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The capital agglomeration of the Republic of Korea as a fuzzy central place system

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Abstract. Explosive urbanization in the Republic of Korea from 1950 to 2010 marked by a growth in extensive urban agglomerations rendered unproductive the approach that was commonly used in the central place theory and which considered every element of the settlement system as a point in a homogeneous space. The paper suggests an alternative concept of fuzzy central place that makes possible the understanding of an internal heterogeneity in the distribution of central functions within the limits of urban agglomerations. This research was conducted using the example of the Capital agglomeration – the main element of the Republic of Korea’s urban settlement system. This “island” country, isolated by North Korea, has seen fantastic economic growth in the second half of the 20th century.

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1. Introduction

The central place (CP) theory presented by W. Christaller (1966) was a smart attempt to find regularities in the urban population distribution. There are different K – values: $K = 3$ marketing, $K = 4$ – transport and $K = 7$ administrative principles; they show how far the sphere of influence of the CP spreads. The optimization was reached through the maximization of the margin in the model of A. Lösch (1967). In accordance with this model, cities on the highest hierarchic levels do not consist of a full assortment of central products specific to lower levels.

Despite the beauty of these intellectual constructions, many scientists suppose that the central place theory is not useful because the quantity of empirical examples corresponding to this theory is too low. However this fact does not stop scientists from studying this theory in detail or reduce their efforts to modify it. Thus, B. Berry established the presence of a direct correlation between the size of towns and the variation of central functions (CF) within them (1960). The correlation between urban growth and a change in the variation of their functions was established together with W. Garrison (Berry, Garrison, 1958).

G.F. Mulligan found out that the length of a trip to purchase goods and services depends on the lifestyle of each individual and the type of central products (1984). E. Ullman proposed to evaluate the CF value through the use of the quantitative value of over the average volume of cities functions consumption (1980). M. Dacey obtained indirect proof of the stochastic nature of CP location in points of a hexagonal lattice (1966).

W. Isard (1971) suggested that the formation of urban agglomerations is a cause of economic landscape irregularity. To solve this scientific problem V.A. Shuper (1995) presented the relativistic theory of CP, in which alternation of heavy and light levels leads to equilibration A.A. Vazhenin (1997) proved that the system supports the rank size distribution by itself during the full evolution cycle from $K = 1$ to $K = 7$ with changes in urban rate.

A. Pred (1973) suggested the idea that CF could not localize only in one point because it will infect neighbour points of space. Besides the urban ag-

glomerations should not be generalized to the level of points because of extreme CF differentiation. Only a few scientists have considered urban agglomeration as a CP system. Thus, H. Carol (1960) found that the central product assortment decreased from the highest to the lowest neighbourhood. His research was based on interviews with Zurich residents. The desire to study the CP system in detail within the urban agglomerations using the ideas of A. Pred and H. Carol has stimulated us to establish an alternative conception of fuzzy CP.

2. The axiomatic apparatus of the fuzzy central place conception

An *element* of the FCP system is identified as a bounded region of a set of points. An element with CF value equal to n is taken as *FCP*, while an element devoid of CF forms a *service area*. By the CF value is meant a quantitative characteristic within the limits of FCP. We suggest using outlines of the lower elements of legal division as the boundaries of the FCP system elements.

FCP is a complex of socio-economic subsystems and population is the key one. It needs to exert primary control over the mechanism for the formation of the FCP system. The location of a service provider indicates the presence of a user contingent in its vicinity. With increasing density of enterprises rendering CF, the variety and assortment of services they supply is expanding. Accordingly, the possibilities of satisfying the need for central products are also growing, both in amount and in quality. Correlation analysis has been performed between the density of service enterprises and population density. In the Republic of Korea (RoK) boundaries of FCP system elements correspond to those of counties and cities in provinces, and to municipal areas in 7 special cities. Seoul became a *Special City* in 1946. After that the status of *Special Autonomous City* was granted to several cities: Busan in 1963, Daegu and Incheon in 1981, Gwangju in 1986, Daejeon in 1989 and Ulsan in 1997. The coefficient of correlation equal to 0.72 calculated for the 2000–2009 period proves a close relationship between the values considered above. In view of those data, it is assumed that the *CF value in a FCP is in di-*

rect proportion to the average population density. The distribution of population and CF was never uniform. Rapid urbanization in the second half of the 20th century aggravated spatial disparities. Taking this into consideration, we assume the CF distribution to be originally not uniform.

