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Analysis of the Dynamic of Effectiveness of City Halls' Social Networking Sites in Poland as a Factor in Building an Efficient Public E-Services

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Abstract:

Purpose: *A characteristic feature of each smart city is a high level of use of information and communication technology in order to increase interactivity as well as to increase the knowledge and awareness of residents. In this article, we analyse only one aspect of the smart city. We treat a city as smart when it undertakes investments in human and social capital and communication infrastructure in order to actively promote sustainable economic development. The Facebook pages of 18 voivodeship cities in Poland in 2020-2022 were analysed in order to examine the effectiveness of the information carrier, which are posts about public services.*

Design/Methodology/Approach: *This contribution presents an evaluation of the effectiveness of building efficient communication based on information technology using the social media platform (Facebook) promoting the public e-services of main city halls in Poland for the period 2020-2022. The research is based on the DEA (Data Envelopment Analysis) and Malmquise Index methods. The aim of the article is to answer the question whether cities use information and communication technologies such as social media to increase communication with residents and build the image of the city.*

Findings: *The results of the analysis show the current state of use of social networking sites by the offices of the largest cities in Poland. The obtained data show the dynamics of the studied phenomenon, as well as the impact of the beginning of the COVID19 pandemic on the bidding for efficient public e-services. The article develops five dynamic models based on the DEA Malmquist Index, allowing to examine the effectiveness of posts in terms of their subject matter.*

Practical Implications: *The results of the analysis can be used to build more effective channels for the interactive exchange of knowledge and information between public institutions and citizens, as well as to effectively create knowledge and build customer relationships. The aim of the paper is to answer the question whether cities use information and communication technologies such as social media to increase communication with residents and build the image of the city.*

Originality/Value: *The added value of the research method used is the research carried out on primary data collected on the basis of the websites of city offices in 2020-2022.*

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1. Introduction

The rapid advancement of information and communication technologies (ICT) has profoundly transformed how modern cities operate, laying the foundation for the concept of "smart cities." A smart city is characterized by its ability to integrate technology into various sectors to enhance efficiency, promote sustainability, and improve the quality of life for its citizens. At the core of this transformation is the use of ICT to foster greater interactivity and participation from residents. Among the key tools enabling this shift are social media platforms, which play a crucial role in the exchange of information, the promotion of public services, and the building of relationships between city governments and residents.

Social media, particularly platforms like Facebook, Instagram, Twitter or LinkedIn has emerged as a primary channel for communication in the digital age. City halls worldwide increasingly rely on these platforms to provide timely information, engage with the public, and enhance the visibility of their services. In Poland, city halls of voivodeship capitals use for example Facebook platform to share updates about public services, events, and other city-related activities, positioning social media as an integral component of public e-services.

Public e-services refer to digital services provided by public institutions that enable citizens to access government information and complete transactions online, such as applying for permits, receiving notifications, or reporting problems within the city.

The COVID-19 pandemic has significantly affected the operation of cities around the world, including the way municipal offices communicate with citizens. Faced with the constraints of the pandemic, social media has become a key tool for staying in touch with citizens and promoting public e-services.

The use of social media in public governance is a growing area of research, particularly in the context of smart cities and the development of public e-services. According to Nam and Pardo (Nam and Pardo, 2011), a "smart city" is not only defined by its technological infrastructure but also by how it fosters better governance, increased transparency, and active citizen participation through digital means. Social media platforms have become essential tools for smart governance, providing cities with the means to engage with citizens directly, share information quickly, and gather feedback on public services.

This article analyses the effectiveness of the Facebook platform use by provincial city offices in Poland in 2020-2022, with particular emphasis on the impact of the COVID-19 pandemic on communication strategies. The use of the Data Envelopment Analysis (DEA) method and the Malmquist index based on it allowed for the analysis of the change in communication dynamics in the analysed period.

