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Transportation Research Procedia 63 (2022) 486–494

Transportation Research Procedia

www.elsevier.com/locate/procedia

X International Scientific Siberian Transport Forum

Transport integration in providing the economic development of the territory

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Abstract

In the presented article it is examined the role of transport integration in providing the economic development of the territory which is both the factor and the result of its development. We defined the notion, we noted the structural and infrastructural character of transport integration, we estimated the impact of different parameters on inter-temporal changes of transport integration indexes, and also its impact on the Gross Regional Product (GRP) development over the period of 2000 to 2018. We set and determined summary index of transport integration for the regions of Siberian Federal District. Using the correlation analysis we estimated the strength of relationship between transport integration summary index and GRP index, between transport integration index and roads density index. Altai Krai, Krasnoyarsk Krai, Novosibirsk Oblast are related to the regions with high relationship of transport integration and GRP indexes. There is "structural break" in inter-temporal changes of roads density indexes on the defined territories. The comparison of the development of roads density, GRP and transport integration indexes has highlighted that there is progressively cyclical relationship between specified parameters, assigned transport infrastructure the status of transport integration driver of the region. We estimated advanced research directions which cover both spatial and dynamic aspects.

Keywords: Transport integration; region; Gross Regional Product (GRP); economic development.

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Peer-review under responsibility of the scientific committee of the X International Scientific Siberian Transport Forum
10.1016/j.trpro.2022.06.039

1. Introduction

Effective interactions between national economy subjects are not possible without creations of a type of “links” which provide its unity under the objectively developed conditions of vast differentiation of regions functioning parameters. This enables to talk about transport as a mean of high economic development support of territories with wildly varied economical dynamics, with funding ratio of different resources etc. The interest in such topic of Russian and foreign scientists (see: Freidman O.A., 2016; Tsvetkov V.A. and others, 2017; Gridko N. P. and Nizhegorodtsev R. M., 2018; Sannikova I.N. and Rudakova T.A., 2018; Akaev A.A. and others, 2019; Berezhnaya L.Y., 2019; Krylov P.M., 2020; Patsala S.V. and Goroshko N.V., 2020; Sirina N., Zubkov V., 2021, Kozhevnikov S., 2021; Ma, Q. and others, 2021; Montoya, J. and others, 2021 and many others) is connected with multidimensionality of its research approaches representing particularly:

- hierarchy of economic system;
- lots of approaches to the estimation of transport role by support of extended reproduction of standards of living;
- specific nature of different means of transport which are examined both individually and in the aggregate.

In the presented article the interaction of transport integration and economical territory development has been estimated – particularly we examined the dependency of auto transport functioning indexes, which accounts for around 80% of freight ton-miles in Russian Federation according to 2020 and around 30% of passenger traffic (Federal State Statistics Service, 2020), and the results of economic complex activities of a region.

By transport integration is meant integrity keeping of territorial area by support with transport services any economical interaction of subjects which is understood as independent activity that is focused at the same time on providing both its own and its constituency performance. In addition, transport integration can be examined in the context of structural (according to transport mode, combination of its separate forms or on their aggregate) and infrastructural aspects (availability of supporting infrastructure – e.g. road net development for auto transport, availability of harbors for water transport etc.).

Taking into consideration that social life is totally covered with transport integration, we offered the following algorithm of this problem execution which reflects research tasks:

- to determine the summary index of transport integration which allows to rank the territories;
- to determine the interaction character of transport integration summary index and economic development of the region, having marked out the areas with high level of connection;
- to determine the infrastructural component influence on the level of transport integration for leader regions which have been marked out in the furtherance of the previous task.

2. Materials and Methods

We have taken freight ton-miles and passenger traffic as an auto transport functioning index (according to official statistics data), that reflects volumes of services connected with support intraregional and interregional services, their intensity is characterized by base indexes (see: Table 1, 2), which serve as a basis for computation of transport integration summary index:

$$\mathrm{ITTI} = \sqrt{\mathrm{IG} \cdot \mathrm{IP}}, \tag{1}$$

where IG is the index for freight ton-miles; IP is the index for passenger traffic.

As a factual basis of research were taken official statistics data in Siberian Federal District (Federal State Statistics Service, 2021).

Table 1. Freight ton-miles indexes of the regions of Siberian Federal District over the period of 2000 to 2018 (on 2000).