Only places of the actual sale of products may be considered as having CF. For example, in the case of the purchase of a car neither the location of construction departments, nor that of assembly plants would serve CF, as they do not participate directly in the transfer of the object of sale to the consumer. In most cases it is car salesrooms or car markets that act as the CF providers and satisfy the consumers' needs.

According to the classical central place theory, a baker's shop at a railway station where people living in the neighbourhood buy their bread may be considered as having CF. Such a statement, however, is erroneous, as people come to the station to use transport services first of all, and not to buy the baker's products. If there were not a bakery at the station, the number of transport service consumers would not lessen, while the baker's shop without the railway station would lose a considerable proportion of its clients. So the baker's shop at a railway station only receives benefit from its good location.

The FCP conception exerts no effect on the rational behaviour of consumers whose requirements are mostly satisfied within the limits of their residence area. If the needed product or service cannot be found there, the choice of a suitable system element for the purchase depends on several factors, the most important of which are the type of product and the distance to be travelled. The latter factor requires additional time and resources. Every element of the system tries to increase its "attractiveness" by expansion of the variety of CF. The customer chooses the most attractive element of FCP. The greater the attractiveness of the FCP is, the less important for the customer the additional expenditure of time and money for travelling to the FCP is.

According to the logic of the classical CP theory, CP of the lowest level included only basic institutions, such as elementary schools providing services in a small area. The next level institutions were middle schools, and so on. With a rise in the hierarchic level, the number of centres decreases, and their service area increases. In the FCP systems CF

value is the key index. In the FCP system elements with a low CF value, not only high schools but even universities may occur. Therefore, the principle stated above appears to be wrong.

To distribute FCP system elements by levels of hierarchy we attempted to find a relationship between medium CF values corresponding to different levels of hierarchy. We studied the distribution of social infrastructure elements in the RoK and in combinations of its provinces and special cities from 1990 to 2009. The ratio between the average CF value in elements of different levels (from level IV to I) was found to be as follows: 1–0.5–0.25–0.1.

The key index in the FCP conception is the *index of the equilibrium of key centres* which was calculated as follows:

$$\sum \frac{S_c}{S_h} = m - 1 - c \quad (1),$$

where S_c is the average distance between the administrative centres of FCP of two neighbouring levels of hierarchy, S_h – the average distance between their centres of gravity, m – the total number of levels, c – the number of missing levels. The distances are calculated from the lower hierarchic levels towards the elements of a higher level located at a minimal distance. The key index permits the equilibrium between positions of expected and real foci of the CF localization to be estimated. Theoretically, points of administrative centres would coincide with centres of gravity.

When constructing a graphic model of the FCP conception we proceeded from the assumption that the CF value in an element of the system corresponds to its value in the centres of gravity. Using them as elevations and applying *IDW interpolation* we drew the *CF quasi-relief* (QR) – the latter thus presenting a graphic model of a non-uniform dispersal of CF in the space. The idea of the CF QR was suggested by Prof. V.A. Shuper in a personal interview with the author. The CF QR modelling was performed using Arc GIS software, as well as Global Mapper.

As relative elevations of the CF QR, elements of an arithmetic progression were used, with the initial term being zero and the common difference of successive members equal to 50. After every relative elevation had been established, the key index

was tested for its consistency with the theoretical value. Such an operation with elevations continued until the index of the equilibrium of key centres fitted the theoretical value best of all; the modification of the FCP system found in this way was considered to be optimal. The CF QR is related to the index of the equilibrium of key centres and to the process of establishing the optimum relative elevation. The FCP system elements with the basic CF value less than the established relative elevation would form a service area and would be “flooded” in the CF QR.

This research was based on Korea Statistical Yearbooks (1952, 1990, 2000, 2011), Municipal Statistic Yearbook of Korea (2000, 2005, 2009), Korean Statistical Information Service (2014), The World Urbanization Prospects (2010) and The World Factbook (2014).

3. The evolution of fuzzy central places systems of the Republic of Korea

The FCP system of the RoK was essentially transformed between 1952 and 2011. Due to the administrative reforms the system elements increased in number from 145 in 1952 to 230 in 2011. Elements of the FCP system of the RoK were distributed over four hierarchy levels ($\sum_{s_n}^{s_c} \rightarrow 3$). While the best correspondence with the theoretical value of the key index in the FCP system was in 1952 at the relative elevation of 100 units, the relative elevation of 300 units was the most suitable in 2011 (Table 1).