2. Literature Review

Public institutions are increasingly using Facebook to improve public e-services, but the effectiveness of these efforts varies. While Facebook offers technological and communication potential to improve public engagement and service delivery, its effectiveness is often limited by the way in which it is used by these institutions.

Linders (2012) expands on this by introducing the concept of "we-government", a model where citizens are not merely recipients of information but active participants in co-producing public services through digital platforms. In this model, social media plays a pivotal role by offering a space for real-time interaction between governments and citizens, leading to more responsive and citizen-centric governance.

The ability of social media to facilitate two-way communication and involve citizens in decision-making processes has been shown to improve the quality of public services and increase trust in government institutions.

Mergel (2013) emphasizes the importance of social media adoption within public institutions, particularly in the U.S. federal government, as a means to increase transparency and improve citizen engagement. Mergel's research highlights that social media adoption in the public sector must go beyond merely disseminating information; it must include strategies that foster dialogue, responsiveness, and accountability. For city halls, this means that social media can be an effective tool for building long-term relationships with citizens if used strategically.

In their research, Reddick and Chatfield (2017) point to limited engagement and thus insufficient effectiveness of public e-services using Facebook. According to Silvallan (2022), many public institutions use Facebook mainly for one-way communication, focusing on promoting their programmes rather than engaging in meaningful dialogue with citizens. This approach limits the potential for a double learning loop, where institutions could learn from citizen feedback to improve services.

Olinski and Szamrowski (2021) highlight that the use of Facebook by public benefit organisations and institutions varies widely. Many public institutions from larger urban centres tend to be more active, while many smaller public entities remain inactive or minimally active, failing to take full advantage of Facebook's potential to engage the public.

According to Machmud, Tobirin and Rokhman (2024) the use of social media platforms by public institutions has a positive impact on the development of e-government and thus on building effective public e-services. Social media, including Facebook, has a moderate to large positive impact on the implementation of e-government, especially in terms of increasing transparency, public trust and citizen participation. Facebook is particularly effective in increasing community participation in e-public service processes, especially in developing countries..

While Facebook has the potential to improve public e-services, its effectiveness largely depends on how public institutions use the platform. Effective use requires going beyond one-way communication and actively engaging citizens and learning from their feedback. Therefore, the study of building effective public e-services on social media platforms prioritises the selection of statistical methods that take into account two-way communication providing the potential for a double learning loop.

To comprehensively evaluate the effectiveness of social media in enhancing public e-services, it is essential to adopt quantitative methods capable of capturing the efficiency and productivity of digital interactions between public institutions and citizens. While prior research highlights the importance of two-way communication and citizen engagement in social media-driven public services, assessing their real impact requires robust analytical tools.

Given the dynamic nature of digital governance, efficiency measurement methods such as Data Envelopment Analysis (DEA) and the Malmquist productivity index provide valuable insights into the performance and development of public e-services.

These methods enable the evaluation of how effectively city halls utilize social networking sites to improve service delivery, increase citizen engagement, and enhance institutional responsiveness. By applying DEA and Malmquist analysis, this study aims to quantify the effectiveness of social media usage in public administration, identifying trends, best practices, and areas requiring improvemen

DEA and the Malmquist productivity index are extensively employed to assess efficiency and productivity in the public sector. Ahn et al. (Ahn *et al.,* 2018) provided an overview of recent advancements in the application of DEA within the public sector, emphasizing methodological progress and emerging areas of application. Similarly, Emrouznejad and Yang (2018) conducted a comprehensive review of DEA literature spanning four decades, identifying trends, developments, and research gaps that continue to influence its use in public sector efficiency analysis.

