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Technique for Assessing the Digital Divide Based on the Engagement Index on VKontakte Social Media Platform

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Abstract. In modern society, social media have become one of the main sources of information. Many local governments began working with the population on social media platforms after this requirement was legally established in December 2022. Without involving the population in the official information agenda, it is impossible to engage them in a constructive dialogue to identify and solve local problems. Due to the difference in experience, Internet communication skills, and time, municipalities cope with this task with varying degrees of success, which indicates a digital divide. The aim of the research is to develop methods for measuring the digital divide in the work of local government on social media using VKontakte social media platform as an example. To do this, the official pages of municipalities in VKontakte were identified, engagement indices were calculated, the influence of socio-economic and other factors on their values was accessed using regression models, and municipal structures were grouped according to the engagement index using cluster analysis. The study covers 615 settlements, 198 municipalities and okrugs of the Northwestern Federal District in the period from 2017 to 2022. The findings indicate that the use of the engagement index to measure the digital divide is practical only within reference groups. It is proved that the value of the engagement index is negatively affected by the number of population, community longevity, proximity to the regional center, and average wage. It is determined that the largest digital divide is typical for a group of settlements with a population of less than 4.1 thousand people. The proposed methods for assessing the digital divide can be used by communications policy administration to evaluate the performance of local governments on social media, build a scaled system of targets, search for best practices and prevent artificial overestimating of engagement levels.

Key words: social media, VKontakte, engagement index, digital divide, municipalities, settlements.

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Introduction

Until recently, municipal entities in Russia created official accounts (communities or pages) on social media as needed. Due to the high social site activity of citizens on local problems, governments had to register their official communities in order to intercept the information agenda from spontaneously created territorial public pages (Dement'eva, 2021) and reframe the dialogue with the population. The increased importance of social media while communicating with citizens has made governments institutionalize relations with the owners of these resources. Since December 1, 2022, an official social media page (government's page) has become mandatory for municipal entities. For these purposes, it is allowed using only the VKontakte (VK) and Odnoklassniki social networks, since they are in Russian jurisdiction. A special mark "Government organization" has appeared on these platforms to identify governments' pages.

The adoption of social media by governments around the world (Hofmann et al., 2013; Larsson, 2013; Lovari, Parisi, 2015) was a response to the request of millions of citizens for whom social networks and messengers have become a familiar and convenient way of communication. Initially, social media were not intended for public authorities' needs, but their use by local governments directly revealed a number of advantages over traditional methods of communication: low cost; rapid widespread adoption; ease of use and transfer rate (Reddick, Norris, 2013). In addition, governments' pages provoke discussions and unite citizens to solve

local problems (Dement'eva, 2021). However, there are some disadvantages in interaction with citizens via social media. First, public employees become available for inquiries around the clock, and citizens expect them to respond quickly (Zavattaro, Sementelli, 2014). Second, the inherent imaginary anonymity of social media causes inhabitants' rudeness toward the authorities and neighbors, which acts as a strong demotivating factor for social media administration employees. Perhaps the main problem identified in the early stages of the adoption of social media was that local governments were not aware of their time and resources expenditure while using social media. They did not know their actual audience, members of their organization who were responsible for communication process, how and when they should respond, and what impact their social media communication had on citizens (Kavanaugh et al., 2012).

The listed problems were also faced by domestic government bodies, who were forced to integrate social media into their working processes. Although some municipal governments' pages had existed for more than ten years by December 2022, a significant number of municipalities had no such experience or it was very little. In this regard, E.N. Rychikhina and A.M. Borovikova indicate such problems of domestic governments' pages as a low level of citizen engagement, plagiarism and little feedback (Rychikhina, Borovikova, 2023). There were no uniform rules or instructions on how to manage such a page, and the guidelines of the Regional Management Center[1] on filling the government's page with information appeared only in the spring of 2024[2]. It should be highlighted that workload of the Regional Management Center's specialists became overwhelming, since not only municipalities, but many subordinate public sector organizations had to create governments' pages. And while the ones of municipal districts and okrugs have been under the supervision of Regional Management Centers since 2020 and their management strategies have been more or less worked out, such systematic work has not been carried out for settlements. As a result, different experience in organizing work on social networks causes a digital divide in this area.

Due to mandatory presence on social media, an increase in the digital divide will reduce the overall efficiency of lagging local governments, as they are often not able to meet the level of the most experienced colleagues on their own and have to spend more time solving the same task. Another manifestation of this problem is the formal attitude toward the management of governments' pages in order to save time, when the main thing is to achieve certain performance targets, and the ways to do that become unimportant. This approach does not contribute to people's trust in authorities, nor to the desire to communicate and solve local problems collaboratively with government bodies. Another important issue that should be worked out to overcome the digital divide is the establishment of criteria for evaluating the effectiveness of the municipality on social media. Intuitively, it is impossible to compare within a single scale, on the one hand, a regional center, where the local administration can number several hundred people and the management of a government's page is under the supervision of an entire department, and, on the other hand, a rural settlement, where its head is the only employee of the administration who solves all issues. In these municipal entities, the number of the happening events and related social media messages will be different. Accordingly, public sector organizations responsible for information policy should set standards and rules for

[1] The Regional Management Center exists in every constituent territory of the Russian Federation to track public complaints on social media and promptly communicate the information received to relevant departments and responsible government bodies.

