The Influence of Accessibility to Inter-Regional Commuting Flows in Slovenia

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Abstract: GIS-tools enable modelling accessibility fields at different levels of spatial structures (or traffic networks) and better incorporation of accessibility indicators in the gravity models. In the paper, a two-stage raster-based approach is presented, which was used to model the accessibility fields in Slovenia (Drobne et al., 2008). The results of the accessibility analysis were embedded in the extended gravity model of inter-regional commuting flows of employed persons in Slovenia that makes the gravity model more stable and applicable for policy makers.

Keywords: accessibility, gravity model, commuting, employed persons, regions, Slovenia

1 INTRODUCTION

Human migrations and periodical (daily or weekly) commuting to working place, school or to location of other activities are considered as the most important factors influencing the demographic and socio-economic nature of regions, the composition of central places on regional level or the characteristics and structures of settlements and their inhabitants in the whole territory of regions. For the general process of regional changes, an understanding of inter-regional migrations and daily or weekly commuting is vital. As Codwallader (1992) and many other researchers have pointed out, policy-makers have become increasingly aware of the role of migrations such as migration of human resources for production or services, which is important also in the context of any other socio-economic issues, especially as regional growth. Here, the migration can be defined as a process which enables to achieve economic efficiency and equity (Chun, 1996).

In developed countries, the state and local governments seek to attract properly skilled migration, because migrants increase employment and contribute to income equalization. A study of migration may show not only how these aims can be achieved, but also highlight other policies needed for inducing growth. The growth of regions relates closely to population growth, which is mostly a result of migration. Migration between regions can be slowed down by commuting (daily migrations), which is becoming surrogate for migration, if the commuting brings higher social well-being than any migration (Anjomani, 2002). If the contacts between regions due to improved transportation abilities and removed barriers are becoming less expensive and easier, the inhabitants often prefer commuting (Nijkamp, 1987).

In our previous papers (Bogataj et al., 1995; Bogataj and Drobne, 1997; Bogataj et al., 2004) we proved that commuting had an important role in the context of a socio-economic issue in Slovenia. In (Bogataj and Drobne, 2005), we summarized results of our investigation of the main factors of inter-regional migratory and commuting flows in Slovenia.[1] We believe that decision-makers, in order to

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[1] More precisely, forecasting results about daily commuting can be calculated when using smaller spatial units than regions. For this purpose, an extended gravity inter-municipal model of commuters in Slovenia was calculated (Drobne and Bogataj, 2005), which has been already implemented for

make good decisions, need to be aware of the relation between the changing patterns of commuting or migration between the regions and changes in the regional and national economic growth.

The gravity models belong to the family of spatial interaction models. But, they miss the integration of the transportation network at the lower levels of spatial hierarchy. This gap can be overcome using the GIS-tools, which enable operative incorporation of the analysed accessibility at different levels of spatial structures (or traffic networks) in the gravity models.

In this paper, our previous work in modelling inter-regional commuting flows of employed persons in Slovenia is extended using not only the economic coefficients but also the accessibility coefficients at the lower levels of spatial hierarchy. The correlation analysis between economic and accessibility coefficients is also provided.

2 THE GRAVITY MODEL OF INTER-REGIONAL COMMUTING GROWTH

Let us study 12 statistical regions of Slovenia with a total of population $P = 1{,}998{,}079$ inhabitants. We denote with i the living and with j the destination region (location of job). The number and structure of external commuters, employed persons, between statistical regions were obtained from the Census 2002 data. Here $\sum_i \sum_j DC_{i,j}^{(2002)} = DC^{(2002)} = 59{,}819 \ (i \neq j)$, where $DC_{i,j}$ is the number of commuters, employed persons, between region of origin (i) and region of destination (j), (2002) denotes that data are from the last Census 2002; in short, $DC^{(2002)}$ is the total number of inter-regional commuters, employed persons, in Slovenia in the year of the Census 2002. Figure 1 shows the number of daily commuters, employed persons, as well as population in statistical regions of Slovenia.

policy-making at the Government Office for Local Self-Government and Regional Policy, The Republic of Slovenia. Using that model, policy-makers can analyse the impact of the investments in the highways to the commuting flows in Slovenia.