№	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Republic of Altai	1.00	0.88	0.98	0.63	0.96	0.85	0.75	0.70	0.67	0.52	0.57	0.71	0.52	0.41	0.95	0.64	0.73	0.90	1.05
2	Republic of Tuva	1.00	1.06	1.13	1.05	1.36	1.12	2.04	1.30	1.44	1.59	1.65	1.96	1.79	1.57	1.79	1.43	1.19	1.11	1.47
3	Republic of Khakassia	1.00	0.72	0.60	0.82	0.51	0.59	0.33	0.37	0.49	0.45	0.58	0.66	0.62	2.70	2.78	0.78	0.63	0.48	0.45
4	Altai Krai	1.00	1.10	1.15	1.15	0.96	0.80	0.70	0.77	0.79	0.85	0.99	1.18	1.15	0.97	1.10	1.07	0.97	1.29	1.47
5	Krasnoyarsk Krai	1.00	0.99	0.78	0.77	0.81	0.87	0.91	1.05	1.15	1.16	1.46	1.50	1.68	1.82	2.34	1.71	1.42	1.62	1.59
6	Irkutsk Oblast	1.00	1.19	1.23	1.57	1.71	1.27	1.06	1.06	1.12	1.33	1.21	1.67	1.43	1.07	1.06	1.19	1.28	1.13	1.15
7	Kemerovo Oblast	1.00	0.96	0.97	0.55	0.53	0.51	0.58	0.40	0.39	0.35	0.39	0.44	0.49	0.50	0.46	0.48	0.47	0.43	0.41
8	Novosibirsk Oblast	1.00	0.75	0.78	1.00	0.88	1.23	0.69	0.93	0.96	0.66	0.72	0.78	0.93	1.01	1.04	1.01	1.26	1.25	1.70
9	Omsk Oblast	1.00	0.95	1.02	1.11	1.09	1.39	1.21	1.26	0.96	0.74	0.80	0.99	0.95	1.51	1.95	1.81	1.63	1.81	1.98
10	Tomsk Oblast	1.00	1.03	1.06	1.48	1.56	1.64	1.82	1.20	0.95	2.52	4.75	5.39	4.41	3.36	2.85	3.17	2.61	3.02	3.11

Table 2. Passenger traffic indexes of the regions of Siberian Federal District over the period of 2000 to 2018 (on 2000).

№	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Republic of Altai	1.00	1.12	1.16	1.18	1.14	0.93	0.91	0.98	1.01	0.91	1.11	1.12	0.78	0.56	1.45	1.37	1.34	0.98	0.99
2	Republic of Tuva	1.00	1.07	1.23	1.71	1.82	2.04	2.40	2.50	2.55	2.51	2.52	2.49	2.52	2.51	2.59	2.70	2.52	2.46	2.63
3	Republic of Khakassia	1.00	0.86	0.64	0.71	0.65	0.71	0.79	0.95	0.97	0.83	0.93	0.89	0.80	0.73	0.94	0.84	0.78	0.84	0.83
4	Altai Krai	1.00	1.01	1.10	1.04	1.24	1.01	1.12	1.43	1.54	1.48	1.50	1.61	1.52	1.41	1.38	1.38	1.36	1.38	1.38
5	Krasnoyarsk Krai	1.00	1.00	1.08	1.07	1.04	0.97	0.84	1.09	1.27	1.21	1.26	1.25	0.82	0.77	1.04	0.96	0.95	0.88	0.81
6	Irkutsk Oblast	1.00	0.92	0.87	0.72	0.66	0.86	0.89	0.98	0.98	0.91	0.98	1.03	1.00	1.00	0.86	0.82	0.88	1.05	0.92
7	Kemerovo Oblast	1.00	1.01	1.00	0.96	0.89	0.87	0.95	0.92	0.93	0.92	0.90	0.88	0.82	0.80	0.78	0.73	0.68	0.67	0.62
8	Novosibirsk Oblast	1.00	0.97	0.93	0.83	0.74	0.48	0.46	1.34	1.37	1.30	1.29	1.28	1.47	0.56	0.84	0.96	1.12	1.31	1.33
9	Omsk Oblast	1.00	1.10	1.07	1.07	1.03	1.00	1.26	1.43	1.42	1.21	1.04	0.93	0.94	0.78	1.00	0.96	0.85	0.74	0.71
10	Tomsk Oblast	1.00	1.01	1.07	1.17	1.21	1.33	1.31	1.15	1.15	1.01	0.89	0.85	0.80	0.71	0.67	0.58	0.68	0.47	0.40

The thesis about the weight of transport components by territory development intensified the need for examination of availability and type of the dependence between such economic activity indexes as GRP (see: Table 3) and ITTI with the use of correlation analyses.

