Data Modelling for Analysis of Readness of Municipal Education in Industry 5.0

Irina Khaimovich
Samara University of Public Administration International Market Institute;
Samara National Research University
Samara, Russia
kovalek68@mail.ru

Vladimir Ramzaev
Samara University of Public Administration International Market Institute
Samara,Russia
ramzaevvm@mail.ru

Vadim Chumak
Samara University of Public Administration International Market Institute
Samara,Russia
imi@imi-samara.ru

***Abstract*—The purpose of the study is to determine the level of readiness of municipalities in the Samara Oblast to introduce Industry 5.0 technologies. The authors propose a mathematical model that allows determining the level of readiness of municipalities in the Samara Oblast to introduce Industry 5.0 technologies with a further increase in the competitiveness of municipalities, select projects that are most suitable for the current level of preparation for Industry 5.0, and identify the main difficulties in their implementation. The study developed innovative indicators of the readiness of municipalities to enter Industry 5.0. The innovative indicators of the analysis that show the level of the preparation of municipalities for entering Industry 5.0 include: the indicator of manufacturability, internetization, the introduction of new technologies and others. The scope of the results is extensive. This study will be interesting to scientists involved in the digital economy, Big Data management.**

***Keywords*—Big Data, Industry 5.0, indicators, mathematical modeling**

I. Statement of the Problem

Today, society is moving towards a new industry 5.0, this industry is also denoted by the following terms: Industry 5.0, Society 5.0, Society 5.0, Super Smart Society. Under any of these terms there is a socio-economic and cultural strategy for the development of society based on the use of digital technologies in all spheres of life [1, 2]. Industry 5.0 includes nine key features (the use of autonomous robots, the modeling of complex objects, the use of integration systems, cyber security, Internet of things, cloud computing, additive manufacturing, and additional reality and Big Data technologies).

This strategy for the society development is based on the technological structure, which is a set of related industries that have a single technical level and develop simultaneously. The change of technological structures occurs in the sequence shown in Figure 1.

To enter Industry 5.0, it is necessary to determine the willingness of municipalities of the Volga region to join this company, for this a study was conducted to determine the readiness indicators of the municipalities to enter Industry 5.0 and it was possible to identify the dependence of increasing the competitiveness of the municipality and new indicators of the assessment system.

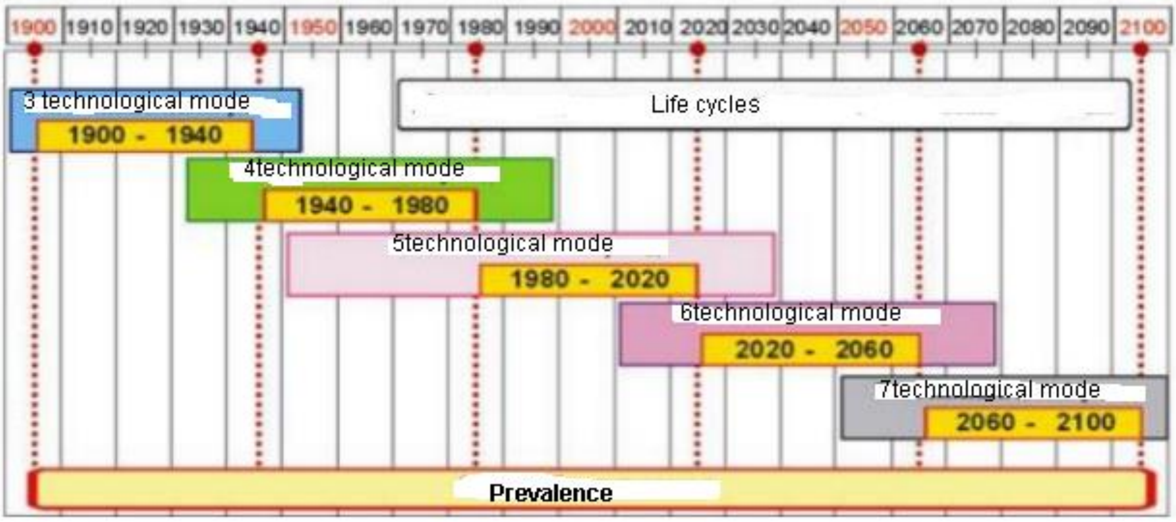

Fig. 1. Change of technological modes.