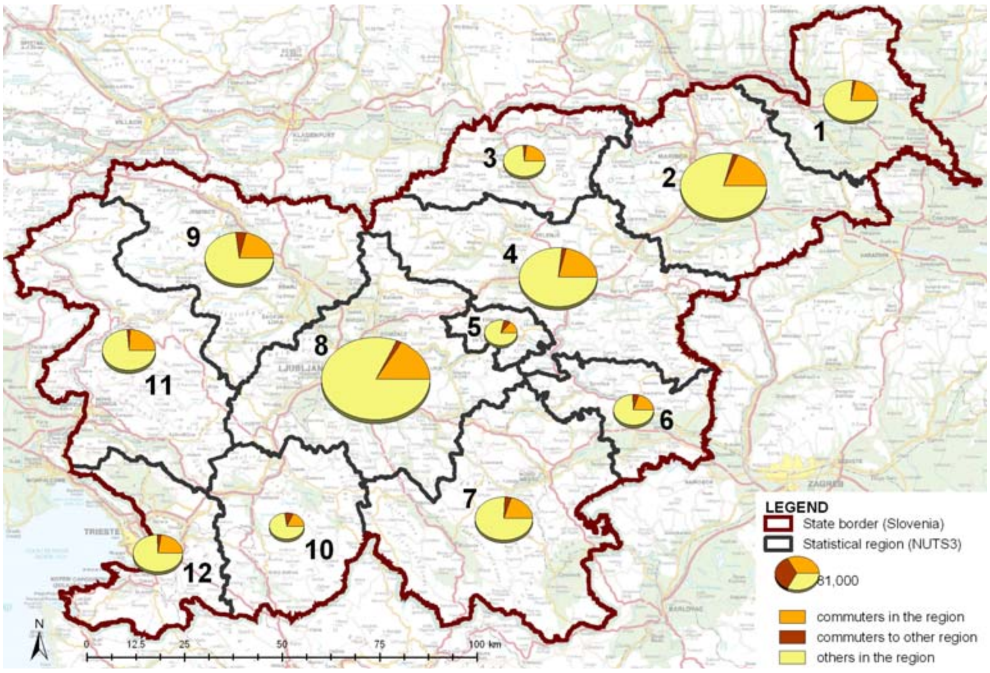

Figure 1: Population and commuters, employed persons, in statistical regions of Slovenia in 2002.

Codes of statistical regions in Slovenia are explained in Table 1. Table 1 and Figure 2 show the intensity of commuting flows for the employed persons in Slovenia in 2002 (Census 2002). From our previous papers (Bogataj et al., 1995; Bogataj and Drobne, 2005; Bogataj et al., 2004) it follows that gravity model helps us to estimate roughly the expected number of commuters $T_{i,j}^{DCs}$ between territorial areas – in our case between Slovene regions on NUTS 3 level in case of equal accessibility:

$$T_{i,j}^{DCs} = \frac{k_{DC}^{REG} P_i P_j}{P} \tag{1}$$

where k_{DC}^{REG} is (daily) commuting coefficient for employed persons (human resources) between statistical regions in Slovenia ($k_{DC}^{REG} = DC^{(2002)} / P = 0.030$), P_i is population in the region of origin, P_j is population in the region of destination, and P is the total population in Slovenia.

Table 1: Number of inter- (and intra-) regional commuters, employed persons, in Slovenia in 2002 (Census, 2002)

STATISTICAL REGIONS		1	2	3	4	5	6	7	8	9	10	11	12
		Pomurska	*Podravska*	*Koroška*	*Savinjska*	*Zasavska*	*Spodnje posavska*	*JV Slovenija*	*Osrednje slovenska*	*Gorenjska*	*Notranjsko-Kraška*	*Goriška*	*Obalno-Kraška*
	Pomurska	25	17	6	18	***c***	7	7	52	10	***c***	15	41
	Podravska	92	57	20	29	31	37	69	22	18	16	79	12
	Koroška	3	71	16	14	***c***	9	8	34	21	***c***	8	9
	Savinjska	32	13	39	52	51	62	86	26	17	4	53	10
	Zasavska	3	39	7	39	63	70	28	29	38	5	10	15
	Spodnjeposav	***c***	13	***c***	86	88	13	17	83	12	5	5	45
	JV Slovenija	7	14	9	25	14	50	27	45	12	26	19	10
	Osrednjeslove	87	75	76	76	42	92	10	76	37	68	50	43
	Gorenjska	16	22	7	14	35	10	10	10	41	76	38	10
	Notranjsko-	***c***	50	***c***	20	33	3	10	26	55	91	34	13
	Goriška	12	23	-	45	5	5	15	12	22	28	28	46
	Obalno-	6	35	4	12	6	6	34	12	70	59	74	22

