ANALYSIS AND ESTIMATION OF THE VOLUME OF PUBLIC PASSENGER TRANSPORT IN THE NORTHERN ADRIATIC FUNCTIONAL REGION

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Abstract

The primary aim of this paper is to analyse and estimate the volume of public passenger transport in the Northern Adriatic functional region. Its purpose is to estimate the volume of public urban traffic between the major centres of the functional region. The paper's main hypothesis is: The establishing of functional regions should contribute towards gaining a higher level of transport interaction, within each of the regions as well as within the entire territory of Croatia. To accomplish the objective and purpose of research and prove the set hypothesis, several scientific methods were applied, in particular the analysis and synthesis method and the mathematical method. The research results are based on a computer-supported gravity model. The paper's main finding points to the modest volume of public passenger transport between major county centres in the Northern Adriatic functional region, which is mostly based on road transport, that is, bus transport, which is neither ecologically nor economically acceptable.

Keywords: public passenger traffic, Northern Adriatic functional region, gravity model

1. INTRODUCTION

The development of the transport system in the Republic of Croatia is seen as exceptionally important for both the country's economic and social growth, and its international connectivity. Although the division of Croatia into counties resulted in improved intra-county traffic connectivity, inter-county traffic connectivity has been neglected. Hence, the Transport Development Strategy of the Republic of Croatia for the period 2017-2030 was devised and adopted. The Strategy divides Croatia into six functional regions (FR) characterized by a high level of traffic interaction within their respective areas. These functional regions are 1) Central Croatia, 2) Eastern Croatia, 3) Northern Adriatic, 4) Northern Dalmatia, 5) Central Dalmatia, and 6) Southern Dalmatia (Figure 1). With regard to the above, the following working hypothesis was formulated: The establishing of functional regions should contribute towards gaining a higher level of traffic interaction, within each of the regions as well as within the entire territory of Croatia. The aim is to make the public transport of passengers more competitive relative to other forms of transport. To prove the hypothesis, this paper uses the methods of analysis and synthesis, the methods of induction and deduction, the mathematical method and the information modelling method. A computer-supported gravity model was developed to estimate the volume of public urban traffic between the major centres of the Northern Adriatic FR.

2. LITERATURE REVIEW

Transportation is often referred to as the lifeblood of cities and regions because it provides the essential link of constantly moving population in this area, thereby helping to shape the region (Vuchic, 1999, Zelenika, 2001). Public transportation is a form of travel offered locally that enables more people to travel together along designated routes. Typical examples of types of public transportation include buses, trains, and trams. High-speed rails, airlines, and coaches dominate public transportation between cities. Regional public transport covers all collective passenger transport services excluding most public transport within cities and urban centres. In general, regional transport services bring captive riders from lower-density and suburban areas to larger city centres and serve small- and medium-sized cities.

The transition of passengers from public transport to private transport means increasing the social costs (Gnap at all, 2006). That means that it's necessery to find the effective methods to increase public transport competitiveness. The main aim of public passenger transport is to increase the level of mobility. Accordingly, organisation of public passenger transport especially in rural areas is a complex process. The transport demand in rural areas is often low, which makes it hard to establish and run an economically sustainable public passenger transport system (Maretić & Abramović, 2020). Public passenger transport can hardly be financed only from revenue from fares. This fact is also confirmed by the studies Tscharaktschiew and Hirte (2012), Poliak (2013) or Drevs et al. (2014). Subsides tend to decrease the level of fares and increase the frequency of public transport links. Subsidies in public passenger transport make sense if they contribute to the improvement of the quality of transport or are of help to those for whom they are intended (Pupavac, Krpan, Maršanić, 2017).

As a framework for studying the quality in the public passenger transport authors often use elements such as (Hanson, et al., 2019): availability, accessibility, information, time, customer care, comfort, safety, environmental impact (cf. table 1).

