services, travel time, and social travel costs.

It is worth pointing out that Plazibat et al. (2015) explored the features and benefits of introducing short sea shipping. Their paper gave an overview of the use of short sea shipping according to the regions of the world. The authors identified four key factors for the introduction of short sea shipping: demand, meeting the requirements of the shipper, satisfaction of the demands of operators, and changes in creating traffic policy. Furthermore, an interesting study on RO-RO short sea shipping was performed by Pupavac (2017). The work was a case study of Norway and Sweden. The authors determined the importance of RO-RO short sea shipping in view of the potential for organising a more efficient and cost-effective transport network. In order to implement this potential, the authors believe that shipping companies have an essential role in providing an adequate supply of their capacity and services to the cargo holders and logistic operators. They have analysed the factors that affect the implementation of RO-RO short sea shipping (advantages, disadvantages, strengths and weaknesses of RO-RO transport; the idea of RO-RO transport; choosing transport modes; logistics management; supply chain; political factors), as well as the entities that should participate in the implementation of RO-RO short sea shipping.

3. THE MODEL

In order to estimate the demand for maritime passenger transport and carry out the evaluation of certain variables for establishing intercity lines in maritime passenger transport, the following abstract mode model has been set:

$$T_{ijm}=e^{\alpha 0}(P_iP_j)^{\alpha 1}(I_{ij})^{\alpha 2}(C_{ijg})^{\beta 1}(H_{ijg})^{\beta 2}(F_{ijg})^{\beta 3} \left(\frac{C_{ijm}}{C_{ijg}}\right)^{y1}\left(\frac{H_{ijm}}{H_{ijg}}\right)^{y2}\left(\frac{F_{ijm}}{F_{ijg}}\right)^{y3} \qquad (2)$$

the following representing:

P_i and P_j - number of inhabitants in city i and the number of inhabitants in city j (in thousands)

I_i and I_j - gross domestic product *per capita* in city *i* and city *j* (in thousands of HRK)

$$I_{ij}=\frac{PiIi+PjIj}{PiPj} - \qquad (3)$$

average gross domestic product *per capita* in city *i* and *j*

C_{ijm} - travel costs between city *i* and city *j* and type of transport (in €)

H_{ijm} - journey time between city *i* and city *j* and the type of transport (in hours)

F_{ijm} - number of departures between cities *i* and *j* by a certain type of transport

α0, α1, α2, β 1, β 2, β 3, y1, y2, y3 – parameters of the model.

C_{ijg}, H_{ijg}, F_{ijg} are three basic limiting model variables: C_{ijg} is the cost of travel, H_{ijg} is the duration of journey, and F_{ijg} the frequency of departures between city *i* and city j. More precisely, C_{ijg} and H_{ijg} are the average values of transport attributes by number of departures, whereas F_{ijg} is the average number of departures.

$$C_{ijg} = \frac{\sum_{k=1}^{M} F_{ijk} C_{ijk}}{\sum_{k=1}^{M} F_{ijk}}, \quad \mathrm{H}_{ijg} = \frac{\sum_{k=1}^{M} F_{ijk} H_{ijk}}{\sum_{k=1}^{M} F_{ijk}} \quad \text{and} \quad \mathrm{F}_{ijg} = \frac{\sum_{k=1}^{M} F_{ijk}}{M} \qquad (4)$$

where M represents the number of types of transport between cities *i* and *j.*

4. DATA

In order to implement the model of intercity fast ship lines in maritime passenger transport, the routes with corresponding values (Table 3) have been selected. When selecting a route, it has been taken into account that there are connections by bus (B), train (T), state road (S), and highway (H) between the cities to be considered. Data for some types of transport were not fully available and are sometimes based on authors' estimates. Assessments for some of the routes relate to the number of passengers transported by cars and are based on the results of the official traffic statistics. The focus was on the routes running towards Rijeka, and those connecting Zagreb – Karlovac and Zagreb - Split, i.e. the routes that carry substantial traffic flow in the Republic of Croatia. The data collected refer to 2019.

