

DETERMINING ACCESSIBILITY OF POST NETWORK ELEMENTS WITH APPLICATION OF GRAVITY METHOD

ODREĐIVANJE DOSTUPNOSTI ELEMENATA POŠTANSKE MREŽE POMOĆU PRIMJENE GRAVITACIJSKE METODE

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ABSTRACT

The accessibility of postal services is guaranteed by international and domestic regulations. Regulating certain density of postal network elements is the most commonly used mechanism that enables the accessibility of postal services to residents of a given country. Commonly used regulatory measures (criteria) are mainly adopted and supervised by regulatory bodies in the postal services market. This paper analyzes the application of the concept of spatial accessibility in the postal system as well as the analysis of the spatial characteristics of the selected research area. Gravity method was used to calculate the accessibility indicator of postal network elements, and therefore postal services.

Key words: service accessibility, postal network, post office, gravity method

Ključne riječi: dostupnost usluge, poštanska mreža, poštanski ured, gravitacijska metoda

1. INTRODUCTION

Concept of the of postal service accessibility is most often described through regulatory measures provided by the state, to maintain the postal network and enable provision of postal services. According to the Postal Directive [1], necessary regulatory measures should be taken in the European Union Member States, in order for the accessibility of postal services to meet the needs of users. It also states the obligation to maintain adequate density of access points in rural and remote regions in order to guarantee access to the postal network. Regulatory measures are most often implemented through several models [2]:

- one post office for a certain number of residents
- number of post offices in specific area
- minimum distance the user has to travel to the nearest post office
- maximum (air distance) between adjacent post offices
- minimum number of post offices that provide universal service
- the percentage of population at a certain distance from the post office.

In Republic of Croatia, the following criteria for density of network access points are set [3]:

1. One post office operates on an average surface of up to 80 km², or
2. One post office operates on average for a maximum of 6 000 inhabitants
3. Universal service provider shall establish a network of access points in the populated areas in such a way that the distance between the access points does not exceed 5 000 m.

The average number of inhabitants and the area in km² refers to the entire territory of the Republic of Croatia, and the network of post offices must consist of at least 700 regular post offices.

It is evident that the accessibility of postal services is most often defined through certain regulatory measures that are adopted and implemented in different countries. Formalized mathematical calculation of postal service accessibility and accessibility indicator haven't so far been the subject of research in the field of postal technology. The aim of this paper is to apply gravity method to calculate the potential accessibility indicators of postal network elements (post offices).

Theoretical basis for determining service accessibility is analyzed in the next chapter, and the notion of service availability in the postal system is introduced.

2.1 CONCEPT OF SERVICE ACCESSIBILITY IN POSTAL SYSTEM

2.1 Theoretical background of determining service accessibility

The definition of accessibility is defined in several ways, since it is used in multiple sectors or areas. Table 1 shows several examples of areas investigating the service accessibility, highlighting the importance of research of accessibility of different services in postal sector as well.

Table 1. Subject of research of accessibility in different areas

Areas	Subject of research
Urban planning	Residential development and accessibility to commercial, industrial, and residential locations, physical planning
Geography and health	Distribution and proximity impact on infant mortality, geographic accessibility to health care facilities in rural area
Public policy	Health care deprivation, residential mobility and location disadvantage
Public health	Health care in urban diabetic population, accessibility to public hospital

Source: [4]

Accessibility is often defined as the ability of people to reach certain locations, services or goods. Accessibility can be measured in distance (Euclidean, Manhattan or online), travel times (by driving, walking or by public transport) or travel cost [4].

Certain research categorizes accessibility measures in four categories [5]:

1. infrastructure-based measures analyze the impact or degree of service accessibility of transport infrastructure (degree of congestion, average road travel speed).
2. location-based measures analyze accessibility at locations (number of post offices, schools, hospitals or other services at a distance of 30 minutes of travel times from the population)
3. person based measures analyze accessibility at personal level (activities where an individual can participate in at a given time),
4. utility-based measures analyze economic benefits that people gain from access to spatially-distributed activities.

Given the characteristics of postal system, location-based measures are discussed in more detail in this research. Such measures are most often described and researched by distance measures, or potential measures. Potential measures indicate calculated potential accessibility, where actual data on the use of a particular service or infrastructure is not taken into account, but rather durability of resources or infrastructure that enables the exploitation of these resources. Measures or methods for calculating potential accessibility are actually ideal for use when it is difficult to get information on the actual use of particular services [6]. Distance measures relate to connecting points in space and are most easily described as a direct line (distance) between two points. Service accessibility is most often calculated within catchment area, determined by boundaries where people are willing to travel in order to arrive to certain services.

In the scientific field of geography, there are numerous researches dealing with accessibility of different types of services to the population. For this purpose, methods have been developed to identify

the areas of deficit, or in other words, the lack of accessibility of a given service. In other words, it is necessary to identify population that has no access to a certain set of services. Simple and easy-to-use methods are:

- supply and demand ratios
- service provider and population ratio
- distance to nearest service provider.

