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EVALUATING LOCAL SEO QUALITY OF MUNICIPAL GEOPORTALS: A MULTI-METHOD APPROACH INTEGRATING AUTOMATED, LINK, AND AI-BASED ANALYSIS

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ABSTRACT

Motives: Research on search engine optimisation (SEO) usually focuses on commercial websites, with limited attention to public sector platforms like geoportals. The impact of SEO on their online visibility and Local SEO quality remains understudied, which presents a research gap worth exploring.
Aim: This study evaluates the SEO quality of selected municipal geoportals using Large Language Models (LLMs). It examines how well these portals are optimised for search engines and whether AI tools can effectively support SEO auditing.
Results: Audits of five geoportals using tools like ChatGPT, Copilot, Gemini, and Perplexity revealed low SEO support from public administrations, poor link building, and weak metadata. Referring domains and quality indicators were limited. Moreover, AI tools do not conduct real-time audits, which restricts their accuracy and usefulness for detailed SEO assessments.

Keywords: Large Language Models, passive SEO, mechanical SEO audit, Local SEO, theoretical SEO audit, geoinformation

INTRODUCTION

Municipal geoportals are interactive and responsive WebGIS spatial information systems. Their purpose is to offer access to current and past planning documents, such as local zoning plans, and masterplans (Michalik & Zwirowicz-Rutkowska, 2023). Municipal geoportals provide information about environmental conditions, cultural heritage, road, tourism, and sports infrastructure, locations of public institutions and facilities, businesses, and public and agricultural service points. By providing the data online, municipal geoportals allow people to access information without office visits. This way, they streamline information dissemination, education, and development. Moreover, municipal geoportals aid with data analysis and processing. This makes them widely used in decision-making and effective in improving public administration efficiency (Dawidowicz et al., 2022).

The quality of municipal geoportals hinges on multiple factors. The primary element is the quality of geodata, which can be considered the quality of geographic and environmental space mapping

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(Feng et al. 2025). Data quality combined with the (software) quality of geoinformation systems makes up the back-end. Put simply, it is 'what you cannot see but makes it work.' The software quality is behind the usability quality of a geoportal (Kellenberger et al., 2016). The latter is quantified with such attributes as performance or responsiveness. On the other hand, the geoportal quality is affected by the user interface as well, or 'What you can see and makes it work' (front end). However, geoportal's comfort of use and applicability can often be limited by insufficient system performance, missing functionalities, and poor usability (Iosifescu-Enescu et al., 2017; Król & Sroka, 2023). All these attributes fall under the umbrella term 'on-page quality'. They determine how much users use the geoportal and how many users it can reach (Katumba & Coetzee, 2017).

Users access information and resources online through social media and backlinks on websites. They increasingly use web applications with artificial intelligence, including Large Language Models (LLMs) (Strzelecki, 2024). Large language models (LLMs) grow increasingly popular among users because they offer quick, synthetic, and context-based answers so that users do not have to search multiple sources themselves. As opposed to traditional search engines that generate lists of results on search engine results pages (SERPs), LLMs deliver direct digests, conclusions, or ready-made solutions (Xiong et al., 2024). This method of interacting significantly reduces the time intensity and cognitive load on the user, making it compelling in terms of quick access to information and growing expectations for personalised content.

Although LLMs are changing how users search for information (Liu et al., 2024), the search engine remains the most popular method for finding specific content. Consequently, it is still the primary objective of most e-commerce enterprises to maintain high visibility of their website among organic search results (Kwak et al., 2021). Optimisation is relevant in this regard. It is aimed at building the website in such a way as to allow it to be as high on the search engine results page as possible for as many search keywords as possible (Erdmann et al., 2022). All this is part of search engine optimisation (SEO). A synergistic SEO strategy improves the website's potential to 'be found online' and its potential to rank high on search results pages, which in turn improves the conversion rate (Roy & Sharma, 2021). The conversion rate means how effectively a website achieves its goals. Needless to say every website is built and maintained for a reason. For sales websites, for instance, conversion means 'turning a guest into a buyer' or 'converting a visitor into a customer or subscriber'. These issues are particularly relevant for commercial entities, but affect public administration as well.

Research Gap and Aim

Studies of various aspects of SEO are most often conducted in the context of online marketing (Chodak & Błażyczek, 2024; Erdmann et al., 2022; Mladenović, 2023) and focus on commercial websites, including sales websites (Schultheiß & Lewandowski, 2023). Other areas of interest in SEO research include the visibility of higher education institutions and educational resources (Poturak et al., 2022) and public administration websites (Csontos & Heckl, 2021; Inal & Ismailova, 2020). Map portals and geoinformation websites, their degree of search engine optimisation, the impact of SEO on the position of geoportals in the online ecosystem, and Local SEO geoportal quality are still underinvestigated. This poses a certain research gap worth addressing.