Route	P_i	P_j	Y_i	Y_j	C_{ijm}	H_{ijm}	F_{ijm}	Number of passengers	
Rijeka-Pula	128624	57460	12305	12711	8,15	2,40	4	7400	T
Rijeka-Pula	128624	57460	12305	12711	13.01	1,50	15	31000	B
Rijeka-Pula	128624	57460	12305	12711	8,36	1,30	96	528520	H
Rijeka-Pula	128624	57460	12305	12711	4,82	1,30	96	372786	S
Rijeka-Delnice	128624	5952	12305	10000	5,39	1,10	6	3900	T
Rijeka-Delnice	128624	5952	12305	10000	6,37	1,00	14	9000	B
Rijeka-Delnice	128624	5952	12305	10000	2,65	0,45	96	242984	H
Rijeka-Delnice	128624	5952	12305	10000	2,24	0,58	96	141000	S
Rijeka-Karlovac	128624	55705	12305	7634	11,57	3,33	1	2100	T
Rijeka-Karlovac	128624	55705	12305	7634	11,15	1,30	24	7000	B
Rijeka-Karlovac	128624	55705	12305	7634	7,43	1,13	96	252105	H
Rijeka-Karlovac	128624	55705	12305	7634	6,10	2,00	96	50000	S
Rijeka-Zagreb	128624	790017	12305	22695	7,96	4,30	5	175865	T
Rijeka-Zagreb	128624	790017	12305	22695	13,27	2,15	38	250000	B
Rijeka-Zagreb	128624	790017	12305	22695	9,29	1,54	96	1873743	H
Rijeka-Zagreb	128624	790017	12305	22695	8,84	3,00	96	200000	S
Zagreb-Karlovac	790017	55705	22695	7634	4,57	0,57	14	40000	T
Zagreb-Karlovac	790017	55705	22695	7634	4,78	1,06	18	49000	B
Zagreb-Karlovac	790017	55705	22695	7634	2,52	0,46	96	2992284	H
Zagreb-Karlovac	790017	55705	22695	7634	2,76	1,30	96	500000	S
Zagreb-Split	790017	178102	22695	7952	19,76	6,10	3	396117	T
Zagreb-Split	790017	178102	22695	7952	17,25	5,00	10	550000	B
Zagreb-Split	790017	178102	22695	7952	24,02	4,00	96	2813785	H
Zagreb-Split	790017	178102	22695	7952	17,55	6,00	96	600000	S

Table 3. Population, GDP / per capita, price, time of travel, number of departures and number of passengers on selected routes (Source: authors, according to various data sources and their own estimates).

5. RESEARCH RESULTS, MODEL TESTING AND DISCUSSION

The data presented in Table 3 allow the values of the individual model elements to be calculated and then logged. Based on the logarithm values of the variables, a regression analysis has been performed and a practical model of the following form obtained (r=0.95):

$$T_{ijm} = e^{88.1077} \cdot (P_i \cdot P_j)^{4.1117} \cdot (I_{ij})^{2.82228} \cdot (C_{ijg})^{5.187109} \cdot (H_{ijg})^{-9.38355} \cdot (F_{ijg}) -36.266 \cdot (C_{ijm}/C_{ijg}) -1.98289 \cdot (H_{ijm}/H_{ijg}) - 2.14475 \cdot (F_{ijm}/F_{ijg}) 0.4185 \quad (5)$$

The calibration of the individual elements of the model would be far more precise if a higher number of routes were considered. However, as the model testing has been carried out on the routes Rijeka - Pula, Pula - Zadar and Rijeka - Zadar, the obtained results serve to make scientifically based conclusions about the size of traffic in the above selected area. Likewise, just one route (Rijeka - Pula) has been selected to provide a detailed presentation of the model test regarding the organisation of fast ship lines in maritime traffic. To begin with, a brief overview and analysis of the existing traffic connections between the two cities are given (Table 4).

Connection	Distance (km)	Duration of journey (hours)	Travel cost (EUR)	Number of departures	Connection
Car via Istrian Y highway	108.32	1.13	16,71	Na	Direct line
Car on state road along the east coast of Istria	103.53	2.07	9,63	Na	Direct line
Bus connection	108.32	2.30	13,67	13	Direct line
Railway connection	108.15	2.22 – 3.26 (mean 3.00)	9,50	3	Transit in Lupoglav

Table 4. Traffic connectivity between the cities of Rijeka and Pula (Source: Authors).