These methods are relatively simple to apply and do not require complex mathematical calculations. Disadvantages of such methods are following:

They do not take into account the distance function, all the population in a certain area is considered to be equally distant from the point of service supply

They do not take into account variations in space, since calculation mainly includes large areas
Equal access to a particular service is given to all population, without spatial distinctions etc.

In order for the supply and demand ratios, or distance to nearest service provider to be implemented in postal system, post office is considered as a place of supply and the population as a place of demand. Question rises on the area that determines the boundaries within which the population will belong to a particular post office. If the administrative boundaries of the post office area are selected, service accessibility according to (2) can be defined as supply and demand ratio for postal service in the selected area:

$$A_i = \frac{S_j}{\text{number of inhabitants of area}}$$

Where:

S_j – capacity of postal services at location of service provider i .

This method of calculating the postal service accessibility is quite simple and will not be considered further. For calculating postal service accessibility, gravity method has been applied to this survey, which, in addition to the capacity of the service at a particular location, takes into account distances between the service supply and demand point.

2.2 Accessibility of postal network elements

Postal service accessibility can be observed through the postal network, or the features specific to the recipient and the sender of the mail, as shown in Figure 1.

Sender-specific features include the sender's ability to access postal services at the location of parcel collection, accessibility of services, and access points opening hours. On the other hand, recipient - specific features include recipients' ability to reach postal services at the point of delivery of the parcel (mailbox, post office, electronic mailbox etc.), accessibility of service and parcel delivery time [7].

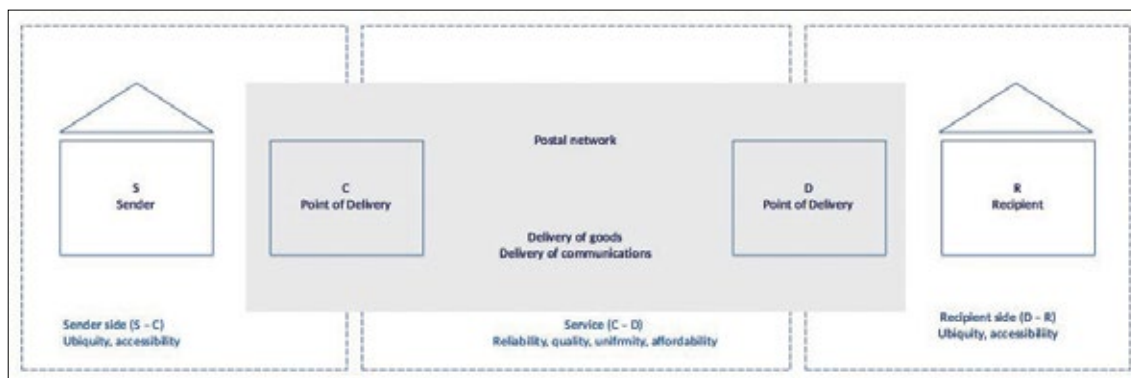


Figure 1. Two sides of postal network accessibility

Source: [7]

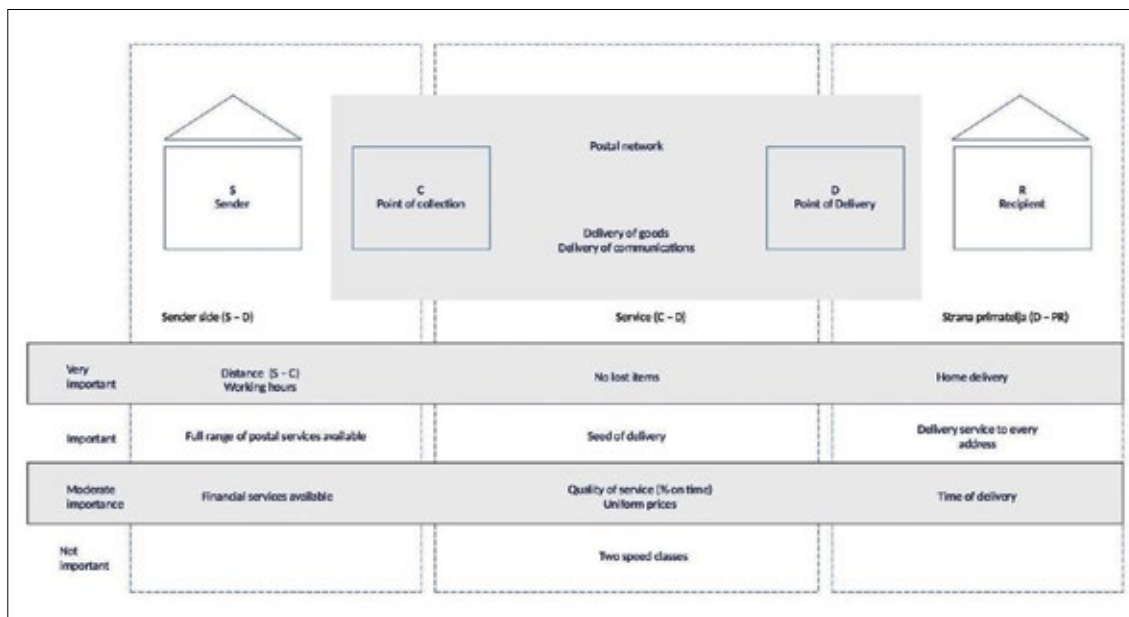


Figure 2. Importance of postal network features according to service postal service users' opinion

Source: [8]

According to [8], for sender-specific features of postal service users, it is important that there is an access point not distant more than 3 km. On the recipient side, home delivery is important, and service providers who do not deliver to all addresses in the country are not preferred. Figure 2 shows the levels of importance of the postal network features and what they include, according to the users of postal services.