[2] They provide practice and examples only from large municipal entities.

the management of municipal governments' pages respectively to the current practice and objective capabilities of municipalities to involve the population in online communication. In this regard, research works aimed at finding ways to reduce the digital divide by introducing effective type-of-municipality-oriented programs of social media presence, are gaining high relevance and great practical value. Therefore, the aim of the article is to develop methods for measuring the digital divide in the work of municipal entities on social media using the VK social network as an example. To achieve it, the following tasks should be solved: 1) determine citizen engagement on governments' pages; 2) identify socio-economic indicators of municipalities that affect the engagement levels; 3) group municipalities by identified factors and rank engagement by groups; 4) determine the parameters of the digital divide within the groups and criteria that should be used to bridge it.

Literature review

Social media collect a variety of quantitative metrics that capture user activity. By combining these metrics, the managers of social media receive information about the engagement of their users. Depending on the platform (Triantafillidou et al., 2016; Trunfio, Rossi, 2021) and the tasks (Larsson, 2013; Agostino, Arnaboldi, 2016; Ravenda et al., 2022), the combination of metrics used to assess engagement varies. The standard available indicators are: 1) the number of *posts*; 2) the number of *like*s; 3) the number of comments; 4) the number of reposts; 5) the number of comments' likes *(com_ likes)*; 6) the number of *views*; 7) the number of followers *(fans)*.

In foreign works (Agostino, Arnaboldi, 2016; Levkov, 2017; Bonsón et al., 2019; Silva et al., 2019), a three-part index proposed by E. Bonsón and M. Ratkai (Bonsón, Ratkai, 2013) was most widely used to assess public engagement on the official government bodies' pages on social media (formula 1). This index shows the average number of actions per post on the community's wall per thousand followers.

$$INDEX_{BR} = \frac{(likes + comments + reposts)}{posts \times fans} \times 1\,000 \quad (1)$$

The undoubted advantage of this index is that it takes into account both the publication frequency of the settlement government *(posts)* and audience coverage *(fans)*, because both of these factors affect the number of comments, likes and reposts. In some works (Haro-de-Rosario et al., 2018; Gálvez-Rodríguez et al., 2018), as an improvement of this index, it is proposed to use the ratio of the number of followers to the number of municipality's population instead of the number of followers. In our opinion, it complicates index interpretation and further analysis of the established interaction practice effectiveness, since, other things being equal, communities with a small proportion of followers relative to the population will show higher engagement.

In domestic studies on this topic, engagement indices were used to audit the communication of the heads of Russian regions (Filatova, 2020) and evaluate the effectiveness of the official VK pages of the following cities: 1) seven administrative centers of the regions of the Central Federal District (Roslyakova, 2023); 2) 170 cities with a population over 100 thousand people[3] (Petrov, Shitova, 2023). And while M.V. Roslyakova in her work (Roslyakova, 2023) stuck to E. Bonsón's approach to assessing engagement, O.G. Filatova developed her own engagement index (Filatova, 2020):

$$INDEX_F = \frac{posts}{\left(fans/\left(\overline{likes} + \overline{comments} + \overline{reposts}\right)\right)}, \quad (2)$$

where $\overline{likes}$ is the average value of likes per post; $\overline{comments}$ is the average value of comments per post; $\overline{reposts}$ is the average value of reposts per post.

[3] The ER_Post indicator is used to assess engagement. Its calculation formula is not given in the work.

However, broadly speaking, formula (2) can be simplified and reduced to the sum of the number of comments, likes and reposts per follower.

In these studies, only spatial sampling was used to calculate the engagement index. In similar works evaluating the activity of local administrations on social media (Guillamón et al., 2016; Faber et al., 2020; Stone et al., 2022) or studying factors contributing to the creation of local governments' official accounts (Triantafillidou et al., 2016; Stone, Can, 2021; Bhatia, Mabillard, 2022), spatial sampling is also used. Only a few works can be noted (Mabillard et al., 2024; Karamagioli et al., 2022; Ravenda et al., 2022), monitoring these processes' rate.

To explain the data received on public engagement, local government activity and official page presence in one or more social media, the researchers studied the effects of many factors. First of all, the characteristics of the population were considered: number; age (average age (Ravenda et al., 2022), median age (Mabillard et al., 2024)); percentage of people in the age group 20–65 and percentage of people in the age group 65+ (Faber et al., 2020); percentage of people with higher education (Faber et al., 2020; Stone et al., 2022); as well as their income level (median income (Stone, Can, 2021; Mabillard et al., 2024), income per capita (Guillamón et al., 2016; Gálvez-Rodríguez et al., 2018; Ravenda et al., 2022), per capita purchasing power (Silva et al., 2019)). Research works show that the size of the population positively influences the activity of local governments on social media (Guillamón et al., 2016; Silva et al., 2019), and negatively influences citizen engagement (Silva et al., 2019). The high intensity of events typical for densely populated municipalities leads to a large number of posts that residents are unable to perceive due to information overload (Agostino, Arnaboldi, 2016). In some studies (Stone et al., 2022), population income factor is considered insignificant. In a number of works, the effect of this indicator on the activity of municipalities, measured by the number of posts, is both negative (Guillamón et al., 2016), which does not align with the results of previous studies, and positive (Silva et al., 2019). Perhaps, there is an influence of national characteristics. If richer and more prosperous municipalities publish posts more often, they will receive fewer likes due to information overload, and engagement index will decrease.