In the context of digital transformation, Horváthová and Mokrišová (2024) applied DEA methods to measure the efficiency of digital transformation in European Union countries, highlighting productivity changes associated with digitization efforts. Similarly, Er-Rays and M'dioud (2024) assessed the technical efficiency of public

hospital networks in Morocco using the DEA method, demonstrating its applicability in public health services. Lan (2022) applied the BCC model and the Malmquist index to assess changes in e-government efficiency and total productivity in 31 Chinese provinces from 2018 to 2020. The results indicate varying efficiency levels among the provinces and highlight the importance of technological progress in improving e-government efficiency. Cichowicz *et al.* (2021) explored the applicability of DEA in evaluating the efficiency of local public employment services, showcasing how DEA can be effectively employed to compare the performance of employment offices, thereby providing insights into labor market policy effectiveness.

Extending this perspective, Krejnus *et al.* (2023) applied DEA to assess the efficiency of electronic public administration as part of broader digitization efforts in the economy and society, reinforcing the method's relevance in evaluating digital governance. Odeck (2005) investigated the use of DEA and Malmquist indices to evaluate target achievements in the public sector, underscoring the role of these methods in tracking efficiency changes over time and identifying best practices among public institutions.

Yalçın (2021) conducted a DEA-based study measuring the efficiency of digitalization in EU countries, complementing the findings of Horváthová and Mokrišová (2024), and demonstrating that DEA is a valuable tool for assessing the impact of digital transformation on public sector efficiency.

In the realm of smart city development, DEA serves as a tool to evaluate the efficiency of implemented solutions and projects. Sun *et al.* (2022) employed a network DEA model with a slack-based measure (SBM) to analyze the eco-efficiency of 284 Chinese cities, considering both economic and social indicators. This study identified factors influencing sustainable urban development and highlighted the role of local governments in delivering public services and enhancing societal well-being.

Similarly, Lombardi *et al.* (2012) utilized DEA to model the performance of smart cities by examining interactions among urban components and the relationships between universities, industries, and governments within the triple helix model. This approach provides insights into the dynamics of innovation and knowledge management in smart urban environments.

The integration of Information and Communication Technologies (ICT) is pivotal for the functioning of modern cities. Fotova Čiković and Lozić (2022) applied DEA to assess the efficiency of ICT utilization across various sectors, identifying areas requiring improvement and resource optimization. Such analyses assist organizations in better managing technological and financial resources. In the tourism sector, Sigala *et al.* (2004) employed a stepwise DEA methodology to

evaluate technological investments, analyzing the impact of ICT on operational efficiency within tourism enterprises.

This research provided valuable insights into optimizing information technology investments to enhance competitiveness in the tourism market.

Social media has become integral to communication between public institutions and citizens. Xu *et al.* (2016) utilized a three-stage DEA model to examine the influence of social media on the operational efficiency of Chinese national scenic areas, demonstrating that social media activity can significantly enhance visitor numbers and resource management. In the Polish context, Kotnis and Guzowska (2021) evaluated the effectiveness of city halls' social networking sites using DEA methodology, identifying key factors affecting communication efficiency with residents and offering recommendations to improve local community engagement.

3. Research Methodology

The Data Envelopnemt Analysis (DEA) method and the Malmquist index based on it were used to examine the dynamics of changes and effectiveness of communication strategies of city offices in Poland. The DEA method is a nonparametric method based on mathematical programming, used to assess the efficiency and effectiveness (Strąk 2012) of units described by input and output vectors. DEA enables the identification of effective and ineffective objects called decision-making units (DMU) in the studied set.

Additionally, this method provides information on what technological changes are necessary to increase the efficiency of ineffective units (Banker et al. 1984, Charnes et al. 1995, Charnes et al. 1978, Cook et al. 2014, Cooper et al. 2007 and Farrel 1957). The input-oriented CRS DEA model (Constant Return to Scale) was used in this work.

In the DEA model, the efficiency (or in this case, effectiveness) of the decision-making units (DMU) is defined as follows.

$$U_q = \frac{\sum_{r=1}^{s} \mu_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} = \frac{\mu_1 y_{1j} + \mu_2 y_{2j} + \cdots + \mu_r y_{rj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} \quad (1)$$

where:
s – the number of outputs,
m – the number of inputs
y_r – output values,
x_i – input values,
μ_r – the weights of outputs,
v_i – the weights of inputs.