The research has shown that the accessibility of collection and delivery of mail is a very important factor preferences of postal service users are considered. Important or moderately important factors relate to the accessibility of a particular service within the post office, quality of the service and the time of delivery of the shipment. When analyzing sender and the recipient side of the postal service, it is apparent that the distance to the postal network elements, the accessibility of full range of services and the delivery to the door are very important for the users.

Demands of the sender can be fulfilled by the existence of a regular post office because, apart from the fact that most offices offer a full range of postal services, their location and the ability to reach the office are a significant factor for the use of the service. Methods of planning accessibility of postal services should take into account the location of the population and its distance to the post offices, which is significant, both on the sender and recipient side. These methods provide service users easier access to the services, especially taking into account the specificity of the area and the available transport infrastructure to reach post offices. For service providers, network planning, delivery processes, and fulfillment of universal service obligations is facilitated.

3. SELECTION AND ANALYSIS OF SPATIAL CHARACTERISTICS OF RESEARCH AREA

3.1 Selection of research area

For the purpose of conducting this research, it is necessary to define a smaller area of analysis, to apply a method for determining the accessibility of universal service in the postal system. Several criteria were considered:

1. The area should be rural, in other words meet OECD Criteria [9] for the classification of rural areas
2. The density of the post office network should be optimal, it is desirable that there are no large areas of postal network inaccessibility
3. The data must be available for usage, provided by relevant institutions

Given that the focus of research is on rural areas, urban (City of Zagreb) and predominantly rural (seven counties) areas are excluded from the selection of research area. After that, an analysis of the coverage by the network of post offices of the remaining areas was carried out. Counties that are relatively scarcely covered by the network of post offices (for example Lika – Senj County) were also excluded from the selection.

Bjelovar - Bilogorska County was selected for the area of analysis where the calculation of postal service accessibility indicators will be applied.

Table 2 shows the basic characteristics of Bjelovar - Bilogora County, namely the number of settlements, the number of census tracts and the number of house numbers. It is evident that there are five cities in the county, with the rest of the municipalities (18).

Bjelovar - Bilogora County belongs among the counties with a lower population density, approximately 46 inhabitants / km². As shown in Figure 3, coverage of the postal network according to current network density criteria is satisfactory. In other words, there are not large areas of county that are not covered by the network of post offices.

Figure 3 shows the locations of the post offices in Bjelovar - Bilogora County with a covering range of 5 km air distance. Further analysis is needed to obtain insight in number of people living at a certain distance from the post office, as well as to determine accessibility indicator for a particular house number. For this purpose, geo-information data on county boundaries, house numbers, location of post offices and all other data required for a high-quality analysis of the postal services accessibility have been collected.