In addition to the characteristics of the population, a range of financial indicators of the municipality was assessed: city income (Bhatia, Mabillard, 2022); financial autonomy (Stone, Can, 2021; Ravenda et al., 2022); economic capacity – percentage of tax revenues in total revenue (Silva et al., 2019); financial sustainability; proper revenues and debt level (Guillamón et al., 2016). Much attention was paid to the political component in the works: voter turnout (Triantafillidou et al., 2016; Silva et al., 2019; Faber et al., 2020); ideological (left-right) orientation (Larsson, 2013; Faber et al., 2020); margin of victory – difference in percentage points between 1st and 2nd place parties (Silva et al., 2019; Ravenda et al., 2022); personal characteristics of the mayor: gender (Guillamón et al., 2016; Mabillard et al., 2024), ideological positioning (Silva et al., 2019), age and education (Ravenda et al., 2022). Based on data on municipalities in Portugal, it was shown that the younger the mayor, the higher his or her activity in social media (Silva et al., 2019). Age, gender and education are significant factors determining the publication frequency on specific topics (Ravenda et al., 2022). In other research works on the activity of local governments, the gender and education of the mayor were not statistically significant (Guillamón et al., 2016;

Mabillard et al., 2024). Russian studies of the VK audience indicate that women are more active (for example, they click the "like" button more often[4]) than men (Kornienko et al., 2021). Therefore, it can be expected that in municipalities headed by women the number of posts will be higher.

Metrics characterizing the level of Internet usage are rare in studies. In some works (Triantafyllidou et al., 2016; Bonsón et al., 2017), use of Internet and e-government services are considered. In the work (Bonsón et al., 2017), social media use by citizens is taken into account. B. Faber, T. Budding and R. Gradus used an indicator of the number of registered ICT businesses per 1000 inhabitants (Faber et al., 2020), and A.O. Larsson – broadband reach (Larsson, 2013). Only two studies assessed the relationship between the citizen engagement and the work experience of local government on social media. On the one hand, the longevity on the platform does not lead to the increased number of comments from citizens (Gálvez-Rodríguez et al., 2018), on the other hand, it has a positive influence on the number of followers and posts per month (Mabillard et al., 2024).

A review of the existing research literature on the use of social media for the needs of local governments has shown that no studies have been conducted to assess the engagement rate. In addition, researchers usually focused on some particular characteristics of municipalities, setting low and high values of the group by population. Full-design studies of municipalities (Silva et al., 2019) are quite rare. In domestic practice, only cities were considered as the object of research (Roslyakova, 2023; Petrov, Shitova, 2023), and the assessment of the relationship between socio-economic factors and public engagement was not carried out. Our study is remarkable for taking into account almost one hundred percent of Russian municipalities throughout the entire federal district[5], both at the municipal district and settlement levels, as well as an assessment of the impact of socio-economic indicators of the municipality and the personal characteristics of its head on public engagement on the government's page. In addition, the engagement itself is presented as dynamic over six years[6]. We have not been able to find studies that use social media metrics to measure the digital divide in municipal and public governance. All of the above forms the novelty of the presented research.

Data and methods

In general, the research algorithm is a series of milestones: 1) list governments' pages in VK; 2) collect VK statistics for governments' pages; 3) calculate engagement indices; 4) collect municipalities' indicators that potentially affect the engagement index; 5) check the significance of these indicators using regression analysis methods; 6) arrange municipalities in groups according to significant indicators using the cluster analysis method; 7) classify municipalities within clusters into quartiles according to the engagement index; 8) determine target engagement index to identify reference municipalities in order to capitalize on the successful experience of social media management.

Most of the local governments of the North-western Federal District (NWFD) are present only on one domestic social network – VK. Odnoklassniki is used as a duplicate page: this practice is typical for the municipal district (okrug) level and is almost not found at the settlement level. Therefore, the object of the research is

[4] To likes all ages yield surrender. Available at: https://vk.company/ru/press/releases/11417/ (accessed: October 10, 2023).

[5] Excluding the federal city Saint Petersburg.

[6] The maximum possible period for which calculations can be carried out according to the methods used.

Northwestern Federal District governments' pages with the mark "Government organization" on VK. As a result of search queries on VK and Yandex[7], 198 governments' pages of municipal districts (okrugs) and urban okrugs and 615 pages of settlements (territorial subdivisions and administrations[8]) were selected. The rest of the municipal entities of the NWFD[9] either did not have official pages, or had not yet received the "Government organization" mark. The time framework of the research (2017–2022) is determined by the availability of data necessary to calculate the engagement index.

Statistics on governments' pages were obtained using the TargetHunter service: *posts* and *comments* on them were collected. Uploaded *posts* are represented by a table with a list of them, the time and date of their publication, the number of *views*, the number of *likes*, the number of reposts. There is a similar table for *comments*. The indicator "number of comments' likes" (*com_likes*) was taken from it. Among these indicators, only the number of *views* has time limits for collection: this indicator appeared only in 2017. In total, over 1.82 million posts and 1.64 million comments were collected during the research period.