Table 3. GRP indexes of the regions of Siberian Federal District over the period of 2000 to 2018 (on 2000).

№	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Republic of Altai	1.00	1.64	1.94	2.52	3.11	3.22	4.24	5.52	6.83	7.27	8.18	9.64	11.12	12.17	14.32	15.40	17.33	17.69	19.75
2	Republic of Tuva	1.00	1.45	1.91	2.26	2.74	3.24	4.21	5.39	6.64	7.49	8.56	9.29	10.40	11.49	12.78	13.16	16.14	18.10	20.50
3	Republic of Khakassia	1.00	1.15	1.46	1.66	1.90	2.40	3.08	3.66	4.15	4.65	5.51	6.49	7.50	8.14	9.09	9.78	11.93	12.52	13.91
4	Altai Krai	1.00	1.32	1.56	1.90	2.46	2.90	3.72	4.78	5.55	5.68	6.48	7.11	7.90	8.90	9.54	10.44	11.39	11.67	12.40
5	Krasnoyarsk Krai	1.00	1.12	1.08	1.27	1.70	2.05	2.73	3.42	3.44	3.49	4.92	5.45	5.51	5.86	6.57	7.77	8.49	9.21	11.06
6	Irkutsk Oblast	1.00	1.17	1.36	1.63	2.07	2.51	3.21	3.91	4.26	4.45	5.30	6.16	7.16	7.82	8.90	9.72	11.06	12.31	14.18
7	Kemerovo Oblast	1.00	1.28	1.53	1.86	2.76	3.33	3.86	4.93	6.49	5.78	7.05	8.47	8.10	7.53	8.48	9.50	10.18	12.37	14.27
8	Novosibirsk Oblast	1.00	1.32	1.71	2.14	2.66	3.27	4.11	5.08	6.30	5.91	6.72	8.31	10.11	11.35	12.65	14.19	14.93	16.38	18.08
9	Omsk Oblast	1.00	1.34	2.01	2.50	4.19	4.79	5.70	6.43	7.56	7.31	8.31	9.81	10.68	11.99	13.09	13.43	14.54	15.20	15.99
10	Tomsk Oblast	1.00	1.41	1.86	2.39	3.27	3.94	4.66	5.29	6.14	6.06	7.02	8.24	9.16	9.93	10.61	11.63	12.85	13.68	15.11

Objective relativities between structural and infrastructural components of transport integration established a need for estimation of relationship between transport integration index of the regions and one of the transport infrastructure development parameters – public hard roads density (see: Table 4).

Table 4. Roads density indexes of the regions of Siberian Federal District over the period of 2000 to 2018 (on 2000).

№	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Republic of Altai	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.07	1.07	1.07	1.07	1.10	1.47	1.50	1.57	1.60	1.63	1.63	1.65
2	Republic of Tuva	1.00	1.00	1.00	1.00	1.00	0.80	1.20	1.20	1.20	1.20	1.13	1.13	1.00	1.20	1.33	1.40	1.40	1.40	1.40
3	Republic of Khakassia	1.00	1.00	1.03	1.03	1.05	1.08	1.08	1.08	1.13	1.15	1.15	1.15	1.88	2.00	2.20	2.18	2.20	2.27	2.31
4	Altai Krai	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.21	1.11	1.07	1.07	2.45	2.60	2.68	2.64	2.60	2.59	2.60	2.52
5	Krasnoyarsk Krai	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.02	1.02	1.13	1.16	2.00	2.00	2.00	2.00	2.18	2.00	2.12	2.11
6	Irkutsk Oblast	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.75	1.81	1.81	1.88	1.88	1.93	1.97
7	Kemerovo Oblast	1.00	1.02	1.02	1.03	1.03	1.03	1.39	1.41	1.47	1.47	1.53	1.63	2.46	2.90	2.98	2.95	2.97	3.00	3.01
8	Novosibirsk Oblast	1.00	1.02	1.04	1.04	1.06	1.06	1.11	1.13	1.13	1.15	1.23	1.25	1.70	1.87	1.92	2.06	2.08	2.09	2.11
9	Omsk Oblast	1.00	1.00	1.02	1.04	1.04	1.04	1.16	1.45	1.45	1.40	1.36	1.38	1.76	1.75	1.78	1.78	1.78	1.79	1.80
10	Tomsk Oblast	1.00	1.00	1.00	1.09	1.09	0.91	1.18	1.18	1.18	1.18	1.18	1.27	2.00	2.09	2.18	2.18	2.18	2.20	2.22