3.2 Analysis of spatial characteristics of selected research area

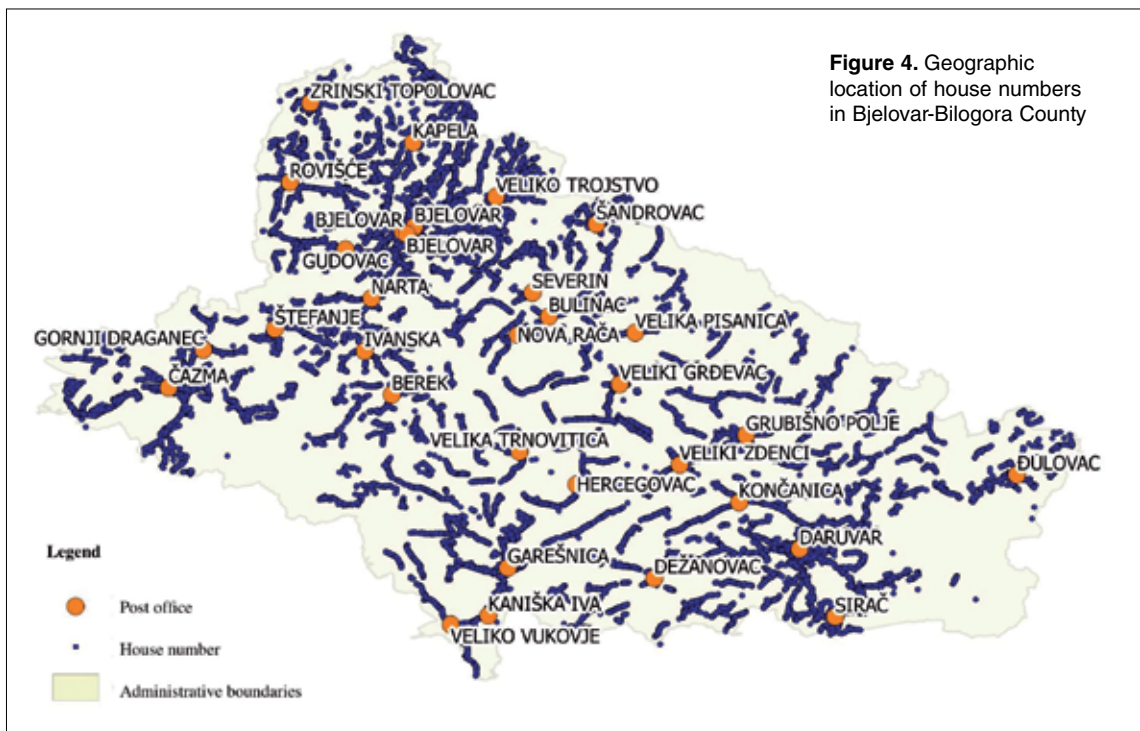
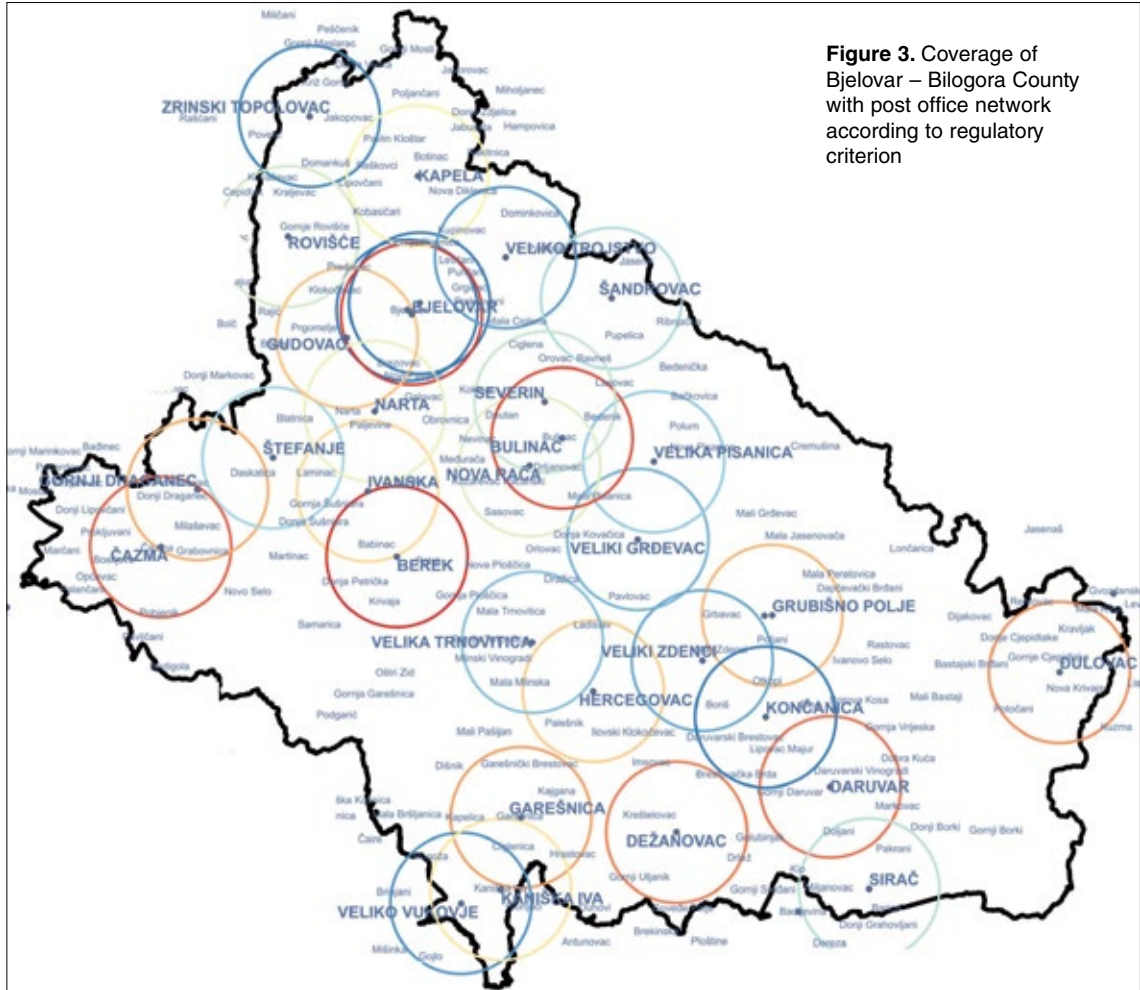
Figure 4 shows a chart containing a layer of information of post offices, house numbers, and the spatial boundaries of Bjelovar - Bilogora County. House number data is used to show and analyze the accessibility of universal service to the population in the area of Bjelovar - Bilogora County. House number data, in the context of the analysis of postal service accessibility, is a better input, given that it covers, not only domestic users of postal services, but also legal persons, companies, public administration bodies, etc.

There are 32 post offices in the Bjelovar - Bilogora County area, as well as 54 763 households.