In Table 1, ***c*** means that data is covered, because of the protection of individual data, where $DC_{i,j}^{(2002)} < 3$; data on intra-regional commuting of employed persons are also provided (denoted by grey colour).[2]

Following the principles of the gravity models, the distances between studied pairs of regions are not equal and should be included in the model. As already proved (Bogataj and Drobne, 2005), corrected number of daily commuters $DC_{i,j}^{*}$ is:

$$DC_{i,j}^{*} = \frac{T_{i,j}^{DCs}}{d_{i,j}^{*}(t)^{\kappa}}, \tag{2}$$

where $d_{i,j}^{*}(\cdot)$ is the new, expected (improved) time spending distance between regions after investments in the transportation network, $(\cdot)$ denotes that a distance can be treated in different ways (Euclidian, road or time-spending distance), and κ is an exponent – usually defined by the regression analysis. Therefore, the ratio ρ of actual to hypothetical number of commuters can be well determined using appropriate method on spatial plans of the construction projects (Bogataj and Drobne, 2005):

$$\rho_{i,j}^{DCs} = \frac{DC_{i,j}}{T_{i,j}^{DCs}}. \tag{3}$$

[2] To perceive if the commuting is a valid option one can compare number of inter-regional commuters, employed persons, (Table 1) with time-spending distances between regions in Slovenia (Table 2).

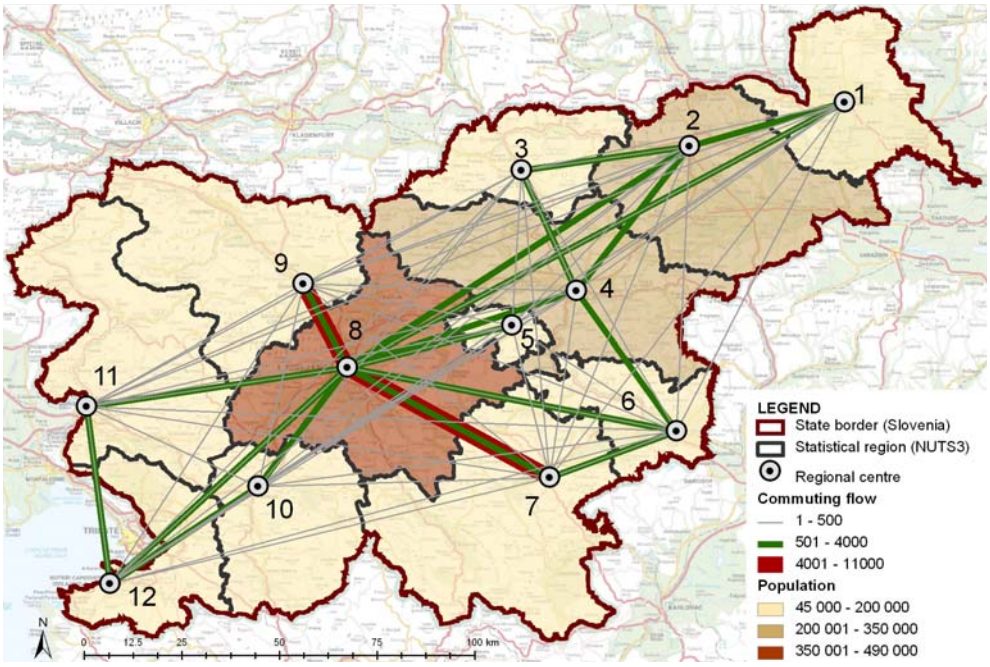

Figure 2: The intensity of inter-regional commuting flows for the employed persons in Slovenia in 2002 (Census 2002).