Local Search Engine Optimisation involves activities aimed at improving the website's search engine results page rank for a specific geographic location, such as a municipality, city, or district. Local SEO focuses on phrases and queries relevant to a specific place as opposed to general SEO strategies, which concentrate on global search engine results. It is particularly pertinent to public institutions, such as city or municipality offices, because their services and information feeds target mainly local communities (Serrano-Cinca & Muñoz-Soro, 2019). Effective Local SEO of geoportals can enhance their accessibility to residents, boost user engagement, and

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support public tasks, such as spatial planning or public consultations.

The article assesses the (Local) search engine optimisation of selected municipal geoportals using Large Language Models (LLMs). It addresses the following research questions:

Q1) How to deploy the most effective optimisation strategy for municipal geoportals in the context of local search results (Local SEO) using available resources?

Q2) To what degree are the selected AI tools useful for (Local) SEO audits of municipal geoportals?

Large language models are sophisticated artificial intelligence systems for processing and generating natural languages (NLP). Some implementations of the technology are ChatGPT (OpenAI), Copilot (Microsoft), Gemini (Google DeepMind), DeepSeek (DeepSeek-Vision), and Perplexity AI. Initially, they were intended as interfaces for human-machine communication and text processing automation solutions (writing, summarising, or translating). Today, they can also be employed in analytical contexts, such as evaluating online content and supporting SEO audits (Chodak & Błażyczek, 2024; Król, 2025). The study uses selected tools to assess the optimisation of city geoportals for local searches. The focus was on identifying metadata, backlinks, and content structure, all of which affect search engine visibility.

The tangible contribution of the article is: 1) assessment of the degree of municipal geoportals search engine optimisation, 2) Local SEO guidelines for local governments, and 3) assessment of the suitability of selected LLMs for SEO auditing. The remainder of the article is structured as follows: Section 2 outlines the background and related work, focusing on the impact of SEO on improving geodata visibility among search results and the benefits of municipal geoportal optimisation. Section 3 offers methodological details, including a characteristic of the subject matter and assumptions for SEO audits. The research results for the mechanical SEO Score audit, link audit, metadata analysis, and LMM SEO audit are presented in Section 4. Section 5 discusses the research, observations, and universal recommendations regarding Local SEO for public administration. The final section covers conclusions, practical implications, and further research.

BACKGROUND

The utmost goal of SEO is to optimise the website and its environment for Internet search engines to improve its rating on the search engine results page and target conversion (Dick, 2011). Therefore, SEO should be assessed for the benefits it can offer to the administration and users, who are mostly local communities. SEO can improve the online visibility of the municipal portal for users looking for specific content, resources, or services, which can yield higher conversion rates. For municipal offices, this can mean an increase in downloaded and completed forms or more public participation in municipality governance, including spatial planning and management. Additionally, SEO can improve both the number of users and their 'quality'. Website publishers are not seeking to increase the general number of 'just any' users. Random users tend to stay on the page for only a short time or leave right after it is loaded. This fuels the adverse bounce rate. A high bounce rate is detrimental to the overall quality rating of a website (Wang et al., 2021).

SEO helps improve website rating on the search engine results page. High search engine results page rating is a token of reliability and instils confidence in the website's content (Myeong et al., 2014). SEO also affects how the website is 'defined' in the results. That means how and with what keywords it is described. Another focus of SEO is technical aspects. These are linked to parameters such as performance, responsiveness, or accessibility (Król & Sroka, 2023). Consequently, high rank on the search engine results page vouches for the business's (brand's) image and its recognizability. Active SEO is not always necessary, especially for websites with functions other than sale. Passive SEO may be sufficient for public administration websites, such as municipal geoportals. It involves a suitable set of functions, metainformation

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structure, and satisfactory website performance (Giannakoulopoulos et al., 2019).

Passive Search Engine Optimisation (Passive SEO) is a strategy to ensure the website's technical parameters are set appropriately without taking action in its environment (off-page). In the case of public administration websites, such as city geoportals, Passive SEO encompasses such aspects as proper metadata structure, optimised HTML code, accessibility conformity, high performance, responsiveness, and security features like an SSL certificate. It may suffice if the website is purely informational and serves the local community rather than competes in a commercial environment. The high technical quality of the website improves its search engine rating, resulting in better visibility among organic search results, even without an extensive backlinking strategy.

SEO Techniques for Visibility of Geospatial Resources

SEO is performed directly on the site (on-page SEO, on-site SEO) and in its environment (off-page SEO, off-site SEO) (Katumba & Coetzee, 2017). SEO audits investigate three primary areas: 1) content (content audit), which entails content optimisation; 2) development (so-called Technical SEO, which usually involves performance, responsiveness, metainformation, usability, and functionality optimisation to elevate the user comfort in general); and 3) links (links audit) to optimise link building. Two other types are Search Experience Optimization (SXO) and Local SEO.