II. Development of Methods for Improving the Municipality Competitiveness of Through the Use of Industry 5.0 Technologies

The calculation of the possibility of entering Industry 5.0 technology is directly related to the notion of competitiveness of municipal entities. Competitiveness is the most important characteristic of the development of socio-economic systems, including territories. This area is one of the priorities for the research center of the Samara University of Public Administration “International Market Institute”. For several years, the university conducted research on the competitiveness of territories: the region, urban districts, including small and single-industry towns, municipalities and rural settlements.

The approach used is based on an understanding of competitiveness as the ability to compete in the process of competition for limited resources [1, 2].

The developed methodology is based on an economic-mathematical model of an additive type for assessing the state of competitiveness of a territory:

$$\begin{cases} KS = (\xi_1 GF + \xi_2 PRF + \xi_3 EF + \xi_4 PPF + \xi_5 APF + \xi_6 GF + \\ + \xi_7 FEF + \xi_8 IfF + \xi_9 UVF + \xi_{10} IF + \xi_{11} InF + \xi_{12} SC) \\ 0 \le \xi_i \le 1, i = \overline{1,12} \\ \sum_{i=1}^{12} \xi_i = 1 \\ 0 \le GF \le 1; 0 \le PRF \le 3; -2 \le EF \le 1; -3 \le PPF \le 12; 0 \le APF \le 6; -3 \le SF \le 29; \\ 0 \le FEF \le 1; -2 \le IfF \le 13; 0 \le UVF \le 1; 0 \le IF \le 2; 0 \le InF \le 3; 0 \le SC \le 1 \end{cases}$$

where *KS* is the competitiveness; *GF* is the geographic factor; PRF is the natural resource factor; *EF* is the ecological factor; *PPF* is the industrial production factor; *APF* is the agrarian business factor; *SF* is the social factor; *FEF* is the financial and economic factor; *IfF* is the infrastructural factor; *UVF* is factor that shows the level of engagement with superior public authorities; *IF* – innovative factor; *InF* is the investment factor; *SC* is the factor of municipality entering into Industry 5.0; ξ is the coefficient of factor significance (is defined by the expert opinions).

In the process of research, 12 factors of competitiveness were identified that are characteristic of the current level of socio-economic development of territories. Each of the factors has its own significance, which determines its weight, contribution to the final value of competitiveness. The weights of the factors are different for territories of different types, which reflect the differentiation in the current state of the development process.

Since access to understanding and visibility of information are important for making managerial decisions, a multidimensional visualization of the analysis results and assessment of the state of competitiveness is proposed. By choosing the dimensionality of space, it is possible to illustrate the level and contribution of certain competitiveness factors for management purposes [3, 4].

The entry factor of municipal entity in Industry 5.0 is calculated as the average of the sum of indicators of manufacturability, internetization, new technology introduction, innovation, intellectualization, financial independence of the budget and energy efficiency. Consider the readiness indicators of the municipal entity for the introduction of new technologies in the transition to the technological structure of Industry 5.0. They include the following indicators [3].

The manufacturability indicator is calculated according to the following dependence:

$$T1 = (n1 + n2 + n3)/ m,$$

where n1 is the number of enterprises upgraded no later than 2012, n2 is the number of enterprises upgraded no later than 2015, n3 is the number of enterprises upgraded no later than 2017, m is the total number of enterprises in municipal entity.

The internetization indicator is related by the following expression:

$T2 = K / 100\%$, where K is the internet coverage indicator in the municipality entity.

New technology introduction indicator is calculated by the following dependence:

$$T3 = (s1 + s2 + s3)/ L,$$

where s1 is the number of media resources for 3 years, s2 is the number of realized individual entertainment for 3 years, s3 is the number of created social enterprises for 3 years, L is the number of created business objects for 3 years.

The innovation indicator of urban infrastructure can be calculated as follows:

$$T4 = q1 / Q + x1 / X,$$

where q1 is the scope of work performed to replace innovation infrastructure facilities, Q is the scope of work, necessary to replace all infrastructure, x1 is the volume of innovation products in techno parks and etc., X is the volume of production at all enterprises in the municipal entities.

The urbanization intellectualization indicator is related to the following dependence:

$$T5 = (g1 + g2 + g3)/ G,$$

where g1 is the number of innovation products, g2 is the number of patents, g3 is the number of grants, G is the total of all new products.