Table 1. Studies about the relative importance of quality attributes in regional public transport

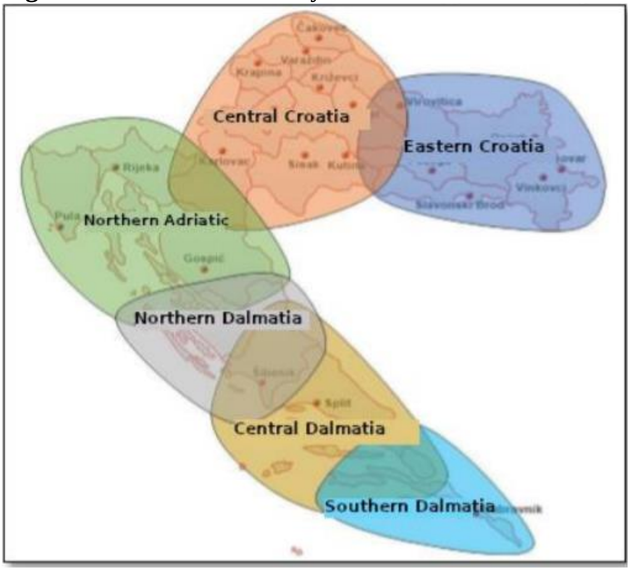
Reference	PT modes	Measure	Travel distance	Cost	Availability	Accessibility	Information	Time	Customer care	Comfort	Safety	Environmental impact
Bouscasse, Joly, & Peyhardi, 2016	Bus and rail	Modal choice	Long	x				x		x		
Majumdar & Lentz, 2012	Bus	Modal choice	Medium	x	x	i		x	x	x	i	i
Rashedi, Mahmoud, Hasnine, & Habib, 2017	Bus and rail	Modal choice	Long	x	i	i	i	i		x		
Zhou, Du, Liu, Huang, & Ran, 2017	Bus	Modal choice	Short	i	x	i	x	x	i	x		
Asensio, 2000	Rail	Demand	N/A	i	x					x	i	
Berežný & Konečný, 2017	Bus	Demand	Short				x	x	i	i		
Román, Martín, & Espino, 2014	Bus	Demand	Medium	i	i		i	i	i	x	i	
Eboli & Mazzulla, 2011	Bus	Satisfaction	Short	i	x		x	x	i	x		
Garrido, de Oña, & de Oña, 2014	Bus	Satisfaction	Short	i	x	i	x	x	i	i	i	i
Grisé & El-Geneidy,2017	Rail	Satisfaction	Medium	x	x	x	i	x	i	x	i	
Guirao, García-Pastor, & López-Lambas, 2016	Bus	Satisfaction	Short		x	i	i	x	i	i	x	
Ramesh, Rao, & Sarkar, 1998	Bus	Satisfaction	Medium	i	x	x		x		x	x	
Rojo, Gonzalo-Orden, dell'Olio, & Ibeas,2011	Bus	Satisfaction	Long	x	x		i	i		x	i	
Stern, 1981	Bus	Satisfaction	Short	i	x			x				

Quality categories included in the analysis (marked by i) and discussed by the authors as being important (x).
Source: Authors' prepared according: Hansson, J., Pettersson, F., Svensson, H. et al. (2019). Preferences in regional public transport: a literature review. Eur. Transp. Res. Rev. 11, 38.

3. PUBLIC PASSENGER TRANSPORT IN THE NORTHERN ADRIATIC FR

The Northern Adriatic FR is one of the six functional regions of Croatia (Figure 1).