2.1 Incorporation of economic coefficients

The model (2) enables to forecast the number of daily commuters between pairs of analyzed spatial units (statistical regions) when distance function ρ is changing between pairs of origin and destination points in the economic area. To extend gravity model, some additional economic coefficients were tested to be incorporated to the model. Before making a decision on inclusion of the additional coefficients in the model, the following economic coefficients were investigated:

$$K_{GEAR,\circ} = \frac{GEAR(\circ)}{GEAR(SI)}, \qquad K_{GDP,\circ} = \frac{GDP(\circ)}{GDP(SI)},$$

$$K_{EMP,\circ} = \frac{EMP(\circ)}{EMP(SI)}, \qquad K_{UEMP,\circ} = \frac{UEMP(\circ)}{UEMP(SI)}, \tag{4}$$

where $(\circ)$ denotes the region of origin i or region of destination j ($i = 1,2,...,12; j = 1,2,...,12$), GDP is the Gross Domestic Product per capita in the region, and in Slovenia (SI) respectively, $GEAR$ is the average gross earning per person in the region, and in Slovenia (SI) respectively, EMP is the number of employed persons in the region, and in Slovenia (SI) respectively, $UEMP$ is the level of registered unemployment in the region divided by the level of registered unemployment in the country, and $UEMP(SI)$ is the level of registered unemployment in Slovenia.

In our previous work (Bogataj and Drobne, 1997; 2005; Drobne and Bogataj, 2005), the model was tested for d being Euclidian distance, the shortest road distance, as well as for the time-spending distances[3]. However, the use of time-spending distance in the gravity model has given the best results. Table 2 shows time-spending distances between statistical regions in Slovenia in 2005.

Table 2: Time-spending distances (in minutes) between statistical regions in Slovenia in 2005

STATISTICAL REGIONS		1	2	3	4	5	6	7	8	9	10	11	12
		Pomur ska	*Podra vska*	*Koroš ka*	*Savinj ska*	*Zasav ska*	*Spodn jeposavska*	*JV Slovenija*	*Osred njeslovensk a*	*Goren jska*	*Notra njsko-Kraška*	*Gorišk a*	*Obaln o-Kraška*
	Pomurska		6	1	1	1	1	1	1	1	2	2	2
	Podravska	6		7	4	8	1	1	1	1	1	1	1
	Koroška	1	7		5	7	1	1	9	1	1	1	1
	Savinjska	1	4	5		4	7	8	6	9	1	1	1
	Zasavska	1	8	7	4		6	7	5	8	9	1	1
	Spodnjeposav	1	1	1	7	6		3	7	1	1	1	1
	JV Slovenija	1	1	1	8	7	3		5	8	8	1	1
	Osrednjeslove	1	1	9	6	5	7	5		2	3	8	7
	Gorenjska	1	1	1	9	8	1	8	2		6	1	1
	Notranjsko-	2	1	1	1	9	1	8	3	6		5	5
	Goriška	2	1	1	1	1	1	1	8	1	5		8
	Obalno-	2	2	1	1	1	1	1	8	1	6	9	

Analysing economic coefficients (4), in the regression analysis of inter-regional commuters, employed persons, who travel by car, only the time-spending distance (see table 2) and the following coefficients gave the best results, where R^2 values were the highest and P-values were the lowest:

$$DC^*_{i,j} = \frac{aP_i^{\alpha_i} P_j^{\alpha_j}}{d(t)^{\beta}_{i,j}} K^{\gamma}_{GEAR,j} \tag{5}$$

We got the regression parameters for the inter-regional commuting flow equation where $R^2 = 79.9\%$ for 132 observations and where $d(t)$ is the time-spending distance in minutes when travelling by car (see Table 3). The inter-regional regression model of commuters, employed persons, who travel by car, is then:

$$DC^*_{i,j} = \frac{2.13 P_i^{0.95} P_j^{1.28}}{d(t)^{2.35}_{i,j}} K^{5.48}_{GEAR,j} \cdot 10^{-5} \ . \tag{5a}$$

[3] To determine time spending distances, OMNITRANS® package has been used for distances evaluation between regional centres, on the bases of the road network classification and GIS Slovenian road database.

Table 3: Coefficients of the gravity model and summary output for Slovenian inter-regional commuting of employed persons $DC^{*}_{i,j}$, where economic coefficients (4) were analysed

Name of Coefficients in (5)	**Value of Coefficients in (5)**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Ln(a)	-	-4.1376	0.0001	-	-5.6125
α_i	0.9536	7.6792	0.0000	0.7079	1.1993
α_j	1.2795	8.6041	0.0000	0.9852	1.5737
$-\beta$	-2.3548	-	0.0000	-2.7099	-1.9997
γ	5.4843	4.2297	0.0000	2.9185	8.0500

From Table 3 it is evident that P-values for all coefficients, entering the final model (5a), are very low. Therefore, the regression model (5a) of inter-regional commuters, employed persons, is very stable – but, it can not be used easily to analyse the policy impact in the region.[4]

2.2 Incorporation of accessibility coefficients

The concept of accessibility can be used in many contexts and in different ways; for instance, as a goal in transportation policy, as a measure in rural development policy, as an indicator of rural deprivation, and as a variable in location analysis. Accessibility is one of the main issues in development and physical planning policies, which are mostly concerned with equity and a better distribution of people and activities in the territory. Therefore, accessibility is considered, by planners and other technicians, to be a key variable for territorial development and planning (Jong and Eck, 1996).