For the studied object marked with the index 0, the input-oriented objective function for the CRS model is defined by formulas (2) - (4). In these equations, it was assumed that θ_0 is the efficiency indicator of unit 0, while the decision variables are the weights related to the analyzed inputs and outputs.

$$\theta_0 = max \frac{\sum_{r=1}^{s} \mu_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{2}$$

under condition

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad \forall j, \tag{3}$$

$$\sum_{i=1}^{m} v_i x_{iq} = 1 \tag{4}$$

$$u_r > \varepsilon, \quad \forall r$$
$$v_i > \varepsilon, \quad \forall i$$

The CRS DEA model operates on the assumption that the optimal balance of input and output variables is not influenced by the scale of operations. This allows for the measurement of effectiveness for each selected city hall in Poland. The objective of the model is to maximize the efficiency score for each city hall, with the constraint that no city hall can exceed 100% efficiency, as the input and output weights must be positive and non-zero.

Based on the results obtained for the CRS model, the Malmquist Productivity Index (MPI) was used to study the efficiency/productivity dynamics. In the empirical analysis, the DEA-Malmquist index, formulated by Caves et al. (Caves et al. 1982), allows to express the MPI in the following way:

$$MPI_0 = \left[\frac{\theta_o^t(x^{t+1}, y^{t+1})}{\theta_o^t(x^t, y^t)} \cdot \frac{\theta_o^{t+1}(x^{t+1}, y^{t+1})}{\theta_o^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \tag{5}$$

where $\theta_o^s(x^t, y^t)$ denotes the efficiency of the *o*th decision unit for the common technology of period s and the technology of the decision unit o of period t and decomposes into two factors (Coelli *et al.*, 2005):

change of efficiency

$$\frac{\theta_0^{t+1}(x^{t+1}, y^{t+1})}{\theta_0^{t+1}(x^t, y^t)} \tag{6}$$

and technological progress,

$$\left[\frac{\theta_0^t(x^{t+1},y^{t+1})}{\theta_0^t(x^t,y^t)} \cdot \frac{\theta_0^{t+1}(x^{t+1},y^{t+1})}{\theta_0^{t+1}(x^t,y^t)}\right]^{\frac{1}{2}} \tag{7}$$

the MPI values characterize three groups of efficiency changes: improving (MPI > 1), unchanging (MPI = 1), and declining (MPI < 1).

4. Data Collection, Inputs and Outputs

The presented analysis employs DEA and Malmquist index methodology to quantify relationships between interactions in the context of electronic public administration services. The selection of institutions encompassed in the study considers e-service priorities within public administration, wherein a unified digital service market is currently under development.

Additional factors determining the selection of public institutions for the study comprise the scope of provided services and the operational range of the respective institution. Consequently, the study encompasses offices of all municipalities in Poland, thereby covering 18 municipal cities, including two towns in the Lubuskie and Kujawsko-Pomorskie Voivodeships.

Within the framework of the research project, statistical analysis of city hall social media profiles was conducted, accompanied by qualitative analysis of published content. Based on observations and interviews, it was established that public institutions maintaining profiles share their activities in a consistent manner.

Furthermore, social network trends and technical capabilities were considered, providing the foundation for identifying the themes of most frequently published posts. To achieve the research objective, the authors identified six thematic groups of posts for four primary scopes of published information.

Thematic Content Categories:

- E-services
    - Communications regarding citizen projects and competitions, participatory budget – messages directly addressed to citizens, e.g., competition announcements, event invitations, participatory budgets, weather alerts, as well as guidelines for waste segregation in the given municipality
    - Communications informing about municipal or citizen initiatives and ecological issues or changes in public transport – notifications about social, municipal, and environmental events
- Ex ante Information
    - Posts informing about forthcoming cultural and entertainment events and anniversary celebrations

- Ex post Coverage
    - Coverage of events attended by public authorities and politicians
    - Coverage of events attended by local community members – highlighting resident presence in the post
- Photo/Panorama
    - City photographs/panoramas/promotional films featuring local attractions – promotion of the city or landmarks

For the identified six thematic groups, quantitative analysis was performed, and the effectiveness of maintained profiles was examined. Within the research framework, quantitative data were analyzed to describe website activity, posting frequency, engagement metrics, and interaction intensity.