Figure 1. Zones for FR analysis

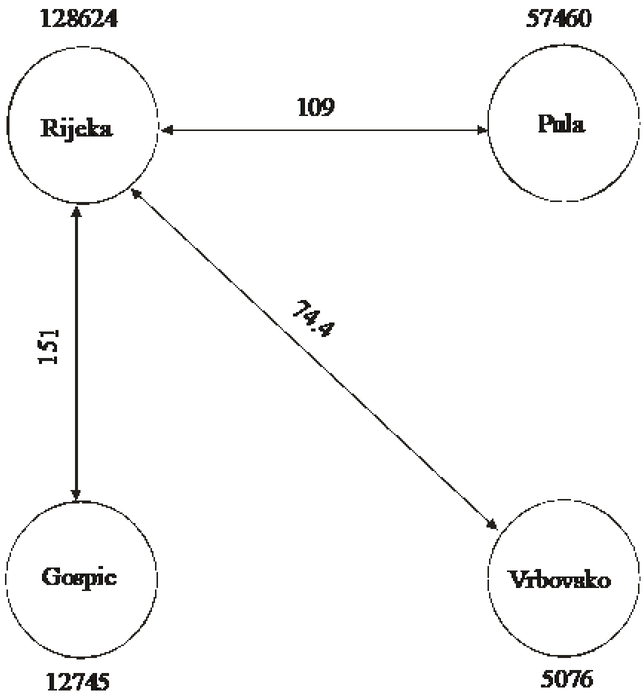


Source: Transport Development Strategy of the Republic of Croatia for the period 2017 – 2030

Public passenger transport in the Northern Adriatic FR is carried out through road, rail, maritime, and air transport. With regard to road transport, the functional region comprises inter-county, county, and urban passenger transport systems, and is served by 469 inter-county lines and 118 county lines with 263 departure points. The towns of Rijeka and Pula have urban public transport systems, with Rijeka being served by 19 urban lines and 33 suburban lines, and Pula, by 9 urban lines and 5 suburban lines. The region’s rail passenger transport system is set up through the national rail transport system and is served by 43 rail lines. With regard to maritime transport in the functional region, public passenger transport is maintained by two shipping lines and two fast shipping lines. With regard to public air passenger transport, the region is served by three airports, Rijeka Airport, Pula Airport, and Mali Lošinj Airport. Daily, these airports have 12 flights on average during the off-season, and 41, during the peak season.

Figure 2 illustrates the major political, economic and cultural centres of the Northern Adriatic FR and the distances between them.

Figure 2. Number of inhabitants of, and distances by road between, major centres of the Northern Adriatic FR



Source: Authors' own construction

We chose to evaluate public passenger transport between the towns of Rijeka and Pula, and Rijeka and Gospić, because these towns are county centres and because there are no direct public transport lines connecting, for example, Pula and Gospić, or Vrbovsko and Gospić. Rijeka and Gospić are connected by only two daily direct bus lines, with departures at 6.00 a.m. and 4.15 p.m. Being the eastern-most point of Primorje-Gorski Kotar County, the town of Vrbovsko was selected because it is a junction point for road and rail transport between the Northern Adriatic FR and the Central Croatia FR. As there is no connection between the railway network of Istria County and the railway networks of Primorje-Gorski Kotar County and Lika-Senj County, travelling between Pula and Gospić by train, takes from 9 hours and 14 minutes to as much as 22 hours and 19 minutes, with three layovers, while travelling from Pula and Vrbovsko can last from 4 hours and 35 minutes to 17 hours and 50 minutes, with three layovers. Travelling by rail from Vrbovsko to Gospić can take from 2 hours and 56 minutes to 13 hours and 51 minutes, with one layover. These numbers suggest that public road transport of passengers is dominant between the county centres of the Northern Adriatic FR.

4. RESEARCH PROBLEM

The largest issue in the public passenger transport system of the Northern Adriatic FR is its exclusive reliance on road transport. Being a relatively large and jagged geographical area, with a low number of inhabitants and poor railway connections, the Northern Adriatic FR does not favour the development of integrated public transport. Accordingly, at present, no novel, innovative, sustainable forms of public transport are being implemented in this functional region. Public passenger transport is largely based on road transport which is neither ecologically nor economically acceptable.

Another issue is that county and inter-county transport operates solely on a commercial basis. Hence, only those lines exist that are considered to be financially viable. This has resulted in the very poor public transport coverage (both spatial and temporal) of areas that are farthest from the larger towns of the Northern Adriatic FR. Over the years, a “vicious cycle” has emerged in this segment, where there is no bus service because there are no passengers, and there are no new passengers because there is no bus service. The inhabitants of the more remote areas are thus compelled to own one or more cars per household, which is not acceptable either financially, or economically, or ecologically.