Table 2. Representation of spatial characteristics of Bjelovar-Bilogora County

Bjelovar – Bilogora County	Number of settlements	Number of census tracts	Number of house numbers
Cities	123	473	30 595
Bjelovar	31	214	13 229
Čazma	36	60	4 040
Daruvar	9	76	4 856
Garešnica	23	67	4 672
Grubišno polje	24	56	3 798
Municipalities	200	402	24 075
Berek	13	17	1 024
Dežanovac	12	28	1 452
Đulovac	29	46	1 971
Hercegovac	5	17	1 106
Ivanska	13	23	1 442
Kapela	26	30	2 337
Končanica	9	22	1 291
Nova Rača	13	27	1 548
Rovišće	12	29	1 924
Severin	2	8	663
Sirač	9	26	1 412
Šandrovac	7	16	991
Štefanje	9	17	1 033
Velika Pisanica	8	21	996
Velika Trnovitica	8	14	721
Veliki Grđevac	11	29	1 881
Veliko Trojstvo	11	24	1 850
Zrinski Topolovac	3	8	443

Source: [10]



X	Y	ZS_JR	SD_DO	BD_DO	KB	KB_ST	SRUSNO	UL_ID	UL_BE	UL_PNE	PK_ID	PK_BE	PK_PNE	SK_ID	SK_PNE	Z_M	KO_PNE
16.9292994	-45.8296884	179	ALLI	ALLI	179	5	NE	27440001	1	KANJKA IVA	49438000	0	PK 000	48628	SK 0049438	3.	Kanjska Iva
16.93290719	-45.39677402	9	ALLI	ALLI	9	5	NE	81920001	1	CIGLENICA	24818000	0	PK 000	24828	SK 0014828	3.	Ciglenica
16.87876305	-45.91809713	13	ALLI	ALLI	13	5	NE	658970007	7	KATARINE KOTL...	122939000	0	PK 000	122939	SK 0122939	3.	Trojstveni Hako...
16.78340084	-45.6858988	118	ALLI	ALLI	118	5	NE	563910001	1	SAHARJICA	103337000	0	PK 000	103337	SK 0103337	3.	Saharjica
16.47676757	-45.78164885	146	ALLI	ALLI	146	5	NE	670240001	1	VAGOVINA	154788000	0	PK 000	154788	SK 0154788	3.	Vagovina
17.14968816	-45.68975095	35	ALLI	ALLI	35	5	NE	455940001	1	ORLOVAC ŽEDN...	82538000	0	PK 000	82538	SK 0081238	3.	Mal Židenci
17.22278896	-45.56717883	62	ALLI	ALLI	62	5	NE	118920001	1	HRVATSKOBRA...	207960000	0	PK 000	20796	SK 0030796	3.	Doljani
17.10940632	-45.80940749	6	ALLI	ALLI	6	5	NE	452110001	1	NOVA PISANICA	77747000	0	PK 000	77747	SK 0057747	3.	Velika Pisanica
16.66517894	-45.76156387	41	ALLI	ALLI	41	5	NE	670240001	1	VAGOVINA	154788000	0	PK 000	154788	SK 0154788	3.	Vagovina
17.04630400	-45.75245023	4	ALLI	ALLI	4	5	NE	682760005	5	PIATICE OUPCA	127736000	0	PK 000	127736	SK 0127736	3.	Veliki Grčevac
17.02415892	-45.84628277	96	ALLI	ALLI	96	5	NE	343880001	1	LAGOČAC	62574000	0	PK 000	62574	SK 0062574	3.	Lagočac
17.13390214	-45.73988214	40	ALLI	ALLI	40	5	NE	676280004	4	KRALJA TOČED...	126349000	0	PK 000	126349	SK 0126349	3.	Velika Bara
16.86873064	-45.91427297	71	ALLI	ALLI	71	5	NE	658970001	1	BURKEVAČKA C...	122939000	0	PK 000	122939	SK 0122939	3.	Bjelovar
16.91803076	-45.67743415	20	ALLI	ALLI	20	5	NE	415840001	1	MLIBNO VINOGR...	74037000	0	PK 000	74037	SK 0074037	3.	Mibuka
16.96970991	-45.79854633	7	A	ALLI	7A	5	NE	130910001	1	ORLJAKOVAC	27998000	0	PK 000	27998	SK 0027998	3.	Orljakovac

Figure 5. Attribute table for data layer on house numbers in Bjelovar-Bilogora County

Each point on the map shows the location of the house number, according to the State Geodetic Administration data. For each point geographical coordinates (length and width) of street, house number, census and statistical tract belonging to them, local government unit, etc. are known. All data are gathered in a database (attribute table) for every 54763 house number. An example of the attribute table is shown in Figure 5.

According to available data on house number location, it is possible to calculate the distances of each house number to its nearest post office. This enables to determine how many house numbers are served by a single post office according to the criterion of 80 km² (5 km air distance). Distances can be ranked, as shown in Table 3.