The research findings present social networking activity of offices during September inn years 2020-2022. The selection of this month was influenced by the fact that September represents Poland's most active business month of the year, as its workflow remains undisturbed by international, national, and religious holidays.

This constitutes a period of intensive business operations, whose effectiveness is guaranteed by the preceding summer holiday months (July and August).

The limitation of the study to the years 2020-2022 and the activity of city halls only to Facebook resulted from the need to use only decision-making units with complete, non-zero data in the DEA method. For this reason, Opole and Rzeszów were excluded from the analysis due to lack of data.

Based on the previously mentioned categories, input and output data were selected for the DEA study. Finally, the input data refers to the type of information published by city offices on the Facebook platform, while the output data consists of likes, comments and shares generated by followers in response to published content, as indicated in Table 1.

Table 1. *Inputs and outputs model*

Inputs	Outputs
Total number of post "E-services" Total number of post "Ex-ante information" Total number of post "Ex-post coverage" Total number of post "Photo/panorama"	Likes= $\sum$ number of Likes posted/ number of followers Comments=$\sum$ number of comments posted/ number of followers Sharing $\sum$ number of shares posted/ number of followers

Source: *Author's calculations.*

Next, the five models shown in Table 2 were analyzed.

Table 2. *Determinants of effectiveness in each model*

	Model I	Model II	Model III	Model IV	Model V
Inputs					
Total number of post "E-services" • Total number of posts informing about the project/contest/budget/ • Total number of posts informing about municipal/civil initiatives	√				
Total number of post "Ex-ante information"		√			
Total number of post "Ex-post coverage"			√		
Total number of post "Photo/panorama"				√	
Total number of posts in all categories					√
Outputs					
Likes= ∑ number of Likes posted/ number of followers)	√	√	√	√	√
Comments=∑ number of comments posted/ number of followers	√	√	√	√	√
Sharing ∑ number of shares posted/ number of followers	√	√	√	√	√

Source: *Author's calculations.*

5. Research Results and Discussion

Malmquist Productivity Index was canted for Models from 1 to 5, for the years 2020-2022. First part of results shows annual changes of MPI for the years 2020-2021 and 2021-2022. Second part of analysis shows MPI changes between 2020 and 2022.

Table 3. *MPI for Model 1 – "E-services"*

	Annual MPI Change		Overall Period MPI Change	
DMU	2020–2021	2021–2022	2020–2022	
Wrocław	0.16	0.19	**Kielce**	**1.29**
Bydgoszcz	0.36	0.37	Gorzów	0.58
Lublin	0.31	0.34	Poznań	0.36
Zielona Góra	0.16	3.89	Olsztyn	0.34
Łódź	0.22	**1.07**	Lublin	0.32
Kraków	0.20	0.15	Bydgoszcz	0.31
Warszawa	0.22	0.48	Gdańsk	0.27
Białystok	0.37	0.30	Warszawa	0.24
Gdańsk	0,26	0.30	Białystok	0.23
Katowice	0,13	0.11	Łódź	0.21
Kielce	**1.76**	0.55	Kraków	0.18
Olsztyn	0.58	0.19	Toruń	0.18
Poznań	0.33	0.51	Katowice	0.17
Szczecin	0.07	0.12	Zielona Góra	0.16

Toruń	0.18	0.44	Wrocław	0.14
Gorzów	0.69	0.72	Szczecin	0.05

Source: *Author's calculations.*

Table 3 shows an analysis of posts related to e-services, a category that includes communications from city offices informing citizens about various initiatives, participatory budgets, contests and guidelines to promote public involvement and awareness.