Table 1. The main indexes of the fuzzy central place system of the Republic of Korea from 1952 to 2011

Year	Value of relative elevation	Number of FCP on different levels: 1–2–3–4	Number of elements without CF	Population on different levels, %				Population of the service area, %	$\Sigma Sc/Sh$
				1	2	3	4		
1952	0 and 50	130–8–5–2	0	82.1	7.9	2.1	7.9	0	3.13
	100	115–7–5–2	16	77.4	6.3	2.1	7.9	6.3	3.07
	150	94–7–5–2	37	66.	6.3	2.1	7.9	17.6	3.15
2011	250	48–21–26–29	106	27.2	16.6	17.7	24.2	14.4	3.28
	300	43–21–29–28	109	25.7	16.6	17.7	24.2	15.8	3.19
	350	45–20–27–28	110	26	16.3	17.7	24.2	15.8	3.25

Source: Author's own work

If in 1952 the main positive landforms of CF QR were dispersed, by 2011 they were positioned around agglomerations or within them (Fig. 1). The conspicuous rising of the FCP elevations was related to the economic breakout of the RoK. In 1963 the GDP per capita was comparable with the poorest countries and in 2010 it was commensurable to that in France and in the UK. If in 1950 agricultural products accounted for more than 46% of the GDP of RoK, in 2010 almost 70% of the GDP fell on the tertiary sector (The World Factbook, 2014).

In an earlier work (Em, 2013) we considered the possibility of applying the rank-size rule (Zipf, 1949) to the analysis of the CF value distribution in the FCP system. The figure formed by trends of real and

theoretical distributions of the CF values in the RoK FCP system elements in 2011 is much larger in area than that formed by analogous trends in 1952 (Fig. 2). Such a circumstance suggests a noticeably worse agreement between the trend line of the real distribution and the curve constructed according to the rank-size rule. It should be noted that along with the enlargement of the figures delineated by curves of real and theoretical distributions (calculated following the rank-size rule), the service “flooded” area also grew in size between 1952 and 2011 (Fig. 1). It seems probable that there is an interrelation between the CF quasi-relief and the trends calculated using the rank-size rule. To gain better insight into this interrelation, further research is needed.

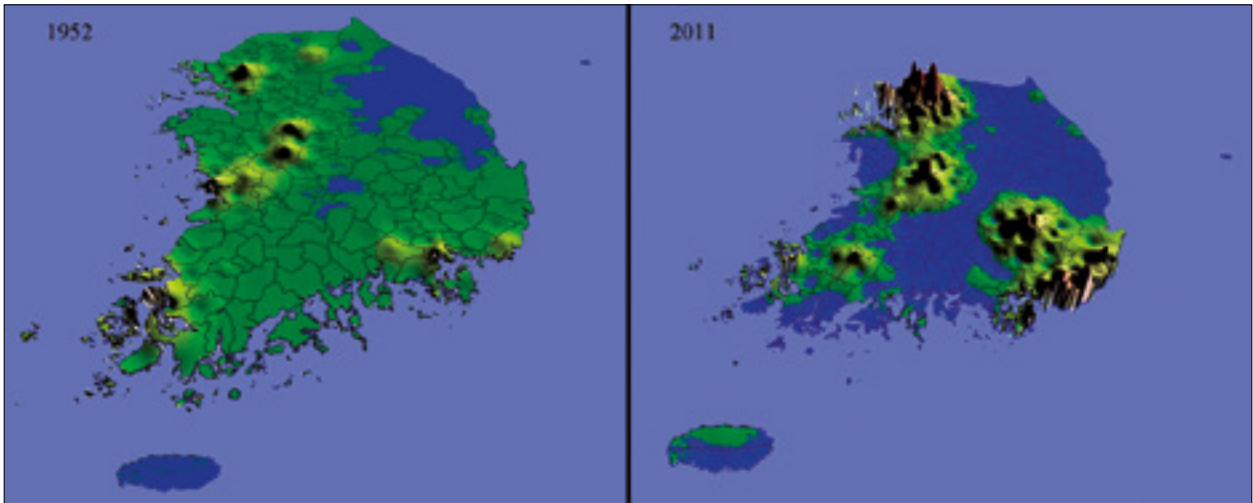


Fig. 1. The central functions quasi relief of the Republic of Korea in 1952 and 2011

Source: Own work based on Korea Statistical Yearbook 1952; Korea Statistical Yearbook 2011