The indicator of intellectualization is associated with innovative products, patents, scientific grants. Significant developments are being carried out in Samara in the field of implementing information technologies in the field of technological production, for example, in the field of hot forging [4-6], milling on CNC machines [7], additive technologies on a 3D printer [8, 9]. Many new developments also relate to the field of creating new materials [10-12] and other technological processes [13-15], in addition to automation of technological production, there are scientific developments in the field of production organization [16] and economic research [17].

The indicator of financial independence of the budget is expressed as follows:

$$T6 = d1 / d2,$$

where d1 is the municipal debt, d2 is the budget income.

The energy efficiency indicator of the urban environment can be calculated as follows:

$$T7 = y1/ Y + c1/ C,$$

where y1 is the volume of energy consumed by enterprises in the municipal entity, Y is the volume of production using energy resources; c1 is the cost of energy consumed by the population, C is the population of municipal entity [18].

TABLE I. RESTRICTIONS ON INDICATORS OF MUNICIPALITY ENTERING INTO INDUSTRY 5.0

Indicator	Ready for implementation	Medium readiness	Satisfactory readiness	Is not ready for implementation
T1	1	0.6	0.3	0.2
T2	1	0.4	0.4	0.3
T3	1	0.5	0.3	0.3
T4	1	0.5	0.3	0.3
T5	1	0.8	0.4	0.2
T6 (-)	1	0.5	0.4	0.3
T7	1	0.6	0.4	0.35
Total	6	3.7	2.5	1.95

TABLE II. ESTIMATED RATIOS OF MUNICIPALITY ENTERING INTO INDUSTRY 5.0

Industry 5.0	Samara	Ulyanovsk
Manufacturability	0.59	0.47
Intellectualization	0.82	1
Financial independence	-0.105	-0.038
Internetization	0.55	0.6
Innovation	0.7	0.87
Energy efficiency	0.43	0.34
New technology introduction	0.4975	0.5403
Total	3.4825	3.7823

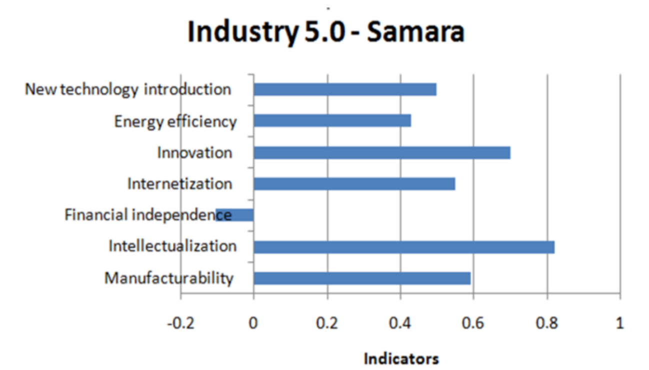

Fig. 2. Indicators of municipality readiness for Industry 5.0 implementation for Samara city.

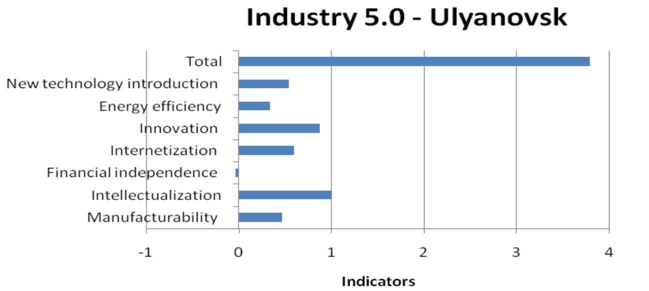

Fig. 3. Indicators of municipality readiness for Industry 5.0 implementation for Ulyanovsk city.

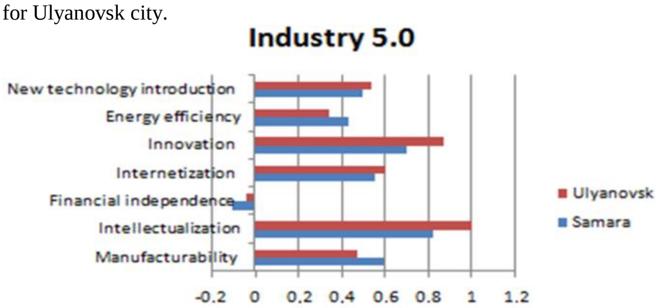

Fig. 4. Combined indicators of municipality readiness for Industry 5.0 implementation for Samara and Ulyanovsk.

The values of the restrictions on readiness indicators for the implementation of Industry 5.0 in the municipal entities are shown in Table 1.