To determine the engagement, the original index developed by E. Bonsón and M. Ratkai (formula 1) is used as a basis. For our calculations, it was upgraded: instead of the number of followers (*fans*), the number of *views* (formula 3) was used. There are several reasons for it. First, the possibilities of retrospectively collecting the number of followers are significantly limited[10]. Second, the number of followers is a more significant metric for closed communities, where only following participants see posts and can be active, while in open communities, which include governments' pages, all VK users can actively participate. As a result, the upgraded index shows the average number of actions per post per 100,000 views.

$$INDEX_v = \frac{(likes + comments + com_{likes} + reposts)}{posts \times views} \times 100\,000 \quad (3)$$

In our opinion, when measuring the digital divide, it is necessary to compare municipalities within the "weight categories", which are determined by the level of their socio-economic development. There is no doubt that a large set of variables can influence citizen engagement. Unlike subject matter of posts and personal characteristics of the head of the municipality, the indicators of socio-economic development cannot be changed quickly and radically. Our work is characterized by studying digital divide and factors influencing it both at the municipal district (okrug) and settlement levels. Since the development of settlements is poorly represented in official statistics, we had to narrow down the list of socio-economic indicators. For the selected years, only the population (*Pop*) and average wage (*Wage*)[11] are available to us. The latest data on local budget revenues and expenditures were published only for 2020, so we

[7] For example, "government of settlement X in VK", "official community of settlement X in VK".

[8] Territorial subdivisions or administrations are outgrowths of the settlements included in the municipal districts that were eliminated during the transformation of municipal districts into municipal okrugs.

[9] The municipalities of Saint Petersburg were not considered.

[10] The exact number can only be obtained at the date of data collection itself. The TargetHunter service, which has been used to upload statistical data from VK since 2017, has an option to collect new followers who joined the community over a definite time period, but there is no option to collect users who unfollowed the community. Without this indicator, an attempt to count the number of followers in previous years seems futile. Preliminary calculations have shown that the cumulative annualized number of new followers in the community may exceed their actual total number. In addition, though it is possible to approximately calculate the number of followers for communities that appeared between 2017 and 2022 using ratio of those who joined the community in a particular year, this method is not applicable for communities created before 2017.

[11] Both indicators are taken from the Rosstat database "Indicators of municipalities".

did not consider the indicators related to financial autonomy. To calculate the average wage at the settlement level, the calculation method based on the 5-PIT (personal income tax) form (Prokopyev, 2023) was used.

The number of days of the official community's presence (*Days*), the proximity of the municipality to the regional center (*Road*), and the characteristics of the head of the municipality are considered as control variables. The number of days of the government's page presence was determined as the difference between the publication date of the first post and December 31 of each year of the research period[12]. This indicator characterizes the experience of the local government in social media. The proximity of the municipality to the regional center was measured by the shortest distance along the highways that was determined using the Yandex Maps service. This parameter is not found in foreign research works, but in Russian circumstances it can affect citizen engagement for a number of reasons, including the mobile Internet speed (Mikhailova, Khvalei, 2023). Personal characteristics of municipal heads are collected according to the data of the Central Election Commission of the Russian Federation[13]. Based on them, the following variables were formed: *Age*; gender (*Male*); education (*Edu*); location (*Loc*); participation in elections as a self-nominated candidate (*Self*). The influence of the last two factors on the engagement has not been tested in the research literature.

Multiple linear regression was used to test the influence of factors on the engagement index. Previously, the dependent variable ($INDEX_v$) and independent variables (factors) were plotted against each other as scatter diagrams, and after their analysis a log-transformation was conducted of some variables and some were excluded. Based on the adjusted data, a correlation matrix was built to filter out factors in order to avoid multicollinearity. Due to the significant difference in the number of observations per year14, the models were built using mainly spatial sampling. Evaluations and model validation were carried out in the R software environment using basic feature set and special packages (lmtest, car and clubSandwich).

Next, municipal entities were divided into clusters using hierarchical clustering by nearest neighbors[15] based on statistically significant socio-economic variables in the models. Each of the generated clusters is divided into quartiles according to the value of the engagement index. The high and low values of quartile groups were analyzed to create a scale that determines the digital divide based on the engagement index.

Results

According to the results of calculations of engagement indices for governments' pages (*Tab. 1, 2*), several patterns can be identified.

First, the values of the engagement indices for municipalities turned out to be lower than for settlements. Settlement communities are exceeded by municipality communities in the absolute number of followers and, most importantly, cannot compete with them on the number of

[12] If the community appeared during the research period, the calculation was carried out only from the year of its appearance.

[13] The data collection algorithm is presented in detail in the work: Gubina O.V., Prokopyev E.A., Shlapeko E.A., Kurilo A.E. (2023). Implementation of social media in the work of local administrations: collecting data to assess the influence of the head factor. *Trudy III Granbergovskoi konferentsii=Proceedings of III Granberg Conference*, 117–122 (in Russian).

[14] The number of municipal districts and okrugs' pages at the end of 2017 was 93, and settlements' pages – only 61. By the end of 2022, 198 municipal districts and okrugs and 615 settlements had pages.

[15] Basic feature set of R software environment was used: *hclust(... , method = "ward.D2")* function.

events happening. Consequently, there are much fewer posts published in these communities, which makes them visible to visitors for longer. Second, communities that have been present for less than a year and/or publish few posts are characterized by high values of the engagement index[16] (*Fig. 1*). This can be explained by the novelty effect. Initially, the government's page accumulates the most active followers who respond to each post. As the audience and the number of posts increase, this audience's activity may not be enough to maintain a high level of engagement. The cessation of the creation of new communities reduces the statistical indicators of the engagement index (see Tab. 1). Therefore, in order to make regression models' evaluations, it was decided to exclude communities that have been present for less than a year and ones with low publication frequency. For municipality communities, this indicator was less than 52 posts, and for settlement communities – less than 26 posts.