In general, the public transport infrastructure in the Northern Adriatic FR is not in good condition. Investments are needed in railway stations, terminals, bus stops, and roads that fail to meet even the minimal requirements for the movement of public passenger transport vehicles. In particular, investments are needed in the railway infrastructure, which is in very poor condition. Rijeka, the regional centre, is in need of a new intermodal passenger terminal (road, rail, ship). The condition of the fleet vehicles in bus transport is far from ideal. Most buses serving the Northern Adriatic FR are more than 10 years old. The integrated ticketing systems used in public transport also are not at the level of those in developed European countries.

5. MODEL

The gravity model is the most common formulation of the spatial interaction method (Božić, 2009, 118). It is named as such because it uses a formulation similar to that of Newton’s law of gravity. The attraction between two objects is proportional to their mass and inversely proportional to their respective distance. According to Evans (1973), a gravity model for trip distribution describes the number of trips between two zones as a product of three factors: 1) zone in which a trip begins, 2) zone in which it ends, and 3) the separation between the zones. The separation factor is a decreasing function of travelling costs, time of travel, or distance travelled. Consequently, the general formulation of spatial interactions can be adapted to reflect this basic assumption to form the **elementary formulation** of the gravity model:

$$Tij = \mathrm{k}\frac{PiPj}{dij} \tag{1}$$

- *Pi* and *Pj* - importance of the location of origin and the location of destination.
- *dij* - distance between the location of origin and the location of destination.
- *k* is a proportionality constant related to the rate of the event. For instance, if the same system of spatial interactions is considered, the value of *k* will be higher if interactions were considered for a year compared to the value of *k* for one week.

Thus, spatial interactions between locations *i* and *j* are proportional to their respective importance divided by their distance.

The gravity model can be extended to include several calibration parameters:

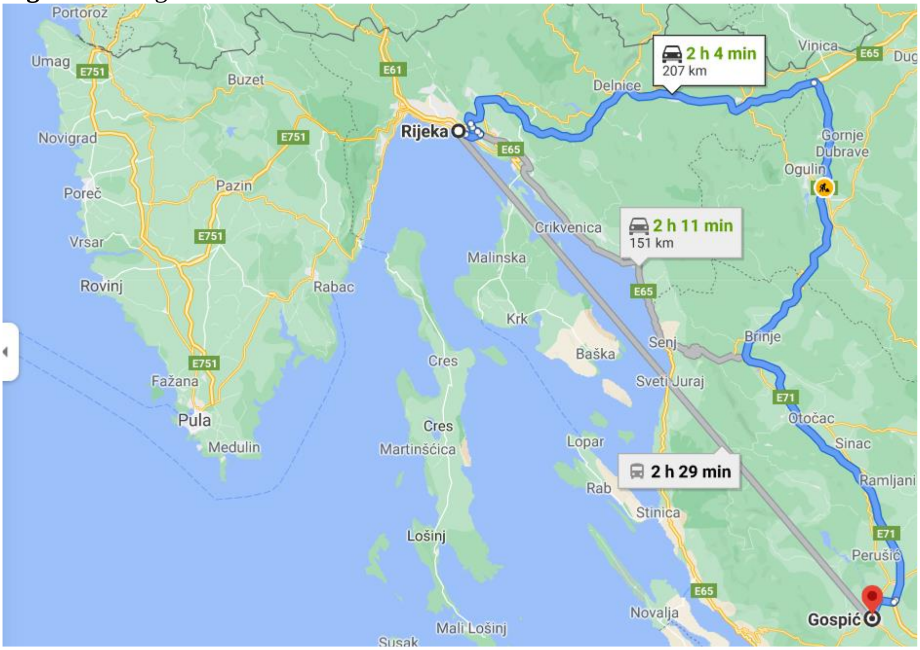
$$Tij = \mathrm{k}\frac{\mathrm{P_i^\lambda P_j^\alpha}}{\mathrm{d_{ij}^\beta}} \tag{2}$$