Local Search Engine Optimization (Local SEO) is a strategy with specific optimisation techniques aimed at improving (business, brand) website visibility on a local search engine results page for a specific geographic region, such as a city, district, or municipality (Stern, 2014). The key Local SEO techniques are using local keywords relevant to local conditions, names, and proper nouns and acquiring backlinks from local, high-quality websites.

Local SEO is recommended for entities operating in a limited geographical area, such as public administrations. It may impact the visibility of municipal portals, which are targeted specifically at local communities. A broader approach, Search Experience Optimisation (SXO) combines SEO, Conversion Rate Optimisation (CRO), and User Experience (UX) Design. SXO aims to design websites and web applications that are optimised for search engines, crawlers, and, most of all, users. Hence, it is referred to as SEO 2.0. SXO strategy is focused on enhancing usability, performance, and subjective user satisfaction to boost user engagement and conversion rate.

Conversion Rate Optimisation (CRO) is an array of activities aimed at improving the website's success by maximising the share of users who perform the desired actions, such as downloading a document, filling a form, or clicking a link. The process involves user behaviour analysis, A/B tests, user interface optimisation, and adjusting the content to the audience (Miikkulainen et al., 2017). User Experience Design (UX Design) is a broader term. It concerns a holistic approach to building interfaces and informational structures that ensure an intuitive, effective, and satisfactory website experience. User Experience Design covers such aspects as accessibility, usability, aesthetics, and emotional impact of the interactions (Stige et al., 2024). Both paths are critical in the context of new optimisation strategies, especially under SEO 2.0, which combines Technical SEO with UX and CRO.

(Local) SEO Contribution to Improved Geodata Visibility

Improved search visibility of websites with geospatial metadata can significantly affect the discoverability of the geospatial resources. Geospatial metadata describe maps, geographic information system (GIS) files, images (rasters), and other geographical information. Katumba and Coetzee (2017) identified and classified search terms users typically employed when searching for geospatial data

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online using general-purpose web search engines. Guided by these terms, they published pages with information about geospatial data on the Web and compared the retrieval effectiveness of two metadata vocabularies (Dublin Core and Schema.org) with Google and Bing web search engines. They found out that pages marked up with Schema.org and Dublin Core are a novel alternative for improving search engine visibility and facilitating the discovery of geospatial resources on the Web. Katumba and Coetzee's results (2017) contributed new insights into SEO and its impact on the search engine visibility of geodata. And yet, the problem still seems to hold many secrets. Scholars, especially programmers, web developers, producers of spatial data software, and SEO experts, are still discussing the optimisation of the search engine crawler geodata indexing process (Minghini et al., 2021). Their complex program structure makes an effort to improve search engine (and user) visibility of geoportals easier by no means. Consequently, it is much easier for municipal offices that usually have no programmer staff to enhance geoportal search engine visibility with such off-page SEO techniques as expanding municipal informational websites rather than work with the software side of geoportals (back-end) (Michalik & Zwirowicz-Rutkowska, 2023).

The literature review revealed that geoportals are relatively rarely subjects of SEO audits. It may be because they are usually considered specialist portals, the primary component of which is geodata, not text. The most researched aspects of geoportals are functionality and usability (Dareshiri et al., 2019; Degbelo et al., 2019; Gkonos et al., 2019), performance and interactivity (De Longueville, 2010), application and potential current and past uses (Maciąg & Leń, 2022).

The specific character of geoportals affects their search engine visibility and search engine results page rank (Katumba & Coetzee, 2017). The nature of geoportals limits on-page SEO options while offering extensive off-page SEO possibilities. Therefore, backlinks may significantly improve geoportal visibility on search engine results pages. The literature review identified a research gap and a need for a better understanding of the possibilities and scope of geoportal search engine optimisation.

MATERIALS AND METHODS

Research Object

The research object comprises city geoportals that were evaluated regarding SEO, specifically aspects of Local SEO. The analysis covered technical parameters, metadata structure, and position in the online ecosystem, which affect geoportal visibility in organic search engine results. The study employs selected analytical SEO tools and LLM tools to support the diagnosis.