Table 4. shows that railway transport is the most cost-effective if the price per passenger is taken into consideration. However, if it is assumed that two passengers drive in a car on the Rijeka-Pula route, then the competitive effect of the railway traffic is lost immediately. In the latter case, the connection with the Istrian Y highway is cheaper per passenger than railway traffic, despite the toll (62.80 HRK). With regard to the speed of transport, there is no doubt that the use of a car at the Istrian Y is a priority in relation to all other types of transport. When observing the number of departures, the preference for using a car is also evident. As for the number of departures, the travellers can decide what time is most suitable for them, but the mathematical calculations can be considered, for example, every 15 minutes or 96 times per day. Bus operators offer 12 departures from Rijeka and 14 from Pula (13 on average), which also results in the advantage of bus transport over railway transport. Concerning the relative performance of some alternative connections on the Rijeka - Pula route, they are summarised in Table 5.

	SR-26	Y	BUS	Train
Duration of journey(h)	1.8	1.0	1.9	2.5
Travel cost (EUR)	0,19	0,20	0,21	0,13
Number of Departures	1.0	1.0	7.4	32

Table 5. Relative performances of alternative connections on the route Rijeka – Pula (Source: authors).

Table 5, presenting the comparisons among the relative performers of alternative travel connections between Rijeka and Pula, shows that the advantage of using a car is evident in the absence of maritime connection between the two cities. In addition to the practical transportation effects, establishing a fast ship maritime passenger inter-city line should bring other benefits that involve energy efficiency, traffic safety, environmental protection, unburdening routes and so on, resulting in a relatively better performance in any of the three listed economic exploitation features. As far as the number of departures is concerned, it is realistic to expect one or two maritime passenger connections on the Rijeka - Pula route and vice versa, with morning departure (between 7 and 9 am) and evening return (between 4 and 6 pm). As for travel costs, it is realistic to expect that a one-way ticket could amount to about 6.64 EUR, making this line relatively competitive with all other forms of transport. At such a price and estimated travel time of around two hours, a significant number of passengers could be expected.

The model has been tested on the Rijeka - Pula route in a way that the included data has been aligned to the following assumptions:

1) Rijeka - Pula intercity fast ship line is performed once per day by a speedboat at a speed exceeding 30 knots (55.560 km/h);
2) The price of the ticket is 10.62 EUR;
3) Travel time is two hours.

Based on the assumptions included in the model, it is estimated that at least 15.668 passengers may be transported in the first year of the introduction of the fast intercity maritime passenger line. This means that, during the first year of operation, a shipper would make a minimum of 166,360.08 EUR on this route.

It can be concluded that the introduction of a fast ship line in maritime passenger transport on the analysed Rijeka - Pula route would result in a significant passenger flow, i.e. passenger transport by sea would exceed railway transport and, at the same time, reach the flow level of bus transport. Certainly, this encouraging data can be of help to shipping companies in maritime transport. It is important to note here that the estimated number of passengers and the estimated effects of the intercity line organisation in maritime passenger transport refer to domestic demand for maritime passenger transport. If tourism estimates were to be included in the previously mentioned model, these effects would be far bigger. In order to obtain a more realistic picture of the potential demand on the above-mentioned inter-city lines, it seems appropriate to include the tourist demand into the model. This means that the calculated potential demand should be multiplied by the coefficient of population growth in tourist towns during the season. Population growth coefficient is estimated at three after a detailed analysis of the number of tourist arrivals in tourist towns during the season.

Accordingly, the estimated domestic demand and tourist demand in three tested routes is given in Table 6.

Route	Domestic demand	Revenue of shippers from domestic demand (EUR)	Tourist demand	Revenue of shippers from total demand (EUR)
Pula – Rijeka	15668	166.360,08	47004	499.080,23
Pula – Zadar	5900	78.306,46	17700	234.919,37
Rijeka – Zadar	21042	349.094,17	63126	1.047,28

Table 6. Estimated number of passengers and shippers' revenue in three tested routes.Based on the data from Table 6, a proposal was made of the capacity of the fast ships that the shipping company would have to use on the tested routes during and off-season.