The analysis shows significant discrepancies in the performance of individual cities. For example, cities such as Kielce and Lodz showed positive productivity growth with a Malmquist index greater than 1(Kielce in 2000-2001, Lodz in 2001-2202), indicating improvements in both productivity and technology adoption in the use of social media in terms of e-services.

On the other hand, cities such as Wroclaw and Szczecin were at the bottom of the list with a very low Malmquist index, signal a decline in efficiency and technological adaptation. These cities struggled to respond dynamically to the changing environment, often publishing less effective posts or failing to engage in a meaningful way.

Table 4. *MPI for Model 2 - Ex-ante information*

	Annual MPI Change		Overall Period MPI Change	
DMU	2020–2021	2021–2022	2020–2022	
Wrocław	0.32	0.34	Łódź	**1.06**
Bydgoszcz	0.31	0.23	Kielce	0.97
Lublin	0.57	0.34	Gorzów	0.81
Zielona Góra	0.29	0.60	Lublin	0.45
Łódź	**1.19**	0.99	Gdańsk	0.44
Kraków	0.10	0.29	Zielona Góra	0.24
Warszawa	0.17	0.37	Białystok	0.24
Białystok	0.30	0.37	Toruń	0.24
Gdańsk	0.55	0.44	Bydgoszcz	0.23
Katowice	0.15	0.14	Wrocław	0.22
Kielce	**1.40**	0.73	Olsztyn	0.21
Olsztyn	0.40	0.39	Katowice	0.14
Poznań	0.16	0.17	Warszawa	0.13
Szczecin	0.07	0.20	Poznań	0.12
Toruń	0.33	0.25	Kraków	0.06
Gorzów	0.90	0.42	Szczecin	0.05

Source: *Author's calculations.*

In the category of ex-ante information covering Posts informing about forthcoming cultural and entertainment events and anniversary celebrations (Table 4), in the Period 2020-2021 only the cities of Łódź and Kielce achieved a Malmquist index greater than 1. In the Period 2021-2022, the Malmquist index for none of the analyzed cities exceeded the value of 1. Achieving a Malmquist index value greater

than 1 in the 2020-2021 period allowed the city of Lodz to also achieve an index value greater than 1 in the 2020-2022 period. In Model 2 - ex-ante information, the cities of Krakow and Szczecin were at the bottom of the list.

Table 5. *MPI for Model 3- Ex-post information*

	Annual MPI Change		Overall Period MPI Change	
DMU	2020–2021	2021–2022	2020–2022	
Wrocław	0.17	0.11	Białystok	0.39
Bydgoszcz	0.24	0.06	Kielce	0.27
Lublin	0.54	0.12	Gorzów	0.27
Zielona Góra	0.23	0.21	Olsztyn	0.19
Łódź	0.38	0.32	Łódź	0.12
Kraków	0.07	0.03	Warszawa	0.12
Warszawa	0.37	0.06	Poznań	0.11
Białystok	**1.22**	0.05	Lublin	0.10
Gdańsk	0.29	0.04	Bydgoszcz	0.06
Katowice	0.30	0.05	Katowice	0.06
Kielce	**1.46**	0.08	Gdańsk	0.06
Olsztyn	0.71	0.07	Zielona Góra	0.05
Poznań	0.58	0.03	Wrocław	0.04
Szczecin	0.01	0.01	Toruń	0.02
Toruń	0.13	0.05	Kraków	0.02
Gorzów	0.93	0.23	Szczecin	0.00

Source: *Author's calculations.*

Model 3- Ex-post information covered two categories of data: Coverage of events attended by public authorities and politicians and Coverage of events attended by local community members - highlighting resident presence in the post. In this model, only in 2020-2021, the cities of Kielce and Bialystok achieved a Malmquist index value greater than 1. In 2021-2021, all the studied cities achieved a Malmquist index value well below 1. Also, in the entire studied period of 2020-2022, the Malmquist index value was well below the value of 1.