The analysis of relationship between the couples of the above indexes is undertaken using correlation analysis which is based on the exercise of the pair correlation coefficient (Eliseeva, 2002):

$$r = \frac{\overline{x \cdot y} - \bar{x} \cdot \bar{y}}{\sigma_x \cdot \sigma_y}, \quad (2)$$

where x is values for factorial feature; y is values for effective feature; σ_x is standard error of factorial feature; σ_y is standard error of effective feature.

The specificity of time-series data as a source of data under econometric modelling demands the use of particular score test together with traditional methods of correlation analysis. This can be caused by the fact that in some cases the existence of the trends in one of the time-series data can be the result from the existence of the trends in the other time-series data which were examined in connection with the first one. Therefore the similar and the opposite direction of trends in time-series data can be stable, but correlation coefficient, which is calculated according to the levels of time-series data, can correspondingly not include false correlation and show true cause-and-effect relationship between the time-series data, that is cointegration which is shown by matching or opposite direction of their trends and random variability.

One of the testing methods for under the null about nonavailability of cointegration between two time-series data is based on use of score test of Durbin-Watson:

$$d = \frac{\sum_{t=2}^{n} (\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{n} \varepsilon_t^2}, \quad (3)$$

where ε_t is the residuals which are got according to the formula of linear regression with one regressor which was formed for two time-series data, which parameters are taken by ordinary least-square method.

The hypothesis is being tested to show that achieved from the formula (3) actual value of Durbin-Watson parameter in coverage is equal to zero. Some scientists (Sargan and Bhargava, 1983) point out the following critical values of Durbin-Watson parameter for the following significance levels: 1% - 0,511; 5% - 0,386; 10% - 0,322. If the testing results show that the actual value of parameter cannot be equal to zero, which means it passes the critical value for target significance level, under the null hypothesis of nonavailability of cointegration between time-series data is rejected. In such a case, the correlation coefficient (2) which is calculated according to initial time-series data can be used for purposes of analyses of time-series data relationships.

3. Results and Discussion

The dynamic pattern of transport integration summary index is shown in Table 5.

Table 5. Transport integration indexes of the regions of Siberian Federal District over the period of 2000 to 2018 (on 2000).

№	Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Republic of Altai	1.00	0.99	1.07	0.86	1.04	0.89	0.82	0.83	0.82	0.68	0.80	0.89	0.64	0.48	1.17	0.93	0.99	0.94	1.02
2	Republic of Tuva	1.00	1.07	1.18	1.34	1.58	1.51	2.21	1.81	1.91	2.00	2.04	2.21	2.12	1.99	2.15	1.97	1.73	1.65	1.97
3	Republic of Khakassia	1.00	0.79	0.62	0.76	0.57	0.64	0.51	0.59	0.69	0.61	0.73	0.77	0.71	1.41	1.62	0.81	0.70	0.64	0.61
4	Altai Krai	1.00	1.05	1.12	1.09	1.09	0.90	0.88	1.05	1.10	1.12	1.22	1.38	1.32	1.17	1.23	1.21	1.15	1.33	1.43
5	Krasnoyarsk Krai	1.00	1.00	0.92	0.91	0.92	0.92	0.88	1.07	1.21	1.18	1.36	1.37	1.17	1.19	1.56	1.28	1.16	1.20	1.14
6	Irkutsk Oblast	1.00	1.05	1.03	1.06	1.06	1.04	0.97	1.02	1.05	1.10	1.09	1.31	1.20	1.04	0.96	0.99	1.06	1.09	1.03
7	Kemerovo Oblast	1.00	0.98	0.98	0.72	0.69	0.67	0.74	0.60	0.60	0.56	0.59	0.62	0.63	0.63	0.60	0.59	0.57	0.54	0.50
8	Novosibirsk Oblast	1.00	0.85	0.85	0.91	0.81	0.77	0.56	1.12	1.15	0.93	0.97	1.00	1.17	0.75	0.93	0.99	1.19	1.28	1.50
9	Omsk Oblast	1.00	1.02	1.05	1.09	1.06	1.18	1.23	1.35	1.17	0.94	0.92	0.96	0.94	1.09	1.40	1.32	1.17	1.16	1.18
10	Tomsk Oblast	1.00	1.02	1.07	1.32	1.37	1.48	1.54	1.17	1.05	1.59	2.05	2.14	1.88	1.54	1.38	1.36	1.33	1.19	1.11