According to spatial regression models' evaluations (*Tab. 3*) it was possible to confirm the impact on the municipal (okrug) engagement index by the population, the number of days of the community's presence, the distance along the highways, the average wage and the participation of the head of the municipality in elections as a self-nominated candidate. All these factors reduce the

Table 1. Municipal districts and okrugs' engagement index rate

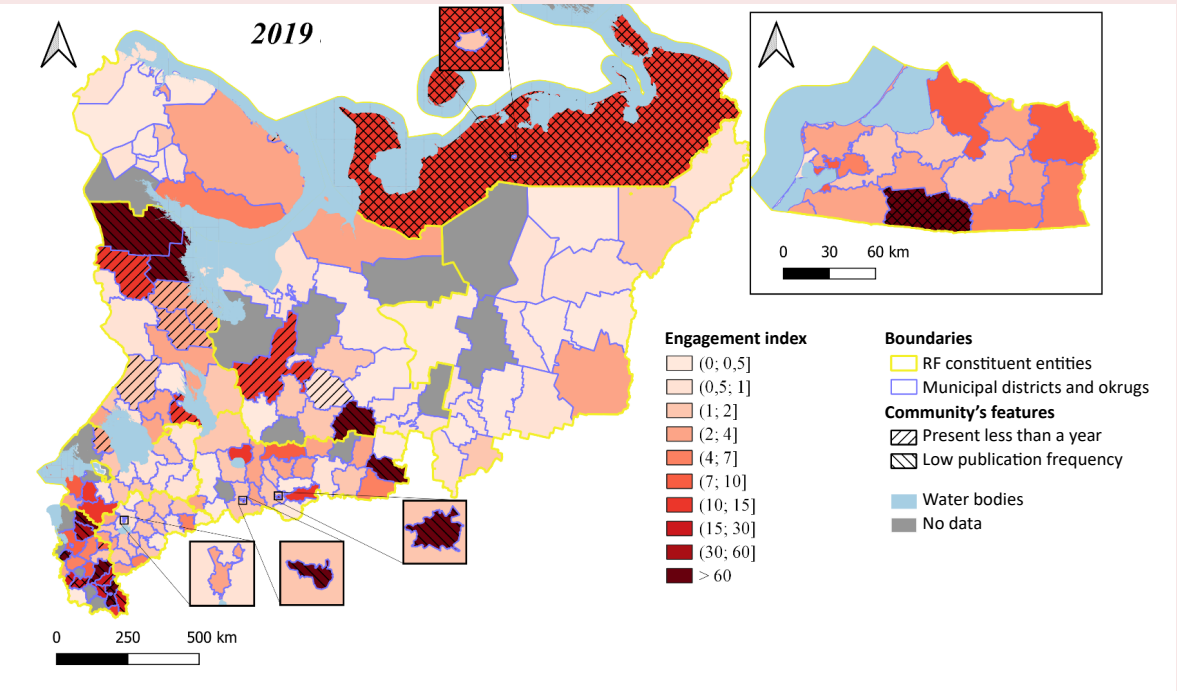
Year	Number of communities		Min.	Max.	Mean	Median	Standard deviation
	Total	Present less than a year, among total					
2017	93	32	0.16	400.64	10.79	1.47	46.36
2018	160	59	0.00	4761.90	108.79	1.49	572.09
2019	181	18	0.14	2811.07	42.23	1.82	255.84
2020	193	10	0.00	24.69	2.31	1.19	3.20
2021	198	4	0.21	46.51	2.38	1.51	3.80
2022	198	0	0.16	7.48	1.44	1.05	1.18
Source: own compilation based on VK data.							

Table 2. Settlements' engagement index rate

Year	Number of communities		Min.	Max.	Mean	Median	Standard deviation
	Total	Present less than a year, among total					
2017	61	20	0.00	294.57	16.78	5.89	41.20
2018	129	65	0.00	2597.40	53.97	6.86	244.11
2019	191	60	0.00	1253.13	45.27	7.68	158.88
2020	258	72	0.00	7692.31	77.41	6.59	529.86
2021	374	110	0.00	3846.15	55.10	9.84	273.41
2022	615	232	0.00	9329.71	137.09	12.49	595.73
Source: own compilation based on VK data.							

[16] There are exceptions. Our sample included several communities that were created at the end of the year and managed to publish only a few posts. There was not a single user reaction to the posts in these communities, and therefore, the engagement index for the current year is zero. It is worth noting that a similar result can be obtained in communities that have been present for more than a year if posts were deleted.

Figure 1. Municipal districts and okrugs' engagement index in 2019



Source: own compilation based on VK data.

engagement. However, the influence of the self-nomination factor is unstable: it was significant only in 2018 and 2022, while the average wage with an increase in the number of observations in the last three years has constantly been significant. The other variables being tested turned out to be statistically insignificant.

The data on the relationship between citizen engagement, average wage and government's page longevity supports conclusions of the research on Belgian municipalities with a population over 10 thousand people (Mabillard et al., 2024). It turns out that the poorer the population, the more they express their dissatisfaction with the work of the authorities on social media[17]. The influence of population on citizen engagement does not contradict foreign studies (Agostino, Arnaboldi, 2016; Silva et al., 2019). The negative impact of distance along the highways can be explained by several reasons. First, mobile Internet becomes less accessible with distance from the center. Second, citizens of municipalities close to the regional capital have more in common to compare changes, in addition, part of the center residents own dachas in neighboring municipalities and participate in discussions of problems with local authorities. Third, due to the concentration of the population in the regional capital, the total number of active citizens in it is greater; therefore, it is more likely that information about the problem in neighboring municipalities will cause a wide public response, while residents of remote municipalities are less likely to be heard and get a reaction from regional government. Participating in elections as a self-nominated candidate indicates that the candidate

[17] Focus groups with heads of municipalities conducted within the project showed that the ratio of negative to positive comments in official VK communities is two to one.