The study involved five municipal geoportals designed and developed by leading map portal providers in Poland. These businesses specialise in creating and deploying sophisticated map applications using original geoinformatics solutions. The selected geoportals were found on Google's first two search engine results pages, displayed in response to the generic phrase 'municipal geoportal' in Polish on

Table 1. Audited geoportals

Acronym	Name	Profile
G1	Trzebinia Town and Municipality Geoportal	Geoportal by GEOBID powered by EWMAPA
G2	Lubicz Municipality Spatial Information System	'E-map' geoportal by Geo-System
G3	Grybów Municipality Spatial Information System	Geoportal by GISON
G4	Miękinia Municipality Spatial Information System	'E-geoportal' geoportal by PROCAD
G5	Zgierz Municipality Spatial Information System	'Zgierz SIP' geoportal by MapMaker

G1: http://trzebinia.geoportal2.pl/; G2: https://lubicz.e-mapa.net/; G3: https://sip.gison.pl/grybow; G4: https://miekinia.e-geoportal.pl/; G5: https://zgierzsip.mapmaker.online/ (accessed on 26 September 2024)
Source: own elaboration.

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a local online computer. Therefore, each of the tested geoportals has a relatively significant potential of ranking high on the search engine results page, is designed using a different technique and branded by a different commercial geoinformatics services provider (Table 1).

Four geoportals are available under a subdomain. Their URLs are part of the main domain name or higher-level domain name. G3's address indicated a subdirectory. The type of URL matters because its structure may affect the test results and behaviour of the test tool. Some test tools are configured to inspect the main domain name instead of subdomains. Therefore, testing requires special attention and validation of results.

Procedure and Tools for the Mechanical SEO Score Audit

The study design is a mechanical SEO audit combined with a benchmarking analysis. The employed black-box testing approach leaves the auditor to observe data inputs and outputs of the software or web application (a system in general). The structure of the tested application and the processes within the service provider's infrastructure remain unknown (Nidhra & Dondeti, 2012). In this case, the auditor is a third party. This ensures an open-minded perspective and helps flag design flaws the publishers could have missed. The structure and algorithms of Google crawlers, as well as those of the test tools and the internal structure and algorithms of the tested geoportals, are covert under the employed research design. What is overt is the values of specific attributes of geoportals that affect their search engine results page ranks and emerge from their SEO quality.

The mechanical SEO audit includes such elements as: 1) manual operations, such as code exploration and inspection; 2) mechanical tests by automated test tools, performance measurement or accessibility flaws detection, for example; and 3) operations by artificial intelligence algorithms (Chodak & Błażyczek, 2024; Król & Zdonek, 2020). Therefore, the study is divided into three stages (Fig. 1). The first stage was the mechanical SEO audit with HTML code inspection (metainformation analysis). The second stage was the off-page link audit (backlink audit). AI SEO audit was the final stage. The results of the three approaches were compared (the benchmarking analysis).

Fig. 1 presents the five elements that comprise the research methods used in the SEO 2.0 audit. Three items are stages of quality audit: mechanical audit, backlink analysis (off-page), and evaluation using LLM-based tools. The fourth component, benchmarking, is for comparing the results of the individual methods. The fifth element, source code inspection, is intended to help with metadata analysis.

A mechanical SEO audit is a meticulous assessment of a website or web application's quality to ensure compliance with best SEO practices. Its purpose includes identifying technical issues through detailed analyses of the following Technical SEO

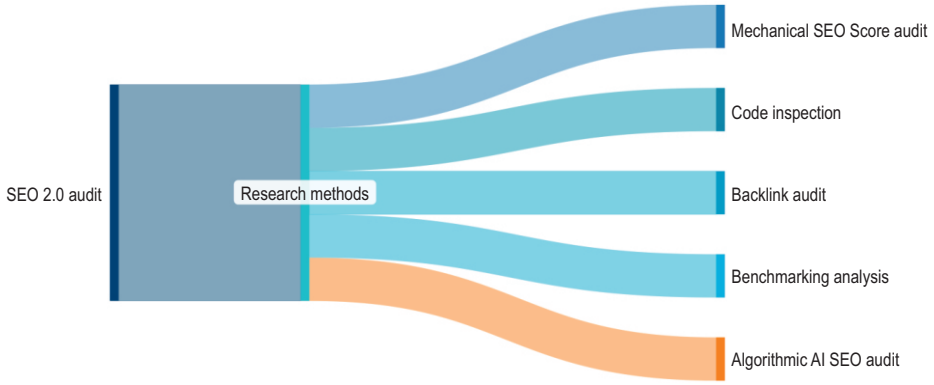

Fig. 1. Research design overview. Research methods comprising the research design
Source: own elaboration.

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areas: performance, responsiveness, internal links, backlinks, and metainformation (Giannakoulopoulos et al., 2019; Król & Zdonek, 2020; Ziakis et al., 2019). Furthermore, an SEO audit covers the assessment of textual components, including semantics and formatting (content audit, URL audit). The audit produces a report with analysis results (descriptive, numerical, and indicator), optimisation actions, and recommendations (guidelines) that may improve the website's search engine results page rank (Król & Zdonek, 2020). The audit is an extensive expert analysis, the results of which are summarised in recommendations. Note that there is no single, universal SEO audit template. Its scope usually hinges on the profile of the website or web application, the auditor's experience, and the employed test design.