As we see form Table 5, there is no single-valued dynamic of transport integration of the regions of Siberian Federal District over the period under review. According to the findings, in 2001 the transport integration index was below the average value in Republic of Khakassia and Novosibirsk Oblast. During the whole period the leader of transport integration level was Republic of Tuva; by the year 2018 the index has grown dramatically in Novosibirsk Oblast thus it has overdrawn the average value. The similar variation of the indicator allows classifying the regions of Siberian Federal District according to the level of transport integration index (see fig. 1, 2):

- regions with transport integration index above average value in the district (e.g., according to figures from 2018 they are Republic of Tuva, Novosibirsk Oblast and others);
- regions with transport integration index below average value in the district (e.g., according to figures from 2018 they are Republic of Khakassia, Altay, Kemerovo Oblast).

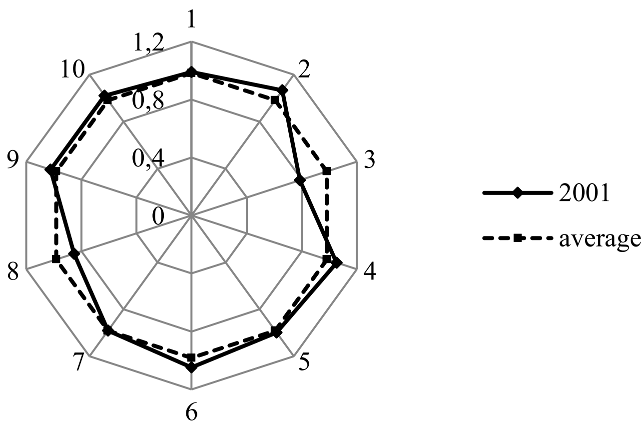

Fig. 1 Transport integration summary index of the regions of Siberian Federal District in 2001.

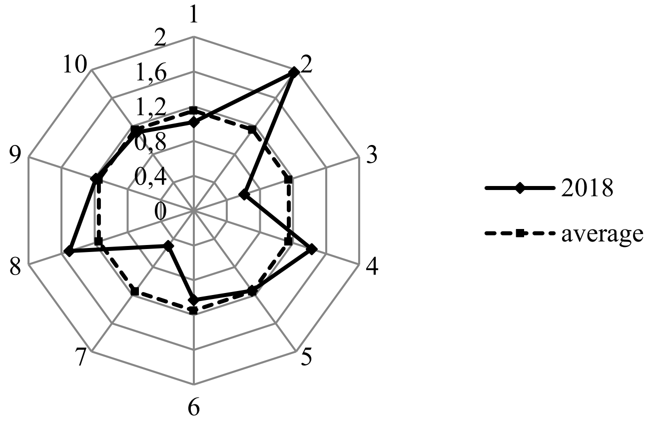

Fig. 2. Transport integration summary index of the regions of Siberian Federal District in 2018.

Table 6 shows values of linear coefficients of pair correlation which are calculated according to the numbers (see Tables 3 to 5) of the regions of Siberian Federal District for the period under review.

Table 6. Correlation coefficients between numbers of GRP and ITTI, ITTI and roads density indexes over the period of 2000 to 2018 (on 2000).

№	Region	Correlation coefficients between numbers of ITTI and roads density indexes	Correlation coefficients between numbers of GRP and ITTI indexes
1	Republic of Altai	0.08	0.06
2	Republic of Tuva	0.47	0.48
3	Republic of Khakassia	0.43	0.25
4	Altai Krai	0.73	0.70
5	Krasnoyarsk Krai	0.63	0.59
6	Irkutsk Oblast	-0.04	0.01
7	Kemerovo Oblast	-0.61	-0.78
8	Novosibirsk Oblast	0.56	0.67
9	Omsk Oblast	0.31	0.29
10	Tomsk Oblast	-0.02	0.09

To the regions with strong correlation dependence of GRP and ITTI indexes should be taken Altai Krai (correlation coefficients values above 0.7 which shows close direct linear relationship between examined numbers); Krasnoyarsk Krai and Novosibirsk Oblast (correlation coefficients values are close to 0.7, which shows moderate direct linear relationship between examined numbers). In these regions correlation coefficients between numbers of ITTI and roads density indexes take high values.