Table 3. Values of spatial regression models: municipalities and okrugs

Variable	2017	2018	2019	2020	2021	2022
Intercept	3.23974* (1.41568)	6.23471*** (1.16349)	4.35330*** (0.77410)	4.17993*** (0.78133)	4.17207*** (0.59500)	2.97675*** (0.51104)
Log *Pop*	-0.26789' (0.13799)	-0.50353*** (0.11309)	-0.33124*** (0.07597)	-0.25542** (0.08264)	-0.24294*** (0.06293)	-0.17335** (0.05446)
Days	-0.00051* (0.00023)	-0.00063*** (0.00016)	-0.00044*** (0.00011)	-0.00049*** (0.00011)	-0.00041*** (0.00008)	-0.00018** (0.00006)
Road	–	-0.00091* (0.00045)	-0.00110** (0.00039)	-0.00141*** (0.00041)	-0.00122*** (0.00031)	-0.00118*** (0.00027)
Self	–	-0.84268* (0.36696)	–	–	–	-0.62951*** (0.17720)
Wage	–	–	–	-0.000009* (0.000005)	-0.000008* (0.000004)	-0.000009** (0.000003)
Number of observations	56	81	149	180	192	170
R2 / R2 adjusted	0.157 / 0.125	0.396 / 0.365	0.261 / 0.245	0.295 / 0.279	0.335 / 0.321	0.350 / 0.330

Note. The assumptions of homoscedasticity, normality, no multicollinearity, and no significant autocorrelation are met.
Standard error is indicated in parentheses.
p-value: *' p < 0.1; * p < 0.05; ** p <0.01; *** p < 0.001.*
Source: own compilation based on data from VK, Rosstat, Yandex Maps, Central Election Commission of Russia.

has good social capital and interacts with people a lot. Initially, it was supposed that this factor would contribute to increased engagement. Apparently, self-nominated heads prefer live communication to virtual one.

For further clustering by municipalities and okrugs, it was decided to use indicators of population and average wages.

In regression models based on settlement data, only three variables turned out to be significant (*Tab. 4*). Moreover, the distance along highways to the regional center in the period 2019–2022 became insignificant. Only the influence of the population and the number of days of the community's presence is stable. To generate clusters for this type of municipality, only the population was used.

Table 4. Values of spatial regression models: settlements

Variable	2017	2018[18]	2019	2020	2021	2022
Intercept	5.5458*** (1.4231)	6.0579*** (1.4289)	4.7836*** (0.7717)	6.0999*** (0.5929)	5.8224*** (0.4210)	5.1900*** (0.3434)
Log *Pop*	-0.5019** (0.1624)	-0.5728** (0.1665)	-0.3697*** (0.0944)	-0.4814*** (0.0716)	-0.4227*** (0.0529)	-0.3733*** (0.0448)
Road	-0.0019' (0.0011)	-0.0018* (0.0009)	–	–	–	–
Days	–	–	-0.0004* (0.0002)	-0.0006*** (0.0001)	-0.0005*** (0.0001)	-0.0003*** (0.0001)
Number of observations	37	57	121	176	241	329
R2 / R2 adjusted	0.224 / 0.178	0.183 / 0.152	0.161 / 0.146	0.287 / 0.279	0.305 / 0.299	0.232 / 0.228

Note. The assumptions of homoscedasticity, normality, no multicollinearity, and no significant autocorrelation are met (excluding 2018).
Standard error is indicated in parentheses.
p-value: ' p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001.
Source: own compilation based on data from VK, Rosstat, Federal Tax Service, Yandex Maps, Central Election Commission of Russia.

[18] Residuals do not follow a normal distribution; therefore, estimated coefficients are shifted.

According to the values, we have developed a method based on a color-coded system to assess the digital divide at the municipal level. To use it, the following indicators are needed: 1) number of days of the community's presence; 2) number of posts; 3) engagement index; 4) population; 5) average wage[19]. If the community has been present for less than a year, the municipality is colored white. It is on a "test period" and is not to be evaluated. If there is no community, the municipality is colored red. Starting from December 1, 2022, this is a law violation: the community must be created[20]. If the number of posts in the community for municipalities and okrugs is less than 52, and for settlements – less than 26, the municipality is colored orange. In these cases, there is a high probability that the community is being pencil whipped, which does not help to attract citizens to government's activities. Therefore, it is necessary to understand the causes of low publishing frequency individually within each municipality.

The remaining municipalities are compared according to the engagement index, but before that they are divided into clusters by population and average wage[21]. Due to clustering, reference municipalities are compared. Within each cluster, there is a division into quartile groups. Municipalities of the first quartile – with the lowest indices – are colored yellow. Green is for the second and third quartiles, purple is for the fourth. High values of the engagement index may indicate the presence of high-profile events or population's dissatisfaction with the government. Practice shows that negative events spread better, gain more comments and likes on social media; therefore, to compare the index values of the best practices in social media, municipalities from the green group that are most similar in socio-economic indicators should be chosen. Thus, the value of the digital divide within the cluster is calculated as the difference between the minimum value of the engagement index (the low value of the yellow group) and the low value of the green group. The decrease in this parameter over time, as well as green group values' amplitude contraction, will indicate bridging the digital gap in the use of social media by local governments.