Domestic demand	Passenger capacity	Tourist demand	Average number of passengers during the season (90 days)	Capacity of a fast ship
15668	200 persons	31336	349	400 persons
5900	100 persons	17700	131	200 persons
21042	200 persons	42084	468	400 persons*

*An additional line during the season is suggested

Table 7. Necessary capacity of fast ships in season and off- season.

6. INTERCITY FAST SHIP LINES IMPACT ON CLIMATE CHANGE

The European Green Deal sets a goal of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 (European Green Deal, 2022). Facilitating a move to the most environmentally friendly forms of transportation can help achieve this goal. Nowadays, it is extremely important to grasp what factors contribute towards our individual carbon footprint growing and how we can take action to reduce it. When considering different types of travelling, besides travel time and cost, it is of great importance to pick the most environment-friendly choice.

Travel mode	CO_2 emissions (g/km per passenger)
International rail	6
Ferry (passengers only)	19
National rail	41
Diesel car, 4 passengers	43
Petrol car, 4 passengers	48
Diesel car, 2 passengers	85
Petrol car, 2 passengers	96
Bus	105
Ferry (cars and passenger)	130
Domestic flight	255

Table 8. Carbon footprint of travel per kilometer, 2018

Table 8 presents how different means of transportation compare in terms of their carbon impact. The amount of greenhouse gases released per person to travel one kilometer is used to get these values. Greenhouse gases are measured in carbon dioxide equivalents (CO_2eq), which takes non-CO_2 greenhouse gases into account, as well as the increased warming effects of aviation emissions at high altitudes.

When international rail is omitted, ferry (passengers only) is the most environment-friendly means of transportation. However, flying is not necessarily the most harmful choice, depending on how long the route is. This role is often taken by the conventional car, if single occupancy is assumed and the road route is longer than the air route.

Every long trip requires people to make a conscious decision and analyse all available transportation options, not just in terms of financial expenses, but also in terms of environmental costs. It is critical to have access to trustworthy and consistent environmental data. Finally, a standardised method for assessing the environmental performance of the many modes of transportation available for a given journey would be a significant step forward.

7. CONCLUSIONS

This research has resulted in a model that provides an estimate of the possible contribution of fast intercity lines towards the development of the maritime passenger transport system in the Republic of Croatia and determines the feasibility of establishing these lines in order to achieve a balance between certain forms of traffic. A meticulous analysis of an abstract type of transport has been performed to propose the model. In addition to relating to the gravity models for estimating demand in passenger transport, the proposed model has also been selected for the following reasons:

1) There is no intercity fast ship maritime passenger transport in Croatia, which implies establishing an entirely new type of transport;
2) The model takes into account the basic postulates of the system theory, namely the fact that maritime passenger transport cannot be observed isolated in relation to other types of transport that provide the same or similar service;
3) The model features a variable of the economic-exploitation characteristics of particular forms of traffic.

In this regard, the ability to establish transport services in maritime passenger transport is reflected in the number of departures, time of transport and travel costs. These variables are essential, not only in modelling the organization of intercity fast ship lines, but also in demonstrating economic justification for establishing such transport. The results of the research confirm the intercity connection via fast ship lines as an active form of diverting traffic from road to sea routes. The organisation of intercity fast ship lines in the maritime passenger traffic of the Republic of Croatia would contribute towards the rationalisation and greater efficiency of traffic, balance of traffic areas, reduced domination of road traffic and its negative impacts, environmental protection in the coastal areas, and improvement of the quality of liner and tourist maritime passenger transport. The projected changes in global shipping and port management, as a result of environmental protection and decarbonisation will have a significant impact on Croatia and the rest of the globe. Changes connected to decarbonization are likely to result in adopting the renewable energy sources and development of new low-carbon technology. Until these technologies are developed and integrated, it is of paramount importance to choose the most environmentally friendly means of transportation - which the proposed model offers. The proposed model for the organisation of intercity fast ship lines can be implemented in similar geographic areas, e.g. in Italy, Greece, Spain, Denmark, Sweden, France, and other countries.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship and publication of this article.

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