Table 6. *MPI for Model 4 - Photo/ Panorama*

	Annual MPI Change		Overall Period MPI Change	
DMU	2020–2021	2021–2022	2020–2022	
Wrocław	0.50	0.44	Gorzów	**3.85**
Bydgoszcz	0.62	0.47	Kielce	**3.05**
Lublin	0.80	0.43	Olsztyn	**1.43**
Zielona Góra	0.54	**1.15**	Białystok	**1.34**
Łódź	0.54	0.87	Gdańsk	**1.16**
Kraków	0.25	0.16	Toruń	0.96
Warszawa	0.62	0.54	Lublin	0.72
Białystok	**1.15**	0.91	Bydgoszcz	0.65
Gdańsk	0.98	**1.19**	Łódź	0.63
Katowice	-	0.59	Warszawa	0.61
Kielce	**2.67**	0.30	Wrocław	0.59
Olsztyn	**1.78**	0.84	Zielona Góra	0.45

Poznań	0.43	0.60	Poznań	0.33
Szczecin	0.18	0.20	Kraków	0.24
Toruń	0.89	0.92	Szczecin	0.18
Gorzów	**3.30**	0.99	Katowice	-

Source: *Author's calculations.*

Model 4 - Photo/ Panorama included activities involving the publication of city photographs/panoramas/promotional films featuring local attractions - promotion of the city or landmarks. In the period 2020-2021, as many as four cities achieved a Malmquist index exceeding the value of 1. These cities were Gorzow with a very high MPI of 3.3, followed by Kielce (MPI=2.67). Olsztyn (MPI=1.79) and Bialystok with an MPI of 1.15. In the 2021-2022 period, two cities achieved a Malmquist index greater than 1.

These cities were Gdansk (MPI=1.19) and Zielona Gora (MPI=1.5). The high effectiveness of communicating with the public through photos can also be seen in the aggregate Malmquist index for the period 2020-2022. As many as five cities achieved an MPI value greater than 1. The top cities were Gorzow (MPI=3.85), Kielce (MPI=3.08), Olsztyn (1.43), Bialystok (1.34) and Gdansk (MPI=1.16). At the end of the list were again the cities of Krakow and Szczecin. Katowice, due to the lack of data in the 2020s in the Photo/Panorama category, was excluded from the analysis for this period and the 2020 - 2022 timeframe.

Table 7. *MPI for Model 5 - Total number of posts in all categories*

	Annual MPI Change		Overall Period MPI Change	
DMU	2020–2021	2021–2022	2020–2022	
Wrocław	0.32	0.45	Kielce	0.91
Bydgoszcz	0.52	0.39	Olsztyn	0.75
Lublin	0.58	0.35	Gorzów	0.69
Zielona Góra	0.36	3.07	Białystok	0.64
Łódź	0.41	**1.43**	Gdańsk	0.63
Kraków	0.23	0.18	Toruń	0.54
Warszawa	0.45	0.50	Lublin	0.44
Białystok	0.54	0.28	Warszawa	0.41
Gdańsk	0.89	0.59	Bydgoszcz	0.41
Katowice	0.15	0.20	Poznań	0.38
Kielce	**1.46**	0.51	Łódź	0.33
Olsztyn	0.99	0.55	Zielona Góra	0.27
Poznań	0.45	0.60	Katowice	0.27
Szczecin	0.07	0.12	Wrocław	0.22
Toruń	0.71	0.56	Kraków	0.19
Gorzów	0.89	0.81	Szczecin	0.05

Source: *Author's calculations.*

Model 5 included the total cumulative number of postings in all categories. In this model, in 2020-2021 only Kielce achieved MPI improvements, while in 2021-22 the MPI value exceeded 1 only for the city of Lodz. In the entire period studied (2020-

2022), none of the analyzed cities improved their efficiency. Kraków and Szczecin again appeared at the end of the list.