Using hierarchical clustering, three municipal district (okrug) groups were formed (*Tab. 5*) and five[22] settlement groups (*Tab. 6*). In both cases, the groups turned out to be uneven. The smallest group of municipal districts and okrugs (MP2) consists of municipalities with the largest population in their region. These are regional capitals, municipalities adjacent to them[23], and the ones competing with regional capitals[24]. The second tier of municipal entities (MP3) mainly represent urban okrugs with enterprises important for the regional economy. Their key difference from the largest group of districts (MP1) is higher average wages. In general, among municipal districts and okrugs with maximum audiences of governments' pages, the digital gap has decreased both between yellow and green groups, and within the green group.

When clustering settlements by population, the following group values were obtained: 1) MO1 – up to 4.1 thousand people; 2) MO2 – up to 12 thousand people; 3) MO3 – up to 18.1 thousand people; 4) MO4 – up to 32.1 thousand people; 5) MO5 – over 32.1 thousand people. The MO5 group includes only two urban settlements – Zanevskoye and Sertolovskoye of Vsevolozhsky Municipal District,

[19] For municipal districts and okrugs.

[20] The legal requirements do not apply to settlements that are part of a municipal okrug.

[21] For municipal districts and okrugs only.

[22] The fifth group consists of only two settlements, so it is not listed in Table 6.

[23] For the Leningrad Region – adjacent to Saint Petersburg.

[24] For example, Cherepovets urban okrug in the Vologda Region.

Table 5. Digital divide rate: municipal districts and okrugs

Cluster	Year	Number of municipalities	Digital divide	
			between low values of green and yellow groups	within the green group
MP1	2020	136	0.30	2.28
	2021	140	0.52	2.30
	2022	144	0.51	1.32
MP2	2020	13	0.10	1.30
	2021	13	0.12	1.45
	2022	16	0.12	0.72
MP3	2020	32	0.17	1.21
	2021	40	0.19	1.34
	2022	37	0.28	0.67
Source: own compilation based on VK data.				

Table 6. Digital divide rate: settlements

Cluster	Year	Number of settlements	Digital divide	
			between low values of green and yellow groups	between the green group's low value and the minimum value
MO1	2020	106	2.7	12.58
	2021	161	4.28	13.38
	2022	236	3.73	14.71
MO2	2020	50	1.06	4.11
	2021	57	1.98	5.80
	2022	67	1.68	4.82
MO3	2020	7	0.71	0.69
	2021	9	0.77	2.39
	2022	15	0.60	4.98
MO4	2020	11	1.10	5.79
	2021	12	0.79	3.84
	2022	10	0.27	4.73
Source: own compilation based on VK data.				

whose rapid population growth is associated with the agglomeration effects of Saint Petersburg. In the future, to measure the digital divide according to the proposed methods, they will need to be classified as municipal districts and okrugs. Since most settlements are characterized by a decrease in population over the years, the number of settlements in quartile groups could decline over the years[25]. As all settlements fulfill the requirements and create governments' pages, the proposed values can be revised and detailed. Under current conditions, the MO1 group turned out to be the most numerous and fastest growing, within which in 2022 there are the largest indicators of the digital gap both between the green group's low value and the minimum value, and within the green group (see Tab. 6). This category of settlements is worth close attention and requires the development of separate instructional guidelines for the management of governments' pages. In the remaining groups, the digital gap

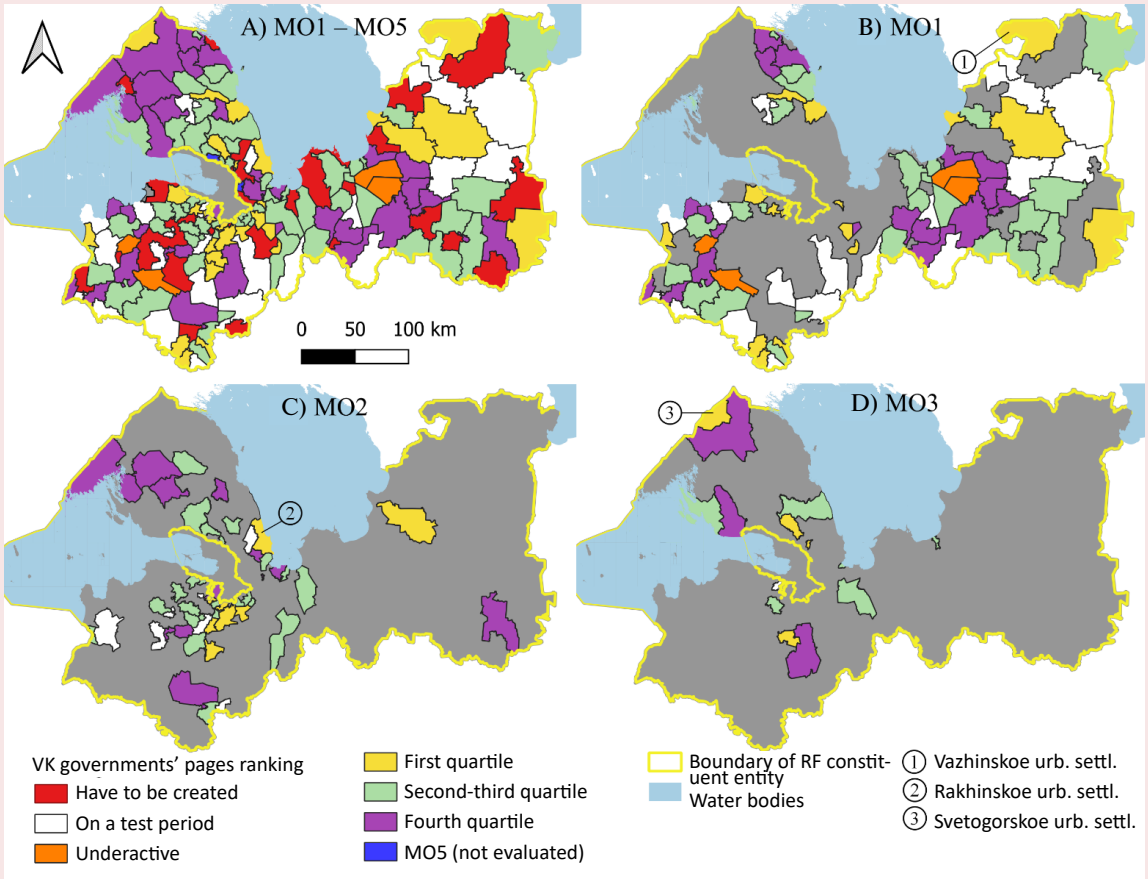
[25] The number of settlements in the MO4 group declined in 2022 compared to 2021.