Contemporary GIS-tools enable modelling accessibility fields at the different levels of spatial structures (or traffic networks) and operative incorporation of the accessibility in the gravity models. For this purpose, we used a two-stage raster-based approach to model an accessibility fields in Slovenia (Drobne et al., 2008), which follows the original ideas of (Donnay and Ledent, 1995). The time-spending distances to centres of different spatial hierarchical structures were calculated: i.e. time-spending distances to the capital (Ljubljana), to 12 regional and administrative centres, as well as to municipal centres. Besides that, time-spending distances to the motorway connections were calculated. Figures 3 shows time-spending distances to the regional centres, and Figure 4 shows time-spending distances to the motorway connections (in 2001). Note, that the time-spending distance was calculated for the ideal circumstances without consideration of traffic flows by day time schedules, traffic restrictions on road segments, etc.

To incorporate the concept of accessibility into the gravity model, we have compared the location of almost 483,000 houses in Slovenia with the time-spending distances to the central places on different levels and motorway connections (junctions):

a) locations of houses where number of inhabitants is greater then 0 (dwelling houses) for the regions of origin, and
b) locations of houses where number of inhabitants is equal to 0 (non-dwelling houses) for the regions of destination (where persons are employed).

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[4] For example, coefficients like coefficient of Gross Domestic Product per capita in the region, coefficient of employment in the region, coefficient of unemployment in the region, etc., can be used more easily for policy analysis than coefficients like the coefficient of average gross earning per person in the region.

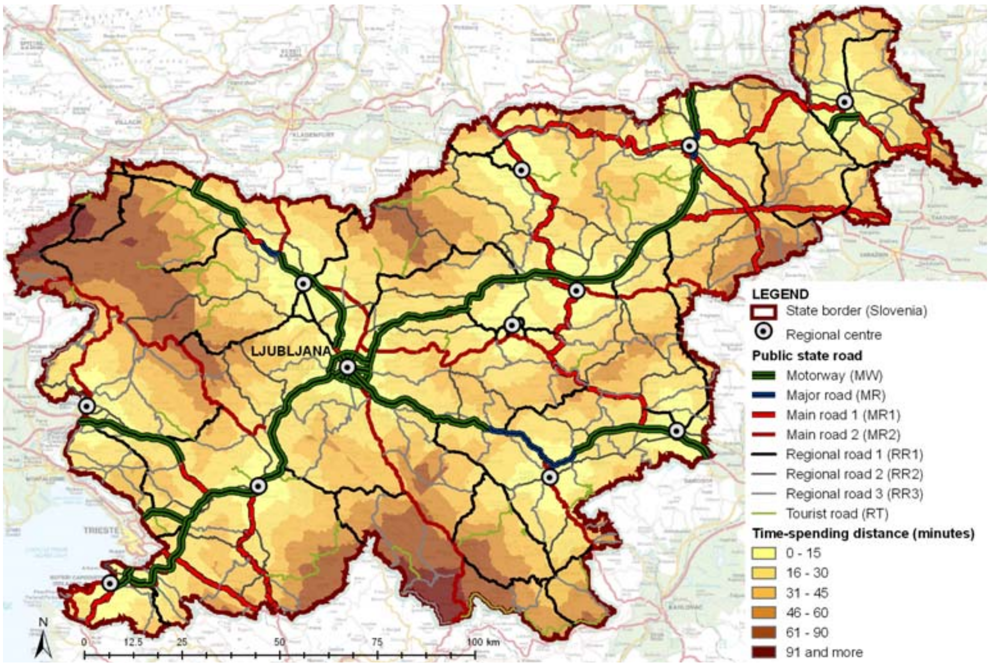

Figure 3: Time-spending distance to regional centres and public road network in Slovenia in 2005