III. The Results of Experimental Studies

After data calculating of indicators for the municipalities of Samara and Ulyanovsk, the following data were obtained (shown in table 2). After assessing the readiness of the municipalities to enter Industry 5.0, it was found that municipality of Samara, has “medium readiness for the implementation of Industry 5.0”, and the city of Ulyanovsk is classified as “ready for the introduction of Industry 5.0” - the values are 3.48 and 3.78 (Fig . 2 and Fig. 3). A joint indicator chart of these cities is shown in Figure 4.

The presented calculation models allow us to determine not only the readiness of the municipal entities to implement Industry 5.0 technologies, but also to identify segments that slow down the process of transition to a higher level group or to a new technological structure. So, the city of Samara, is in the group of “medium readiness to introduce Industry 5.0 technologies” due to the high financial dependence of the city budget (T6), the insufficient implementation of new technologies (T3) and the insufficient energy efficiency of the urban environment (T7). To solve the above problems, the implementation of effective management decisions is required, which will enable the Samara municipality to move to the group of “ready for the introduction of a new technological structure Industry 5.0”.

To calculate the coefficient of factor significance in the regression model of competitiveness according to the frequency analysis, we use the formula:

$$\xi_i = x_{spi} / n,$$

where x_{spi} is the average value of group of factors, n is the number of factor groups in the research in question.

Let us determine the coefficients in the mathematical model of competitiveness according to the frequency analysis according to the formula:

$$\xi_i = y_{spi} / m,$$

where y_{spi} -is the average value of specific factor, m =5 is the maximum of importance degree of a factor. The average values of groups of factors for competitiveness are shown in the table 3.

From here let us determine the values of the significance coefficient of factors: $\xi 1$ = 9,13/12 =0,76; $\xi 2$ = 0,61; $\xi 3$ = 0,79; $\xi 4$ = 0,29; $\xi 5$ = 0,81; $\xi 6$ = 0,3; $\xi 7$ = 0,4; $\xi 8$ = 0,42; $\xi 9$ = 0,63; $\xi 10$ = 0,42; $\xi 11$= 0,38; $\xi 12$= 0,68. As a result, the competitiveness model for the municipality will take the following form:

$$KS = (0{,}76GF + 0{,}61PRF + 0{,}79EF + 0{,}29PPF + 0{,}81APF + 0{,}4FEF + 0{,}42IfF + 0{,}63UVF + 0{,}42IF + 0{,}38InF + 0{,}68SC).$$

TABLE III. COMPONENT TRANSFORMATION MATRIX

	N	Mean
1_1. Factor rank (geographic)	15	9.13
1_2. Factor rank (natural resources)	15	7.33
1_3. Factor rank (ecological)	14	9.50
1_4. Factor rank (industrial production)	15	3.47
1_5. Factor rank (agrarian business)	15	9.73
1_6. Factor rank (social)	15	3.60
1_7. Factor rank (financial and economic)	15	4.80
1_8. Factor rank (infrastructural)	15	5.07
1_9. Factor rank (engagement with public authorities)	15	7.60
1_10.Ранг фактора (innovative)	15	5.07
1_11. Factor rank (investment)	15	4.53
1_12. Factor rank (municipality entering Industry 5.0)	15	8.20
Valid N (skipped)	14	

IV. Conclusion

In further research, large volumes of streaming data in real time should be used to develop a model for predicting the competitiveness of territories. The purpose of this study is to develop models and methods for making managerial decisions based on forecasting the competitiveness of territories. The objectives of this study include: determining competitiveness factors, developing a model of territorial competitiveness using expert assessments, generating information on experts using BIG DATA technology. The research results include models for making managerial decisions on the competitiveness of territories using expert assessments using BIG DATA technology [19]. Practical results include improving the quality and timeliness of decision-making on territorial management based on a model for predicting the development of the region.

ACKNOWLEDGMENT

This study was carried out in the framework of the Russian Foundation for Basic Research (RFBR) grant 13-06-00085 “Methodology of managing the competitiveness of territories in the process of innovative development of socio-economic systems”. The authors are grateful to the Ministry of Education and Science of the Samara Oblast for their support in conducting these studies.

REFERENCES

[1] Society 5.0 – Japanese approach to digitizing of economic growth [Online]. URL: mitsubishielectric.ru.

[2] L.I. Lopatnikova, “Economics and Mathematics Dictionary: Dictionary of Modern Economic Science,” M.: Delo, 2003, 520 p.