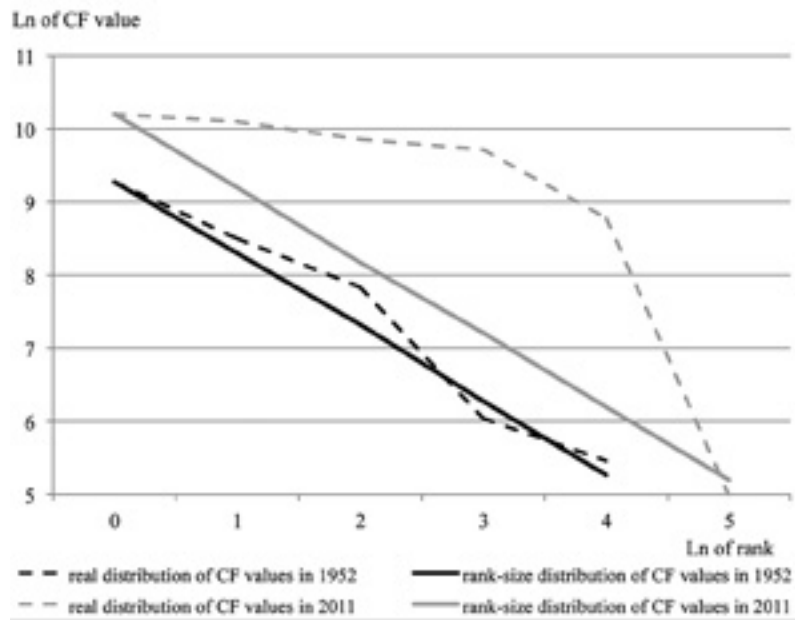


Fig. 2. The dynamics of the distribution of fuzzy central place system elements in the Republic of Korea in accordance with the “rank-size” rule from 1952 to 2011

Source: Own work based on Korea Statistical Yearbook 1952; Korea Statistical Yearbook 2011

The greater the $\sum \frac{S_i}{S_n}$ deviation from 3 at four levels of hierarchy in the FCP system of the RoK, the less stable the system is, and vice versa. To estimate the deviation of the empirical index values from theoretical ones, we calculated the difference between them. The changes in the calculated val-

ue reflect the wave-like dynamics of the stability of the FCP system in the RoK between 1952 and 2011 (Fig. 4). A similarity between the empirical ratio $\sum \frac{S_i}{S_n}$ and the theoretical value in 1970–1990 increased in parallel with high rates of economic growth in the RoK. In 1952–1970 the $\sum \frac{S_i}{S_n}$ lessened

along with the development of the RoK's economics, and a similar tendency in the 1990–2011 period may be attributed to the influence of the Asian financial crisis of 1997–1998 and to the World economic

crisis of 2008 (Fig. 3). Reasoning from the above data, we suggest that the balance of the FCP system in the RoK is related to the level of the country's economic development.

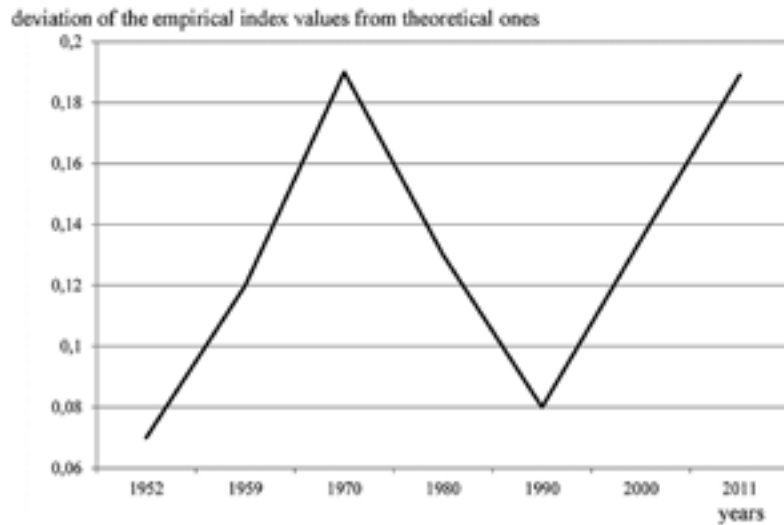


Fig. 3. The dynamics of the deviation of the empirical index of the equilibrium of key centres from the theoretical value in the Republic of Korea from 1952 to 2011

Source: Own work based on Korea Statistical Yearbook 1952; Korea Statistical Yearbook 1990; Korea Statistical Yearbook 2000; Korea Statistical Yearbook 2011; Database of Korean Statistical Information Service