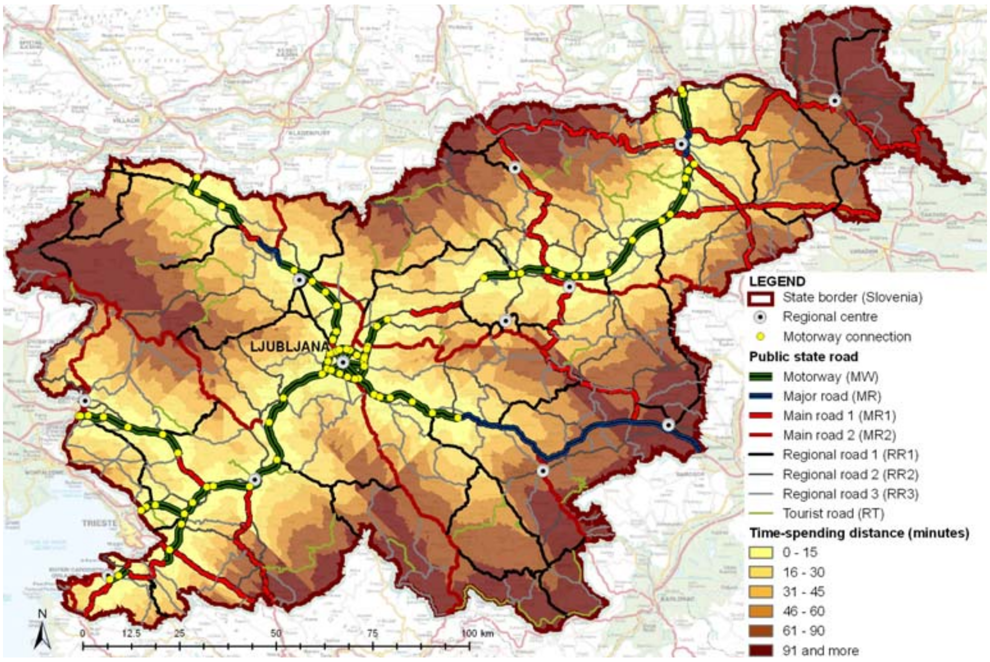

Figure 4: Time-spending distance to motorway connections and public road network in Slovenia in 2001

To analyse the influence of accessibility to inter-regional commuting flows of employed persons in Slovenia, the gravity model (2) was extended with the following accessibility coefficients:

$$K_{TCAP,\circ} = \frac{TCAP(\circ)}{TCAP(SI)},\quad K_{TREC,\circ} = \frac{TREC(\circ)}{TREC(SI)},\quad K_{TADC,\circ} = \frac{TADC(\circ)}{TADC(SI)},\quad K_{TMUC,\circ} = \frac{TMUC(\circ)}{TMUC(SI)},$$
$$K_{TMOC,\circ} = \frac{TMOC(\circ)}{TMOC(SI)},\quad K_{TMOC,\circ} = \frac{TMOC(\circ)}{TMOC(SI)} \tag{6}$$

where $(\circ)$ denotes the region of origin i or region of destination j ($i = 1,2,...,12;\ j = 1,2,...,12$), $TCAP$ is the average time-spending distance to the capital (Ljubljana) in the region, and in Slovenia (SI) respectively, $TREC$ is the average time-spending distance to the regional centre in the region, and in Slovenia (SI) respectively, $TADC$ is the average time-spending distance to the administrative centre in the region, and in Slovenia (SI) respectively, $TMUC$ is the average time-spending distance to the municipal centre in the region, and in Slovenia (SI) respectively, and $TMOC$ is the average time-spending distance to the motorway connections in 2001 in the region, and in Slovenia (SI) respectively (note: all time-spending distances are in minutes).

The extended gravity model of employed persons was tested for economic (4) and accessibility coefficients (6), together and separately. However, the gravity model extended by the economic coefficients (5a) can not be improved with simple adding the accessibility coefficients (6). Moreover, adding all or selected above mentioned accessibility coefficients to the model (5a) makes the model more instable. On the other hand, the gravity model (2) has became very stable when only the time-spending distance to the motorway connections in 2001 in the region of destination $K_{TMOC,j}$ was consider and included in it. In the regression analysis, consideration of the time-spending distance and following coefficients has given the best results (R^2 is the highest and P-values are the lowest):

$$DC^*_{i,j} = \frac{aP_i^{\alpha_i} P_j^{\alpha_j}}{d(t)^{\beta}_{i,j} K^{\delta}_{TMOC,j}}\ . \tag{7}$$

Table 4 shows the regression parameters for the inter-regional commuting flow equation where $R^2 = 80.3\%$ for 132 observations and $d(t)$ is the time-spending distance in minutes when travelling by car.