For the regions which have the highest value of correlation coefficients (Altai Krai, Krasnoyarsk Krai and Novosibirsk Oblast) the hypothesis of availability of cointegration has been tested. The results of the hypothesis testing verify the availability of cointegration of examined time-series data because the values of all factorial values of Durbin-Watson parameter are above the critical one which is equal to 0.386 for significance level of 5%. Consequently, in Altai Krai, Krasnoyarsk Krai and Novosibirsk Oblast there has been high dependence level between GRP and ITTI base indexes, whereas ITTI indexes linearly depend on roads density.

The comparison of dynamic between GRP, transport integration and roads density indexes for these regions is shown in fig. 3 to 5.

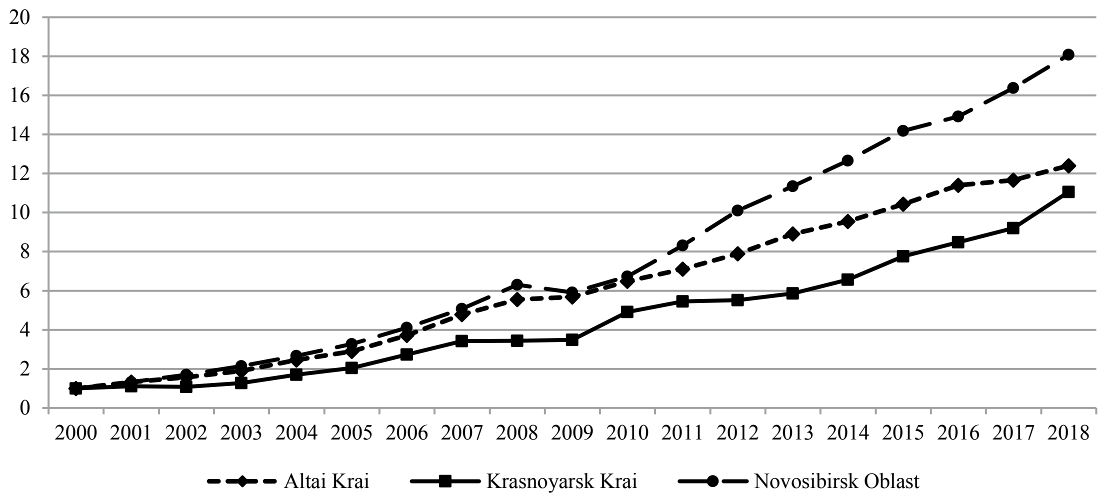

Fig. 3. GRP base indexes.

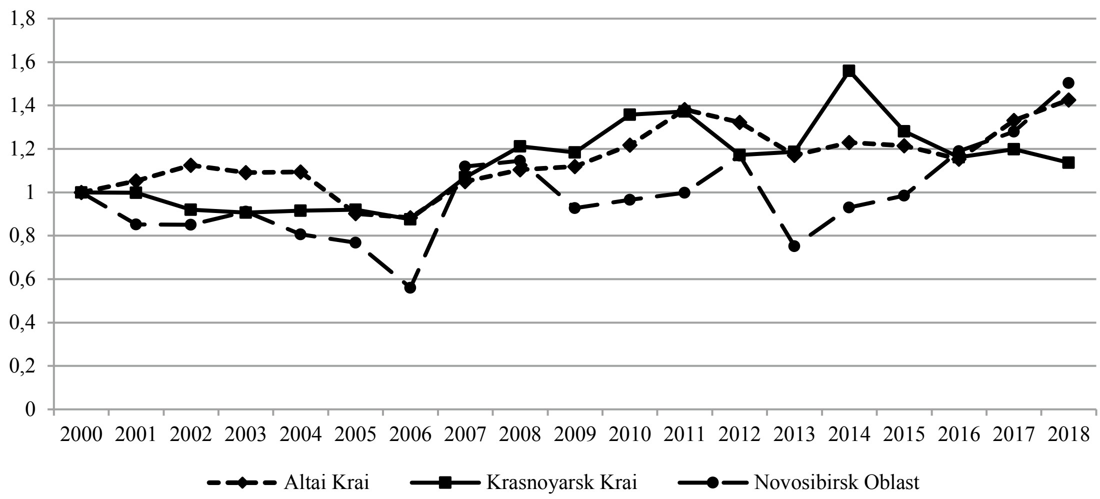

Fig. 4. Transport integration base indexes.