SEO audits usually involve various tools that automatically test selected SEO attributes. Their results are usually detailed and also presented with synthetic, aggregated overall scores (Król & Zdonek, 2020). Code inspection or exploration can also provide details of SEO quality. It involves manual or algorithmic verification of code syntax in domains such as HTML, CSS, and scripts and metainformation inspection. Therefore, the SEO audit of the geoportals was conducted using selected test tools (Table 2). These tools were chosen because they have been proven effective in other studies (Giannakoulopoulos et al., 2019; Król & Zdonek, 2020). In addition, one geoportal was audited using selected AI tools.

The audit also included a manual inspection of the HTML code of the geoportals aimed at identifying critical metadata important for SEO. The analysis covered the occurrence and content of the following tags: <title>, <meta name="description">, <meta name="keywords">, and any potential structural data. This stage aimed to complement the results of the automated and algorithmic audits by evaluating components that are often not fully accessible to external tools. The code inspection was an auxiliary tool for interpreting quantitative results, rather than a separate audit method in and of itself. Manual code inspection involved recording content attributes enclosed in selected meta tags (Table 3).

Table 2. SEO audit tools

Item	Test tool	SEO quality metric	Metric scale	Metric unit
T1	WeNet audit SEO	SEO Score	0–100	%
T2	Pixaura Free SEO Audit Tool	On-Page SEO	A+ / F-	unitless
T3	SEOmator Free SEO Audit Tool	SEO	0–100	%
T4	RankMath SEO Analyzer	SEO Score	0–100	unitless
T5	Seobility SEO Checker	SEO Score	0–100	%
T6	Website Grader	SEO	0–30	unitless

T1: https://audytseo.wenet.pl/; T2: https://www.pixaura.com/free-seo-audit/; T3: https://seomator.com/free-seo-audit-tool; T4: https://rankmath.com/tools/seo-analyzer/; T5: https://www.seobility.net/en/seocheck/; T6: https://website.grader.com/ (accessed on 26 September 2024)
Source: own elaboration.

Table 3. List of manually verified meta tags

Item	HTML meta tag attributes	Function
1	Meta description	The <meta name="description"> element provides a summary of a page's content that search engines include in search results.
2	Title	A succinct description of the page in the header section <title>#</title>. The title tag is displayed in the web browser tab label and on the search engine results page.
3	Keywords	Keywords relevant to the page enclosed in <meta name="keywords" content="#">

Source: own elaboration.

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Method and Scope of the Link Audit

Internal links and backlinks are an integral part of the SEO audit. A backlink link audit maps the position of the website in the online ecosystem. Every backlink is a recommendation. Additionally, the number and quality of backlinks can determine the website's position on the search engine results page. Indeed, there is a substantial association between the number of quality backlinks and the website's search engine results page rank (Ziakis et al., 2019). Therefore, the author assumes that high values of aggregate SEO metrics are associated with a large number of backlinks. This assumption was verified with a backlink audit using two test tools (Table 4).

Table 4. Selected characteristics of hyperlinks verified through the backlink audit

Item	Test tool	Characteristic / quantitative metric
1	Backlink Watch Backlink Checker	Referring Domains (RD) Total Backlinks; Nofollow Backlinks .gov Backlinks; .edu Backlinks
2	Ahrefs Backlink Checker	Backlinks Referring Domains

1) https://www.backlinkwatch.com/; 2) https://ahrefs.com/backlink-checker (accessed on 26 September 2024)
Source: own elaboration.

Approach and Workflow for the Algorithmic AI SEO Audit

The AI SEO audit was conducted under the 'regular user' model. It assumed the perspective of a user of a typical public GUI of selected LLM AI tools. The auditor used general and specific prompts (Table 5). This SEO audit employed selected online LLM AI platforms.

ChatGPT is a sophisticated language model based on the GPT architecture (Generative Pre-trained Transformer). It has been developed and powered by OpenAI (San Francisco, California, US). Microsoft Copilot (Redmond, Washington, US) is an AI tool integrated into many applications, such as Microsoft 365 and GitHub Copilot for programmers. Gemini Google DeepMind consists of AI systems capable of processing, generating, and understanding natural languages. They can support various Google applications and tools. Finally, Perplexity AI (San Francisco, California, US) is an AI-powered research and conversational search engine that answers queries using natural language predictive text. All these tools are based on Large Language Models (LLM), which can process and generate natural languages.