[3] O.O Komarevtseva, “Simulation of data for determining the readiness of municipalities to implement smart city technologies,” DAMDID/RCDL, pp. 167-177, 2017.

[4] I.N. Khaimovich, “Computer-aided design of blank forging production facilities for aircraft engine compressor blades,” Russian Aeronautics, vol. 57, no. 2, pp. 169-174, 2014.

[5] I.N. Khaimovich and A.I. Khaimovich, “Computer-aided engineering of the process of injection molding articles made of composite materials,” Key Engineering Materials, vol. 746, pp. 269-274, 2017.

[6] A.I. Khaimovich and I.N. Khaimovich,” Methods and Algorithms for Computer-aided Engineering of Die Tooling of Compressor Blades from Titanium Alloy,” IOP Conference Series: Materials Science and Engineering, vol. 302, no. 1, 012062, 2018.

[7] O.S. Surkov, A.I. Khaimovich and I.N. Khaimovich, “Practice in the application of specialized technologic process patterns of 5-axis machining operation of blade rings of blisks,” Russian Aeronautics, vol. 59, no. 1, pp. 112-117, 2016.

[8] V.G. Smelov, A.V. Sotov and A.V. Agapovichev, “Study of structures and mechanical properties of products manufactured via selective laser sintering of 316L steel powder,” Chernye Metally, vol. 9, pp. 61-65, 2016.

[9] A.V. Agapovichev, A.V. Sotov, V.V. Kokareva, V.G. Smelov and R.R. Kyarimov, “Study of the structure and mechanical characteristics of samples obtained by selective laser melting technology from VT6 alloy metal powder,” Nanomechanics Science and Technology, vol. 8, no. 4, pp. 323-330, 2017.

[10] F.V. Grechnikov, Ya.A. Erisov and S.E. Alexandrov, “Effect of anisotropic yield criterion on the springback in plane strain pure bending,” CEUR Workshop Proceedings, vol. 1638, pp. 569-577, 2016.

[11] F.V. Grechnikov, Y.A. Erisov, S.V. Surudin and V.V. Tereshchenko, “Theoretical and experimental study of plastic anisotropy of Al-1Mn alloy taking into account the crystallographic orientation of the structure,” Materials Physics and Mechanics, vol. 40, no. 2, pp. 274-284, 2018.

[12] F.V. Grechnikov and Y.A. Erisov, “Virtual material model with the given crystallographic orientation of the structure,” Key Engineering Materials, vol. 684, pp. 134-142, 2016.

[13] A.V. Nikonorov, M.V. Petrov, S.A. Bibikov, V.V. Kutikova, A.A. Morozov and N.L. Kazanskiy, “Image restoration in diffractive optical systems using deep learning and deconvolution,” Computer Optics, vol. 41, no. 6, pp. 875-887, 2017. DOI: 10.18287/2412-6179-2017-41-6-875-887.

[14] N.A. Smelkina, R.N. Kosarev, A.V. Nikonorov, I.M. Bairikov, K.N. Ryabov, E.V. Avdeev and N.L. Kazanskiy, “Reconstruction of anatomical structures using statistical shape modeling,” Computer Optics, vol. 41, no. 6, pp. 897-904, 2017. DOI: 10.18287/2412-6179-2017-41-6-897-904.

[15] E.G. Demyanenko and I.P. Popov, “Boundaries of the applicability of the flanging process for obtaining thin-walled conical shells,” News of Higher Educational Institutions. Aircraft Engineering, vol. 4, pp. 60-62, 2012.

[16] M.A. Frolov and I.N. Haimovich, “Improvement of Technological Process of Multiproduct Production on the Bases of Simulation Modeling of Production Unit,” Key engineering materials, vol. 684, pp. 487-507, 2016.

[17] M.I. Geras'kin and A.G. Chkhartishvili, “Analysis of Game-Theoretic Models of an Oligopoly Market under Constrains on the Capacity and Competitiveness of Agents,” Automation and Remote Control, vol. 78, no. 11, pp. 2025-2038, 2017.

[18] V.M. Ramzaev, I.N. Khaimovich and P.V. Chumak, “Models for forecasting the competitive growth of enterprises due to energy modernization,” Studies on Russian Economic Development, vol. 26, no. 1, pp. 49-54, 2015.

[19] V.M. Ramzaev, I.N. Khaimovich and V.G. Chumak, “Big data analysis for demand segmentation of small business services by activity in region,” CEUR Workshop Proceedings, vol. 1903, pp. 48-53, 2017.