- *P*, *d* and k refer to the variables previously discussed.
- β (beta) - a parameter of transport friction related to the efficiency of the transport system between two locations. This friction is rarely linear as the further the movement, the greater the friction of distance. For instance, two locations serviced by a highway will have a lower beta index than if they were serviced by a regular road.
- λ (lambda) - potential to generate movements (emissivity). For movements of people, lambda is often related to an overall level of welfare. For instance, it is logical to infer that for retailing flows, a location having higher income levels will generate more movements (customers).
- α (alpha) - potential to attract movements (attractiveness). Related to the nature of economic activities at the destination. For instance, a centre having important commercial activities will attract more movements (Rodrigue, Comtois, Slack, 2006, 167-168).

6. RESEARCH RESULTS AND DISCUSSION

The Northern Adriatic FR encompasses three counties: Istria County, Primorje-Gorski Kotar County and Lika-Senj County (see Figure 3).

Figure 3. Range of the Northern Adriatic FR



Source: Authors' own construction, after: https://www.google.com/maps

Figure 3 demonstrates that the town of Ogulin (Karlovac County) is in the overlapping zone of the Northern Adriatic FR and the Central Croatia FR. Namely, Lika-Senj County and Primorje-Gorski Kotar County are connected via Ogulin by a rail and road (motorway) transport network. Pula, Rijeka and Gospić are major county centres and places regulating public passenger transport within their respective counties.

Of the total number of passengers transported on land on typical days in a year in Primorje-Gorski Kotar County, 457 passengers are transported by rail and 72,831, by bus, accounting for 99.4% of passengers in land transport. When the number of passengers (3,652) carried in maritime transport on typical days in a year is added, road transport passengers account for 94.6% of the overall number of passengers in public transport; however, as a certain part of road transport also uses maritime, that is, ferry lines, a substantial number of the passengers carried in maritime transport are also passengers carried in road transport.

Of the total number of passengers in public transport on typical days in a year in Istria County, 633 passengers are transported by rail and 2,418, by bus, accounting for 85.3% of passengers carried in road transport.

Of the total number of passengers in public transport on typical days in a year in Lika-Senj County, 5 passengers are transported by rail and 491, by bus, accounting for 99% of passengers carried in road transport.

The above illustrates the obvious dominance of road passenger transport over other forms of transport. These facts suggest that other forms of transport are poorly developed and their potential, underutilised. In particular, this applies to rail transport and to the inadequate offering of rail lines, within the entire territory of the Northern Adriatic FR, that would be able to compete with road transport, that is, the public transport of passengers on inter-county and county bus lines. Also evident is the lack of a satisfactory public maritime transport offering, particularly with regard to Istria County, as there is no maritime alternative to public road transport of passengers, such as county or local shipping lines between towns on the west coast of Istria.

In Lika-Senj County, passengers carried by road transport account for fully 100% of the total number of passengers in public passenger transport, indicating that rail transport has been completely neglected. Hence, there is no demand for travel by rail due to the inadequate transport and exploitation features of railway lines and networks in this county.

Being major county centres, Pula, Rijeka and Gospić also regulate the public transport of passengers among their respective counties. The potential volume of public passenger transport between the centres is estimated using the gravity model, which is the best known, the most often used, but also the most disputed model (Pupavac, 2017).

Based on equations (1) and (2) and the data presented in Figure 1, a gravity model was developed using the Excel spreadsheet (Table 2).