Table 3. Number of house numbers at a certain air distance to post office

Distance (km)	0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	> 5	Total
House number (number)	13 191	10 436	8 240	7 613	6 395	8 888	54 763
House number (%)	24,09	19,06	15,05	13,90	11,68	16,20	100
Number of inhabitants	28 848	22 823	18 020	16 649	13 986	19 438	119 764

Table 3 shows that around 45 875 house numbers have an accessible post office within 5 km of air distance, while for 8 888 house numbers this criterion is not met.

It is evident that approximately 85% of the population in Bjelovar - Bilogora County is within 5 km distance to post office and around 44% of the population within 2 km to the nearest post office. For universal service provider, as well as for the regulator body in Republic of Croatia, this analysis is interesting, as well as approach to organization of network of access points.

Figure 6 shows gradation of distances based on the values obtained by table 3 for house numbers to the nearest post office, using the QGIS tool.

Figure 7 shows cumulative distribution function of house numbers distances to post offices. It is evident that 83% of the population lives under 5 km distance, while up to 8 km distance 96% of the population.

Table 4 shows statistical analysis of the distances of the points representing 54 763 (total number of points) house numbers to the post offices. The mean value of the distance is 2.89 km, with a deviation from the mean value (standard deviation) 2.23 km.

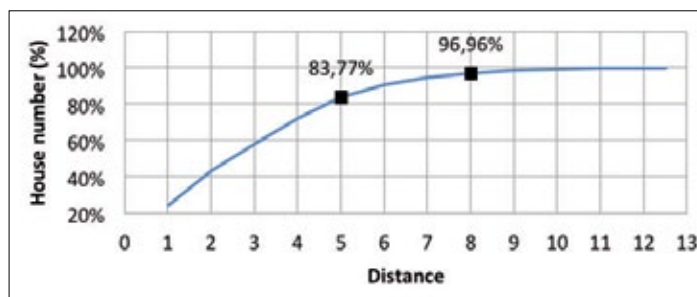
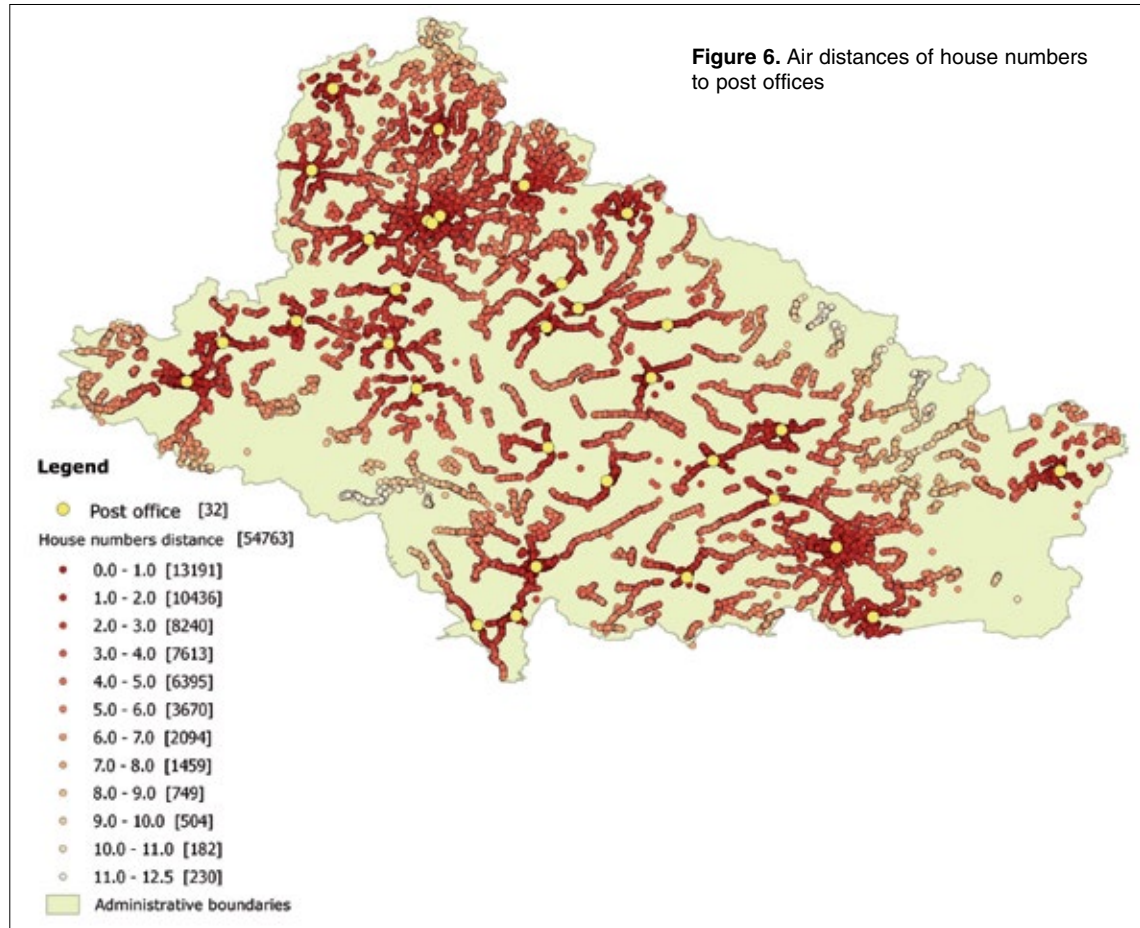


Figure 7. House numbers (%) at a certain distance to post office

Table 4 Statistical analysis of air distances of house numbers to post offices

Mean value	2,89
Standard deviation	2,23
Minimum value	0.0042692
Maximum value	12.503
Total number of points	54 763
Unique values	42 322

It is interesting to observe that the nearest house number (minimum distance value) is about 4 m distant from the post office, while the farthest (maximum distance value) is 12.5 km. There are 12 441 house numbers in the observed area, with the same distance to the post office, and 42 322 (number of unique values) with different distances to the post offices.