Sometimes rural settlements perform certain functions at a lower price and provide a wide choice and better quality. The number of rural FCP in the RoK decreased by a factor of 22.4, from 112 to 5, and their population fell more than tenfold, from 96% to 7.9% (Table 2). The main cause of those changes was a dramatic increase in the urbanization rate from 21.4% in 1950 to 81.9% in 2010. Some urban elements with a large area and small

population have also been found. They lost CF, which were attracted by some adjacent “stronger” system elements. Over the years most rural FCP elements in the RoK increased the CF value and their population. Such changes necessitated administrative-territorial reforms that favoured changing their status from rural to urban. Hence the FCP of rural status may be considered as potential cities.

Table 2. The rural fuzzy central places in Korea

Year	Quantity of rural FCP on the first level of hierarchy	Inhabitants of rural FCP among the first level population, %	CF value inside rural FCP in elements of the first level, %	Number of cities without CF
1952	112	96	97.4	0
1990	47	39.3	20.5	0
2011	5	7.9	14.1	25

Source: Own work based on Korea Statistical Yearbook 1952; Korea Statistical Yearbook 2011

4. The capital agglomeration of the Republic of Korea as a fuzzy central place system

The main constituent of the settlement system in the RoK was always *Seoul City*. *Incheon City* developed independently nearby. The two were drawn together and in the late 1980s formed a dual-core *Capital agglomeration*. In 2005 *Suwon*, as a city with a population of a million-plus, formed the third core of the Capital agglomeration, the main elements of which are connected together by a well-developed subway. The negative migration balance in Seoul is caused by the fact that people migrate from the capital to cheaper and ecologically clean regions in its vicinity. To define the Capital agglomeration limits we estimated 0.5-, 1- and 1.5-hour isochrones from the core city using the method suggested by P.M. Polyán (1988).

There were 73 settlements within the limits of the Capital agglomeration with a total population of

23.8 million inhabitants in 2011 and 49.6% of the population lived outside the main core. Some settlements appeared with a population markedly below that of city status. Nevertheless, about 80% of their residents are employed in the tertiary sector of economics. Geryong City, for example, with a population of about 36 000 (with the standard size of the population for a town being 40 thousand) acquired the status of a city. In the 1990s elite regions with exclusive real estate appeared. One of them *Gangnam* in Seoul, which attained worldwide popularity thanks to the song “Gangnam Style” by a Korean singer PSY.

The considerable dispersion of the CF values in the Capital agglomeration is illustrated in the CF QR profile. It goes from the Jun-gu municipal area within Incheon city (A) to Chungcheon City (B) (Fig. 4). When moving from the centre of the Capital agglomeration of the RoK towards the periphery, no distinct tendency for the average CF value decreasing has been found (Fig. 4).