Table 2. Computer-supported gravity model to estimate the weekly volume of public passenger transport in the Northern Adriatic FR

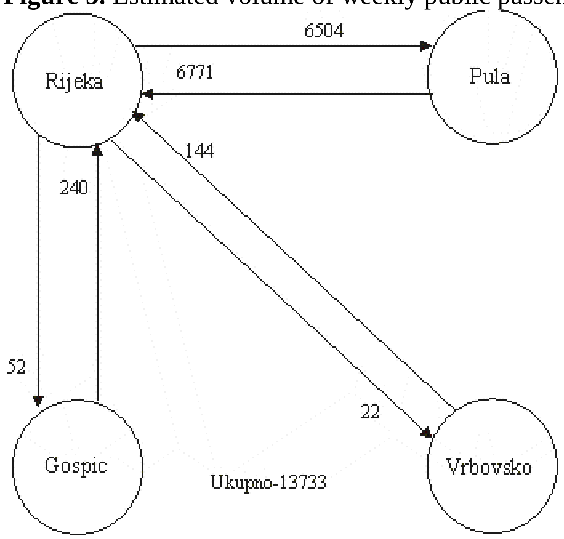
	A	B	C	D	E	F
4		Population	Lambda	Alfpa		
5	City V	5076	0,85	0,7		
6	City R	128624	1,1	1,15		
7	City P	57460	1,05	1,1		
8	City G	12745	0,9	0,8		
9						
10	Parameters					
11	Constant k	0,0000125				
12	Beta	1,05				
13						
14	Distannce Matrix					
15		City V	City R	City P	City G	
16	City V		74,4			
17	City R	74,4		109	151	
18	City P		109			
19	City G		151			
20						
21	Elementary Spatial Interaction Matrix					
22		City V	City R	City P	City G	Ti
23	City V		109,6935			109,6935
24	City R	109,693452		847,5614	135,7047	1092,96
25	City P		847,5614			847,5614
26	City G		135,7047			135,7047
27	Tj	109,693452	1092,96	847,5614	135,7047	2185,919
28	Simple Spatial Interaction Matrix					
29		City V	City R	City P	City G	Ti
30	City V		143,6058			143,6058
31	City R	22,1757222		6503,821	51,70235	6577,699
32	City P		6771,212			6771,212
33	City G		239,613			239,613
34	Tj	22,1757222	7154,431	6503,821	51,70235	13732,13

Source: Authors' own construction

The first and second parts of the table comprise input data: number of inhabitants, parameters (α, β, λ), the constant (k), and the distances between the various towns in the Northern Adriatic FR. As the values of the parameters and the constant (k) are the result of experiential estimation by the authors, objective calibration of these values should be the focus of a separate study. The calibration of parameters (Naser et. al., 2020) has to be based on real data. Formulas in accordance with model (1) in the address field B23:E:23 and model (2) in the address field B30:E:33 were pasted into the second part of the table.

The estimated volume of weekly passenger transport between the above-mentioned centres is given in field F34 and amounts to 13,733 passengers, or 1,962 passengers per day. The highest volume of weekly passenger transport was estimated for transport between Rijeka and Pula, which is understandable considering these are the two largest towns in the Northern Adriatic FR (Figure 5)

Figure 5. Estimated volume of weekly public passenger transport



7. CONCLUSION

The Northern Adriatic FR is one of six functional regions in Croatia. Functional regions were established to improve inter-county transport connectivity and, in turn, ensure more balanced transport connectivity within the entire territory of Croatia. Public passenger transport in the Northern Adriatic FR consists of road, rail, maritime, and air transport. Public road transport of passengers is the dominant form of transport, and reasons for this are small numbers of inhabitants, a lacking and inadequate transport offering, no connections between railway transport networks, poor transport infrastructure, and the financial unsustainability of certain transport lines. The overall volume of public passenger transport is estimated at 13,733 passengers per week. Areas farthest from the larger towns of the Northern Adriatic FR are very poorly covered by public transport. The largest weekly volume of public passenger transport was estimated for the Rijeka-Pula route, while the weekly volumes of public passenger transport for the Rijeka-Gospić route and Rijeka-Vrbovsko route are almost negligible. In both of the former cases, transport demand is greater in the direction of Rijeka than from Rijeka in the directions of Gospić and Vrbovsko. The main limitation of this paper is the subjective experiential calibration of gravity model parameters by the authors. Future studies should focus on carrying out further research to obtain a more objective estimation of the model's parameters and, in turn, a more objective estimation of the volume of public passenger transport.

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