Table 5. AI applications used in the AI SEO audit

Item	Tool	Prompt
1	ChatGPT OpenAI SEO Audit Tool (DIAP Media)	1) Analyse the SEO of this URL: www* 2) Behave like an SEO auditor. Perform a Local SEO audit of geoportal: www 3) Behave like an SEO auditor. Perform a Local SEO audit of geoportal: www regarding metainformation
2	Microsoft Copilot	Perform an SEO audit of website: www
3	Gemini Google DeepMind	Perform an SEO audit of website: www
4	Perplexity AI	Analyse the SEO of this URL: www

1) https://chatgpt.com/; 2) https://copilot.microsoft.com/; 3) https://gemini.google.com/app; 4) https://www.perplexity.ai/; (accessed on 26 September 2024)
*www: https://sip.gison.pl/grybow (accessed on 26 September 2024)
Source: own elaboration.

Results Validation

The results interpretation was improved by using a benchmark. The benchmark for the present study was the geoportal at https://polska.geoportal2.pl (G6/G7) (accessed on 26 September 2024). The website offers critical map resources available in Poland. These are central, district, and municipal-level geospatial resources. Therefore, it was assumed that links to this portal are posted on more websites than links to individual municipal geoportals. Additionally, the Open PageRank (OPR) was measured for each geoportal to profile them better. The OPR is a global metric ranging from 0 to 10. Its value hinges on the number and quality of backlinks to a large extent (OPR, 2025).

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RESULTS

SEO Score audit results

The aggregated results revealed that G1 and G6 achieved the lowest SEO Score value under the employed research design (Table 6). At the moment of measurement, the SEO Score values reached 37 to 42 for G1. The results are relatively consistent across the measurement tools, except for SEOmator (T3), which seems to offer overestimated values. The SEO Score for G1 is not greater than 42, for G6, the threshold is 55 (out of 100), which is low on the scale.

Geoportal G4 reached the highest score at the moment of measurement. Still, it is an 'average' result considering the measurement scale. The SEO Score for G4 ranges from 53 to 75 (Table 6). The values are relatively consistent across all the test tools except for SEOmator (T3). Similar results were noted for G5. However, relatively significant differences to its disadvantage were noted in the results for test applications T1 and T5. SEO score for G5 ranges from 36 to 56 except for the results from T3 as discussed in section '5.2. Observations'.

Link Audit Results

Geoportal G1 had the most backlinks. The smallest number was found for G2. Referring Domains (RF) turned out to be the most accurate metric (Table 7). According to both applications, each of the tested geoportals had referral links on only a few unique

Table 6. Results of the aggregate SEO Score, BTB

Item	Test tool	G1	G2^	G3	G4	G5	G6
T1	WeNet audit SEO	37	53	46	59	36	33
T2	Pixaura Free SEO Audit Tool	F	D	N/A	C+	D-	D-
T3	SEOmator Free SEO Audit Tool	82	N/A	82	92	100	82
T4	RankMath SEO Analyzer	42	64	40	53	54	44
T5	Seobility SEO Checker	41	N/A	68	75	56	55
T6	Website Grader	25	25	30	30	30	25

SEO Score (BTB – bigger-the-better)
G1: http://trzebinia.geoportal2.pl; G2: https://lubicz.e-mapa.net; G3: https://sip.gison.pl/grybow; G4: https://miekinia.e-geoportal.pl; G5: https://zgierzsip.mapmaker.online; G6: https://polska.geoportal2.pl (accessed on 26 September 2024)
N/A – the test could not be completed; Pixaura Free SEO Audit Tool (T2) – metric scale: F, E, D, C, B, A (F–E – poor), D–C (average), B–A (good); Website Grader (T6) – metric scale 0–30
▪ 0–49 (T6: 0–9) (poor), ▪ 50–79 (T6: 10–19) (average), ▪ 80–100 (T6: 20–30) (good), based on (Król & Sroka, 2023)
^ The robots.txt configuration prevents selected crawlers from accessing the resources. This renders the audit impossible (mark N/A).
Source: own elaboration.

Table 7. Link audit results according to Backlink Watch Backlink Checker

Geoportal	Referring Domains*	Total Backlinks	Nofollow Backlinks	.gov Backlinks	.edu Backlinks
G1	3	23117	852	0	0
G2	8	302	0	2	0
G3	4	3636	0	0	0
G4	19	646	14	0	0
G5	0 (no backlinks to report)	—	—	—	—
G6/G7	9/34	134/146	6/94	0	0

*The number of unique websites with referral links to the geoportal (accessed on 26 September 2024)
Source: own elaboration.

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websites. The small number of RF was confirmed by relatively small values of OPR, which did not exceed 2/10 (Table 8).

In the case of application Ahrefs, the number of recorded backlinks does not depend on the mode of the audit except for G3 (Table 8). This may be because G3 is the only tested geoportal with a URL indicating a subdirectory, while the addresses of the other geoportals are subdomain names. Note that the number of backlinks recorded in the different G3 test modes is relatively large. It may be because in the 'Subdomains' mode (S), Ahrefs reports results for the main domain name (https://www.gison.pl; accessed on 26 September 2024), rather than the subdirectory, i.e. https://sip.gison.pl/grybow (G3; accessed on 26 September 2024). The number of unique referring domains seems to confirm it. These are the unique domain names with backlinks to G3 (Table 8).