Table 4: Coefficients of the gravity model and summary output for Slovenian inter-regional commuting of employed persons $DC^*_{i,j}$, where the accessibility (6) and economic coefficients (4), were analysed

Name of Coefficients in (7)	Value of Coefficients in (7)	t Stat	P-value	Lower 95%	Upper 95%
$Ln(a)$	-	-4.3397	0.0000	-	-5.9969
α_i	0.9533	7.7504	0.0000	0.7099	1.19675
α_j	1.2721	8.7416	0.0000	0.9841	1.56003
$-\beta$	-2.3575	-	0.0000	-2.7085	-2.0060
$-\delta$	-0.6864	-4.5450	0.0000	-0.9853	-0.3876

Considering above mentioned economic and accessibility coefficients together, the best fitted inter-regional regression model of commuters, employed persons, who travel by car, is then:

$$DC^*_{i,j} = \frac{1.63 P_i^{0.95} P_j^{1.27}}{d(t)_{i,j}^{2.36} K_{TMOC,j}^{0.69}} \cdot 10^{-5} \quad . \qquad (7a)$$

Comparing the regression parameters from Tables 3 and 4, we can notice that both regression models (5a and 7a) are very stable. Even more, the powers in the models are very similar.

2.3 Correlation between economic and accessibility coefficients

Likeness between models (5a) and (7a) released the correlation analysis between coefficient of average gross earning per person in the region of destination $K_{GEAR,j}$ and time-spending distance to the motorway connections in 2001 in the region of destination $K_{TMOC,j}$. The pure correlation between the time-spending distance to the motorway connections in the region of destination and average gross earning per person in the region of destination has been tested using the regression model (8). Table 5 and model (8a) show the results of pure correlation between the time-spending distance to the motorway connections in the region of destination and average gross earning per person in the region of destination.

$$K_{TMOC,j} = \frac{a}{K_{GEAR,j}^{\phi}} \quad . \qquad (8)$$

Table 5: Summary output for pure correlation between the time-spending distance to the motorway connections in the region of destination and average gross earning per person in the region of destination ($R^2 = 64.9\%$).

Name of Coefficients in (8)	Value of Coefficients in (8)	t Stat	P-value	Lower 95%	Upper 95%
$Ln(a)$	-0.4578	-	0.0000	-0.5471	-0.3686
$-\phi$	-6.7522	-	0.0000	-7.6137	-5.8907

Then

$$K_{TMOC,j} = \frac{0.63}{K_{GEAR,j}^{6.75}} \quad . \qquad (8a)$$

The last results of pure correlation between the time-spending distance to the motorway connections in the region of destination and average gross earning per person in the region of destination (Table 5 and model (8a)) show, that the regions of destination, which have better accessibility to the motorway connectors, have also better average gross earning per person. For that reason, the economic variable of the extended gravity model (5a) could be substituted by the spatial variable, which define accessibility to the to the motorway connectors (7a). In this way, the gravity model could be directly used for policy analysis. Using model (7a), the impact of the investments in the highways on the inter-regional commuting flows can be analysed - but the coefficient of average gross earning per person in the region can not be easily used for policy (impact) analysis.

3 CONCLUSIONS AND FURTHER RESEARCH

In the paper, we extended our previous work in modelling inter-regional commuting flows of employed persons in Slovenia analysing the accessibility coefficients at the lower levels of spatial hierarchy. The incorporation of time-spending distance to the motorway connections in the region of destination in the regression model of commuters has given a very stable inter-regional gravity model of commuting for the employed persons in Slovenia.

From the results here, we can conclude that the average gross earning per person in the region of destination correlates to the accessibility to the motorway connectors in the region. For that reason, the economic variables of the extended gravity model could be substituted by the spatial variables, which define accessibility at different hierarchical levels of spatial structures. In this way, the gravity model can be more easily used for policy (impact) analysis.

Further research can be focused on lower spatial hierarchical units (administration unit, municipality etc.) where the commuting analysis is of big importance in the decision making on the local levels. Taking into consideration lower levels of spatial units, the influence of accessibility to the location of destination on commuting may change evidently. Therefore the results of inter-regional gravity model can not be simply transferred to the commuting models for the lower spatial levels.

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