To estimate the number of residents living at a certain distance to the post office, it was necessary to determine average number of inhabitants per house number. According to data from the last national census [11, 12], average number of households in the Bjelovar - Bilogora County is 2.88. Since the number of households and the number of house numbers in the county is not equal, it was necessary to allocate the average number of inhabitants to each household number. When the total number of people living in the area of Bjelovar - Bilogora County is divided by the total number of house numbers, the average number of inhabitants per household in the county equals 2.2. Determining the average number of inhabitants per house number will allow estimation of the number of residents who have postal ser-

vice accessible or, on the other hand inaccessible when determining universal service accessibility in the postal system.

4. APPLICATION OF GRAVITY METHOD FOR DETERMINING ACCESSIBILITY OF POSTAL NETWORK ELEMENTS

Measures of potential accessibility (gravity-based models or methods) are frequently used in the literature to describe spatial accessibility and determine accessibility of opportunities (services) in a given zone or in a given area. It is the most commonly used method for modeling interactions between supply and demand points in a particular area. It was first introduced by Hansen [13] in 1959, while the conditions were derived from the specificity of the postal system, represented by the expression (2):

$$A_i = \sum_{j=1}^n \frac{S_j}{d_{ij}^\beta} \quad \text{for each } d_{ij} \leq d_{max}$$

$$A_i = 0 \quad \text{for } d_{ij} \geq d_{max}$$

Where:

A_i – accessibility indicator of population location i (for example: place of residence or point of interest)

S_j – capacity of service at service provider location j , (for example: number of post offices within an observed area)

d_{ij} – distance, shortest air or network distance between points i and j

β – distance decay parameter indicates the user's willingness to travel to a particular service. If the distance to a certain service is longer, the user is less willing to travel to access that service.

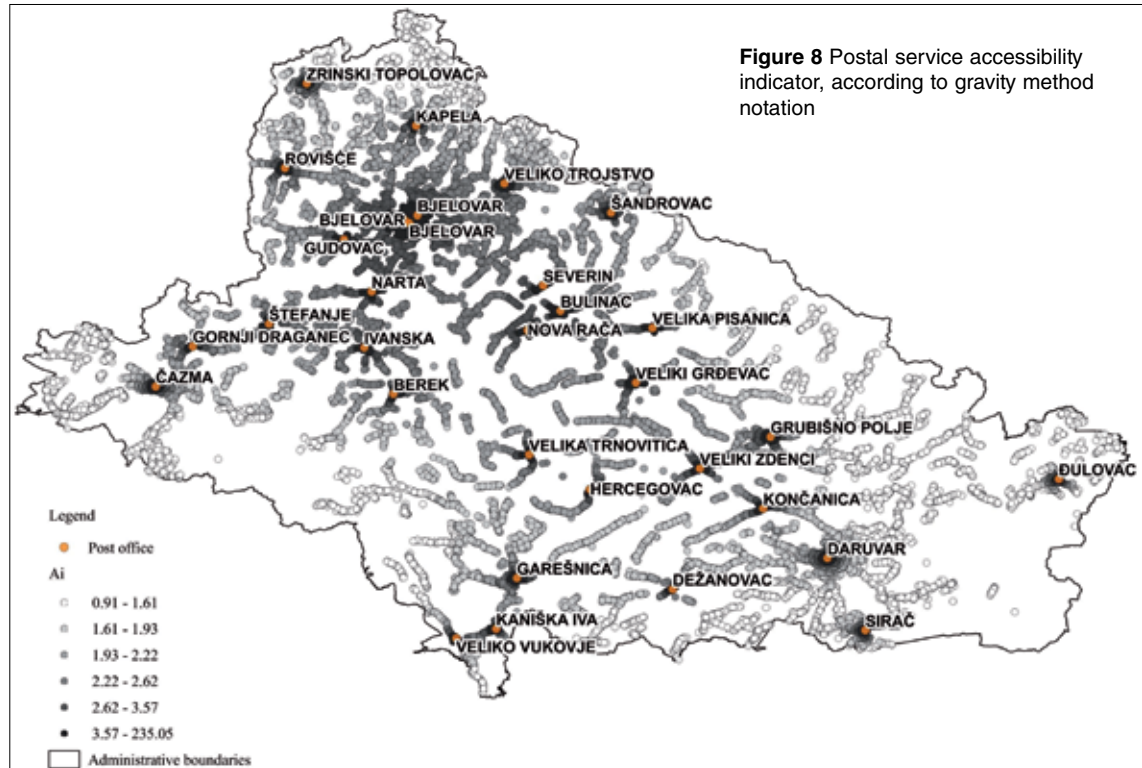
The value of β parameter is the subject of discussion in literature, since there are no generally accepted used values. Some authors believe that its value depends on the service, or the industry, where accessibility is being determined, as well as on the region or area where it is being researched [4]. Luo and Wang [14] tested different coefficient values in their research and came to the conclusion that the lower coefficient value β corresponds to longer travel times. In other words, smaller the value of β parameter, people are willing to travel longer to reach certain services. For this reason, different coefficient values should be used in urban or rural areas [15].