6. Discusion

The results of the study, conducted using the DEA method and the Malmquist index, revealed significant variations in the communication effectiveness of provincial cities in Poland between 2020 and 2022. Notably, cities such as Kielce, Gorzów, and Białystok achieved the highest effectivnes scores in promoting public e-services, indicating that they adopted more effective strategies for engaging citizens through social media.

Conversely, cities like Kraków, Szczecin, and Poznań showed minimal productivity changes, suggesting either less dynamic communication efforts or insufficient adaptation of their strategies to changing conditions. The findings indicate that the highest effectiveness was observed in posts containing visual materials, such as city photographs, panoramas, and promotional videos.

These types of content significantly influenced user engagement and interaction levels, suggesting that visual communication is a key factor in building relationships between city halls and residents. In the categories related to informing about public services and city events, the results were more varied—some cities demonstrated improvements in efficiency, while others struggled to expand their reach and level of interaction.

Over the entire period (2020-2022), it was observed that although social media usage by cities increased, the effectiveness of communication efforts remained largely dependent on individual strategies and the adaptation of published content to audience preferences.

The COVID-19 pandemic had a significant impact on city communication strategies through social media, which was reflected in the analysed data. During the period of the strictest sanitary restrictions, city halls increasingly relied on Facebook as their primary communication channel, delivering real-time updates on the pandemic situation, changes in public service organization, and initiatives supporting residents.

The increased activity of city halls on social media platforms was particularly evident in the early phase of the pandemic, when the number of published posts surged, and user interactions intensified. However, between 2020 and 2021, substantial differences were observed among cities—some municipalities successfully adapted their communication strategies, leading to higher efficiency scores, while others failed to achieve similar results.

The analysis suggests that between 2021 and 2022, cities gradually reduced the number of pandemic-related posts, returning to more standard communication

models. At the same time, the pandemic contributed to long-term changes in communication strategies, leading to a greater reliance on digital tools for engaging with residents. The findings indicate that cities that effectively leveraged social media during the pandemic managed to maintain higher levels of engagement even after the crisis subsided.

7. Coclusion

The conducted analysis demonstrated that social media is a crucial communication tool between city halls and residents, particularly in the promotion of public e-services. The use of DEA and Malmquist methods allowed for an evaluation of the effectiveness of communication efforts, considering both dynamic changes and the impact of the COVID-19 pandemic on municipal strategies. In addition, the study paid particular attention to the aspect of the two-way communication loop (Reddick and Chatfield, 2017), i.e., the intensity of active information exchange between public institutions and the citizens of a given city. The more comments and shares, the greater the effectiveness of public communication.

The most effective communication strategies focused on the use of visual content, which generated the highest level of user engagement in the form of likes. This seems to be an effective form of building communication between a public institution and the people of that city. However, this form of posting does not generate a loop of two-way communication with citizens, and is therefore the most effective form of citizen activation.

Cities that flexibly adapted their approach to the specifics of social media and audience preferences achieved higher effectiveness scores. In contrast, a lack of responsiveness to changing conditions resulted in lower effectiveness in some content categories. Cities such as Kraków and Szczecin achieved the lowest effectiveness index.

The reason for this in this case is the lack of a transparent name for the profile of the city of Szczecin (fan page under the name: Szczecin Floating Garden), which would unambiguously identify this institution and its offer of public e-services, as well as the few posts published on the fan page of the Kraków City Hall, which should be regarded as a lack of a coherent e-strategy for this city.

The impact of the COVID-19 pandemic on city communication was significant, leading to increased activity on social media platforms. Although some cities scaled back their presence on social media after the pandemic, the results suggest that a more intensive use of digital tools in public communication can yield long-term benefits.

For future research, it is recommended to continue monitoring the effectiveness of city communication strategies and to analyze emerging trends in social media that

may influence the development of public e-services and the strengthening of relationships with residents.

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