Table 8. Link audit results according to Ahrefs

Geoportal	Backlinks		Referring Domains		Open Page Rank Value
	D	S	D	S	
G1	24K	24K	3	8	1.68
G2	16	16	4	4	1.31
G3	3.5K	5.9M*	8	503	ND
G4	12K	12K	5	8	1.37
G5	4.8K	4.8K	2	2	0.41
G6/G7	41/138	1M/499	14/22	67/63	3.39/2.53

G1: http://trzebinia.geoportal2.pl; G2: https://lubicz.e-mapa.net; G3: https://sip.gison.pl/grybow; G4: https://miekinia.e-geoportal.pl; G5: https://zgierzsip.mapmaker.online; G6: https://polska.geoportal2.pl; G7: https://www.geoportal2.pl (accessed on 26 September 2024)
ND – test impossible because of the structure of the URL
S – test configuration: 'Subdomains' (the result includes linking to URLs at variance with SEO guidelines)
D – test configuration: 'Exact URL' (the result covers only linking to the exact URL: http://trzebinia.geoportal2.pl) (accessed on 26 September 2024)
*In the case of a URL that indicates a subdirectory, when the crawler is set to the 'Subdomains' (S) mode, all the links with the initial part of the URL are counted, i.e. https://sip.gison.pl, and there are many such links (accessed on 26 September 2024). Therefore, such a result applies to the landing page of GISON rather than the geoportal of Grybów municipality
Source: own elaboration.

The analysis of the results for the reference geoportal (G6/G7) could suggest that external websites can link to the main website (G7) rather than the geoportal, which is under a subdomain name (G6). It is corroborated by the results of the backlink audit of the main domain name (G7). However, it is not corroborated by the so-called 'domain name strength' defined as the value of the Open Page Rank (OPR). The difference in OPR values for G6 and G7 is relatively large, amounting to 3.39 (G6) and 2.53 (G7), respectively. Note here that the value of OPR is estimated mainly based on the number of backlinks. The quality of the links remains unknown.

Code Inspection: Metadata Analysis Results

Exploratory research revealed that the HTML code of all the tested geoportals contains meta title, keywords, and description tags. Most of them have content (Table 9), but the content is of dubious value in the context of Local SEO.

The analysis of the content of the <description> meta tags revealed that they do not contain keywords at all or contain a description of the geoportal's functionalities, which offers no value in the context of Local SEO. A municipality name appears only for G2 and G4 (Table 10). The untapped potential of the

Table 9. Measured lengths of titles and descriptions of the geoportals according to RankMath SEO Analyzer

Geoportal	Title (number of characters)	Pass*	Meta description (number of characters)	Pass
G1	24	1	none	0
G2	53	1	283	0
G3	31	1	none	0
G4	51	1	95	1
G5	8	1	96	1
G6	11	1	none	0
G7	29	1	none	0

*According to RankMath SEO Analyzer, most search engines truncate meta description to 160 characters and meta titles to 75 characters (accessed on 26 September 2024)
Source: original work based on RankMath SEO Analyzer.

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meta description tag is easily seen in the case of G5. Its meta description tag contains a characterisation of the geoportal's underlying geoinformatics system rather than the municipality it represents (Table 10).

Table 10. Meta description tag content

Geoportal	Meta description*	Pass
G1	none	0
G2	e-map: the municipal geoportal (a website by Lubicz Municipality Office) is a detailed, up-to-date, and free map. It represents administrative boundaries, an orthophoto, a cadastral map, a base map, addresses, and local zoning plans and has a plot and address search engine	1
G3	none	0
G4	Spatial Information System – Miękinia map portal local zoning plans	1
G5	MapMaker – Advanced tool for creating, editing and publishing digital spatial data and GIS maps	1
G6	none	0
G7	none	0

*Website description as specified in the source code in (meta name="description"). Original text in Polish and its English translation
Source: own elaboration.

The analysis of the title meta tag shows that these tags do not contain keywords of any value regarding Local SEO. Most of the titles are general, unspecific and contain the generic phrase 'spatial information system'. A municipality name appears only for G2 and G4 (Table 11), which can be considered consistent with Local SEO recommendations. Note the situation of G4. It is not recommended to put dates in the title tag because they do not hold any Local SEO value and become irrelevant fast.