β parameter is the biggest disadvantage of the gravity method because it is not easy to determine [15]. In theory, it should be calculated from actual data on the use of a particular service, and given that these data are often unavailable, the authors in the calculations include different values [14], for example, the ones already defined in the literature.

Hansen [13] found that the values of the distance decay parameter may range from 0.5 - 3; depending on the purpose of the trip. The parameter will be lower, if is the purpose of travel more important: travel to school or shopping destination (2.0), social travel (1.1), travel to the workplace (0.9).

Based on the conducted analysis, in the first step of determining the universal service accessibility, the value of $\beta = 1$ is assigned as the distance decay coefficient. This value for determining accessibility of universal postal service, was taken for several reasons. Since the gravity method has not been applied before to determine the accessibility of any postal service, this value was chosen for simplified presentation and application of the method. Given that the emphasis in the research is on rural areas, it is to assume that people are willing to travel longer to get to a certain service. In future research, it would be useful to conduct a more detailed analysis of the different values of the decay coefficient, to analyze the impacts of these values on the accessibility of postal service, and to gain conclusions on the possibility of using different values of the β coefficient in the postal system.

The condition $d_{ij} \leq d_{max}$ denotes the catchment areas where service accessibility is calculated. In this case, the area covers the entire county. In other words, within the county boundaries, distances between each house number and the nearest post office is calculated. Smaller the distance, greater the value of the accessibility indicator. This is particularly noticeable in urban areas where the accessibility



indicator of individual house numbers is extremely large. Figure 8 shows the values of accessibility indicators in Bjelovar - Bilogora County, according to (2).

The values of accessibility indicators are larger for house numbers nearest to the post office. For selected $\beta = 1$ value, the accessibility indicator values drop significantly for smaller distance values. For example, if a house number is just a few meters away from the post office, the accessibility indicator will show value greater than 200. If it is significantly distant, the accessibility indicators are closer to 0, as shown in more detail in Table 5.

The values of accessibility indicators can be compared with the distances of a particular house number to the post office as shown in Table 5. Higher values, greater the accessibility of the location, or in other words distance is smaller.

Table 5. Accessibility indicator values and belonging air distances

[km]	
0 - 1	234 - 1
1 - 2	1 - 0,5
2 - 3	0,5 - 0,33
3 - 4	0,33 - 0,25
4 - 5	0,25 - 0,2
> 5	< 0,2

CONCLUSION

The accessibility of postal services or postal network elements is an important concept that significantly affects the layout and organization of the postal network. Studies show that the accessibility of post offices and distance of access points is an important factor for the users of postal services. The accessibility of postal network elements in the EU countries is largely governed by the regulatory criteria that universal service providers must fulfill.

In this research, an analysis of the postal network elements (post offices) accessibility was carried out according to the currently existing criteria for determining the density of access points in the Republic of Croatia. The analysis was made and implemented using the example of the Bjelovar - Bilogora County. The results of the analysis show that, according to the existing criteria, over 16% of the county's population has no post office accessible.

The implementation of gravity method for determining the accessibility of postal network elements has shown the possibility of a different way of determining postal service accessibility. In this way, accessibility of a particular house number is determined, resulting in insight of population accessibility of a particular area. This gives the service provider the ability to improve the quality of the service, especially for those users to whom the service is inaccessible.

By introducing methods for calculating spatial accessibility in the postal system, the possibility of further exploration of the concept of spatial accessibility in the postal system opens. In further research, it would be useful to focus on the analysis of the impact of different distance decay parameters on the accessibility of postal network elements. Also, it would be valuable to determine accessibility using capacities of different services (different postal network elements or different types of postal services).

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SAŽETAK

Dostupnost poštanskih usluga zajamčena je međunarodnim i nacionalnim zakonskim odredbama. Regulacija određene gustoće elemenata poštanske mreže mehanizam je koji se najčešće koristi u ostvarivanju dostupnosti poštanskih usluga stanovnicima određene zemlje. Općenito korištene regulativne mjere (kriteriji) uglavnom se usvajaju i nadgledaju od strane regulativnih tijela na tržištu poštanskih usluga. U ovom se radu analizira primjena koncepta prostorne dostupnosti u poštanskom sustavu, te se analiziraju prostorne karakteristike odabranih istraživanih područja. Pomoću gravitacijske metode napravljen je izračun indikatora dostupnosti elemenata poštanske mreže i poštanskih usluga.