between the yellow and green groups has decreased. At the same time, in the MO3 and MO4 groups, it has increased within the green group.

As an example of testing methods on the data of the Northwestern Federal District for 2022, we present the distribution by groups in the Leningrad Region (*Fig. 2A*). The result is as follows: 25 municipalities are red, 28 are on a "test period", 4 are orange, 30 are yellow, 61 are green, 37 are purple; two settlements (MO5) were not evaluated.

Nine municipal entities from the red zone have created official communities, but the "Government organization" marks have not been received. At the same time, 16 out of 17 municipal districts' centers of the Leningrad Region do not have governments' pages[26]. Another characteristic of the region is that in order to assign the status of a "Government organization" to the community, some settlements re-created official accounts. In the MO1 group, 17 Leningrad settlements appeared in the yellow zone (*Fig. 2B*). One of its representatives is Vazhinskoe urban settlement of Podporozhsky District with an index of 3.87 and a population of 2.6 thousand people. The range of

Figure 2. Distribution of settlements in the Leningrad Region by engagement level, 2022



Source: own compilation based on VK data.

[26] Except for Kirovskoye urban settlement of Kirovsky Municipal District.

green zone engagement index for the MO1 group is from 4.25 to 18.97. As a target for Vazhinskoe administration, it can be suggested to study the experience of comparable Nifantonovskoe rural settlement of Sheksninsky District of the Vologda Region (index 18.10) or Voznesenskoe urban settlement neighboring in the municipal district (index 10.52). Similarly, for Rakhinskoe urban settlement of Vsevolozhsky District (population – 8.9 thousand people with an engagement index of 2.14) the experience of government employees from the MO2 group, whose engagement indices are greater than 2.02 and less than 7.02, will be useful. It can be governments' pages of Lyubanskoe urban settlement of Tosnensky District of the Leningrad Region (index 3.76) or Kemskoe urban settlement of the Republic of Karelia (index 6.56). And the administration of Svetogorskoe urban settlement of Vyborgsky District (population – 17.5 thousand people with an engagement index of 1.39) should pay attention to the government's page of Sortavalskoe urban settlement of the Republic of Karelia, whose engagement index (3.81) is in the middle of the green zone of MO3 (from 1.65 to 6.63).

Discussion and conclusion

Using the example of municipal governments' pages on the VK social network, methods for assessing the digital divide in the area of interaction between authorities and the population through social media have been developed. Its novelty lies in the fact that for these purposes it is proposed to use an updated engagement index, the features and conditions of its application are revealed. It is shown that it is impossible to focus only on the index values without analyzing the publication frequency, the community longevity and the socio-economic situation of the municipal entity. For the first time, the impact of socio-economic parameters of municipalities and personal characteristics of their leaders on the citizen engagement in the information agenda of governments' pages was assessed on Russian data. Among the large number of assessed factors affecting the engagement level, only the population and the official page longevity turned out to be statistically significant for both municipal districts (okrugs) and settlements. The influence of proximity to the regional center and the average wage has also been confirmed for the municipal districts. A decrease in the engagement index over time is an objective process facilitated by high publication frequency. To increase it, it is necessary to pay attention to the factors that require separate research: 1) content and length of posts; 2) list of posts' topics and their combinations; 3) timing of posts.

A comparison of municipal engagement indices by reference groups confirmed that the digital divide is greater among settlements rather than among municipal districts and okrugs. This problem especially concerns a large group of settlements with a population of less than 4.1 thousand people. For this category of settlements of all others it is necessary, primarily, to develop their own criteria for evaluating the effectiveness of work on social media, separate instructional guidelines for managing governments' pages, find and spread best practices among them, and train employees responsible for official pages. As the settlements are fully covered by governments' pages and they accumulate experience, it will be advisable to divide this group into subgroups for further improvement of work with the population.

The proposed methods can be applied both within a single region and nationwide. The latter is of the greatest practical interest, since it allows setting normative indicators and determine criteria for evaluating the effectiveness of work on social media based on objective reality for different groups of municipal entities. According to our methods,

local government can select several targets similar in socio-economic parameters, including those located outside the "home" region, with a high probability that someone else's experience will be applicable and useful for them. The practice of the purple group's municipalities should be studied in detail by specialists responsible for information policy. It is necessary, on the one hand, to highlight original techniques and solutions that should become standards in the future and, on the other hand, to identify and stop artificial ways of overestimating the engagement level.

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