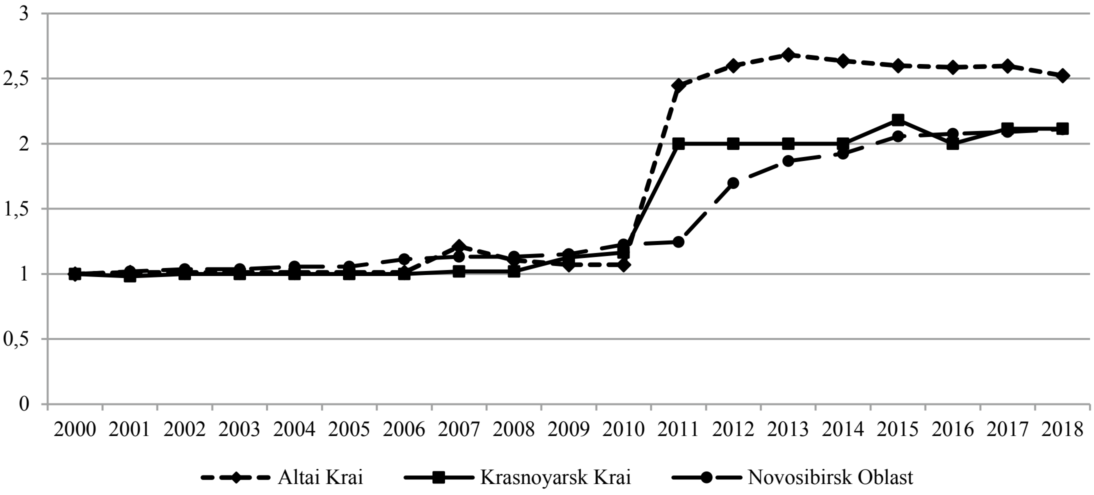

Fig. 5. Paved roads density base indexes.

By estimation of dynamic of roads density base indexes (see fig. 5), which are interpreted by the authors as infrastructural component of transport integration, in leader regions "structural break" (2010) is being observed which is an entry point for the following growth of the first one, that makes a background for factorial analysis of the mentioned phenomenon.

According to the determined dependence hypothesis of availability of linearly cyclical characterized relationship between examined parameters can be formulated (see fig. 6).

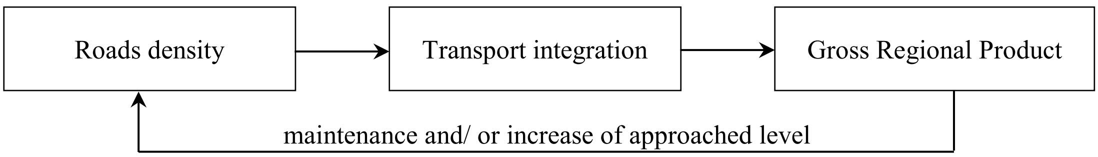

Fig. 6. Interaction of transport integration component and GRP.

The presented relationship points out the possibility of getting the status of transport integration "driver" by infrastructural components of transport integration and as a result the one of commercial dynamic of territory which in exchange is a management instrument of the parameters of the first ones and provides expanded reproduction`s cyclicality of region functioning conditions. It is sure that the list of infrastructural components can and must be expanded for their ranking to find out more effective "instruments" of development for particular region.

4. Conclusions

It is to be noted that obtained results involve motor transportation only and are limited by the territory of Siberian Federal District. Although, the suggested approach can be used for impact estimation of other means of transport (both individually and in the aggregate) on the economy not only of the concerned district but also of the others (of particular note is that there are some difficulties in such research which are connected with the scarcity of factual data that are found in official statistics). This will help to estimate prospective for transport integration development in relation to structural and infrastructural aspects, which are both a factor and a result of regional economic performance.

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