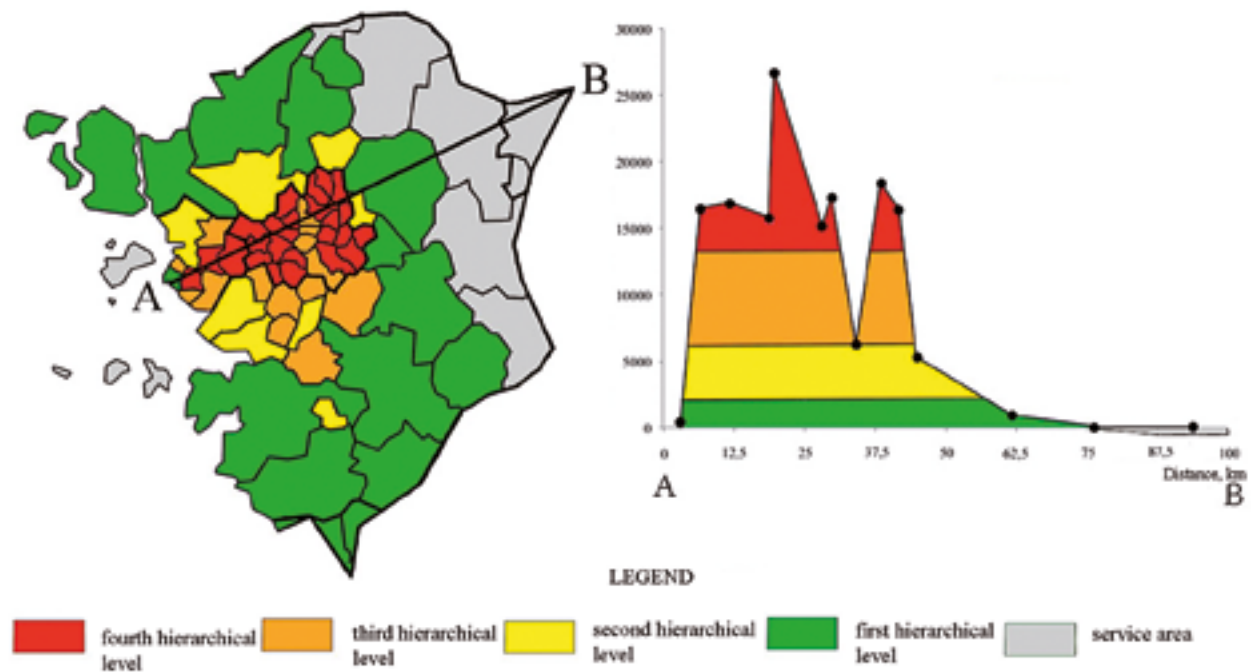


Fig. 4. The profile of the central functions quasi relief of the Capital agglomeration of the Republic of Korea
 Source: Own work based on Korea Statistical Yearbook 2011; Database of Korean Statistical Information Service.

Residents of different FCP system elements within the limits of the Seoul agglomeration differ in their lifestyle. An attempt at finding a correla-

tion between the place of the customers’ residence and the distance they go to buy various groups of goods and services was made by way of interviews.

The sample included 150 respondents from each of three chosen places: the principal core – Seoul City; a lesser core of the Capital agglomeration – Suwon City; and one of the Counties within the agglomeration – Yoncheon-gun. The results of the interviews emphasized the special position of the capital, where the residents satisfy up to 99% of their needs in the city where they live. The majority of food products, medicines, as well as health care and postal services are bought by Seoul citizens within their residence area (Table 3). The residential district provides a high proportion of services in health care

(41%) and banking services (44%). In Suwon and Yoncheon County the consumers' behaviour differs from that of the residents of the capital. Most clothes, footwear, and cultural services (> 50%) are bought outside their resident element. Surprisingly, the proportion of medical services provided within the limits of the resident area is higher in Suwon and Yoncheon than in Seoul. An average resident of Suwon is provided with a sizeable share of banking services (42%) within the district of his residence, while in Yoncheon up to 95% of the banking services are provided in the rural settlement of residence.

Table 3. The distribution of the Korean Capital agglomeration inhabitants according to the place of purchase of goods and services

Goods and services	Goods and services purchased in different areas of the Capital agglomeration, %										
	Seoul City				Suwon City				Yoncheon-gun County		
	1	2	3	4	1	2	3	4	5	6	7
Food products	97	2	1	0	97	1	0	2	97	2	1
Clothes and footwear	3	6	90	1	10	10	25	55	12	21	67
Medical services	54	41	4	1	80	6	12	2	59	38	3
Medicines	80	11	8	1	72	20	5	3	71	28	1
Banking services	50	44	5	1	30	42	27	1	94	5	1
Postal services	75	20	5	0	64	32	3	1	91	8	0
Cultural services	5	10	80	5	1	5	7	87	7	10	83

*Comments: 1 – In municipal area of residence, 2 – in district of residence, 3 – in City of residence, 4 – outside residence City, 5 – in rural settlement of residence, 6 – in County of residence, 7 – outside the County of residence.

Source: interviews made by the author

5. Conclusion

The usage of the suggested FCP conception apparatus made it possible to understand the spatial structure, dynamics of CF value and development of the Capital agglomeration of the RoK. This agglomeration is the greatest CF focus in the RoK FCP system. It has been found that average CF values within the Capital agglomeration do not necessarily tend to decrease from the centre to the periphery. The constructed profile of CF QR shows conspicuous variations in CF values between elements of the Capital agglomeration of the RoK.

The agreement between the actual and theoretical distribution of the CF values in the FCP system elements was calculated using the rank-size rule in the RoK and appeared to be much worse in 2011 than in 1952. Accordingly, the flooded service area in the FCP system also increased from 1952 to 2011. Seemingly, there is a relationship between the CF QR and the rank-size rule to be investigated later. It was found that the balance of the FCP system in the RoK is related to the level of economic development. Many FCP have been found among rural elements as well as urban elements which lost their CF because of a large area and small population. Rural FCP may be considered as potential cities.

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