Table 11. Page title in the header section of metainformation and the HTML specification

Geoportal	Title*	HTML specification
G1	GEOPORTAL 2 GEOPORTAL 2	HTML5 charset=Windows-1250
G2	Lubicz – Spatial Information System – e-mapa.net	XHTML 1.0 Strict charset="UTF-8"
G3	Spatial Information System	HTML5 charset="UTF-8"
G4	Miękinia Municipality spatial information system 2021	HTML5 no meta tag http-equiv="Content-Type"
G5	Mapmaker	HTML5 charset="UTF-8"
G6	GEOPORTAL 2	HTML5 charset=Windows-1250
G7	GEOPORTAL 2 • project website	HTML5 charset="UTF-8"

*Website title as specified in the source code in the (<title></title>) HTML tag. Original text and its English translation
Source: own elaboration.

Table 12. Meta keywords tag content

Geoportal	Keywords*	Pass
G1	Poland. Maps, Cities	0.5^
G2	map, addresses, streets, wms, emuia, geoportal, data, impa, address points, geo-system, inspire, current, online, detailed, geodetic, base, satellite, free, municipality, city, village, investments, local zoning plan, spatial development, local plans, development study, plots, plot numbers	1
G3	spatial information system, spatial planning, map portal, GIS, hard infrastructure, WMS layers, public consultation, APP resources	1
G4	map, geoportal, local zoning plan, spatial development, local plans, development study, plots for sale, poi	1
G5	none	0
G6	Poland, Maps, Cities	0.5^
G7	none	0

*Keywords specified in the (meta name="keywords") HTML tag of the source code
^ The tag content should be carefully considered and useful for SEO purposes. Although the website's code contains keywords, they are too few and too generic to have any SEO value
Source: own elaboration.

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The keywords meta tag of G1 contains generic keywords. They are not specific to the website and fail to offer a unique description of its profile or content (Table 12). It is not advisable to use generic keywords in the keywords meta tag such as 'up-to-date', 'streets', 'data', 'base', 'GIS', or 'map', as is the case for G2, G3, and G4 because they have no Local SEO value.

The study shows that the meta title, keywords, and description tag content is adequate in terms of quantity (character count) but lacks semantic value. It is not enough to enter just any content in the tags. It should be carefully considered so that the keywords best describe the profile of the specific geoportal and municipality.

LLM SEO Audit Results: a Case Study

The results from the LLM-based tools are presented as a case study because they concern a single, representative geoportal subjected to qualitative analysis. This approach is exploratory and has a different scope and presentation method than the previous, quantitative SEO audits. Unlike in automated tests, LLM evaluation is based on reconstructing end-user experience and performing a semantic analysis of search results generated by AI models.

The case study involves G3, which is the only tested geoportal made available under a subdirectory URL. The results of the audit conducted using the ChatGPT SEO Audit Tool seem to follow from the exploration of text elements of G3 (Table 13). The main difference between the other test tools (mechanical SEO Score audit) and the ChatGPT SEO Audit Tool is that ChatGPT offers monitoring results, general recommendations, and specific proposed changes (examples) in selected SEO attributes, particularly for Local SEO. Although the report is extensive, it is also superficial. Perplexity also offered targeted SEO tips.

Table 13 presents SEO audit results for geoportal G3 conducted with the ChatGPT SEO Audit Tool. The analysis concerned key SEO areas, such as metadata structure (title, description), headings hierarchy (H1, H2), website responsiveness, loading time (s), mobile friendliness, accessibility, and indexability. The results show that G3 meets some basic SEO criteria, but some highly relevant issues were also identified, such as suboptimal metadata, overgeneralised titles (<title>), inadequate mobile optimisation, and long loading times. The SEO Audit Tool had specific optimisation recommendations. It flagged areas in need of improvement to boost the website's SERP rank and usability.

The SEO Audit Tool analyses the current state and offers a list of recommendations based on the results. In response to a detailed prompt (second-degree prompt): 'Behave like an SEO auditor. Perform a Local SEO audit of geoportal: https://sip.gison.pl/grybow' (accessed on 26 September 2024), the system output ad-hoc analysis results and multiple recommendations (Table 14). However, the recommendations are far from perfect and need to be edited for format and semantics.

Table 14 is a list of recommendations for G3 generated by the ChatGPT SEO Audit Tool focused on Local SEO. The recommendations aim to improve the website's visibility in local search results and its accessibility to users from a specific region. The recommendations include adding local keywords to the metadata (such as city or region), creating and optimising Google Business Profile (former Google My Business), adding it to maps and local industry directories, adding contact data in a standardised format (schema.org) with location data, and increasing the number of backlinks from local sources. The recommendations demonstrate that Local SEO can enhance the regional availability of digital services, even for public institutions such as city geoportals.

The ChatGPT SEO Audit Tool does not offer in-depth audits of technical attributes: performance, accessibility, or responsiveness (Technical SEO). It recommends using dedicated tools, such as Google Lighthouse. Therefore, the ChatGPT SEO Audit Tool seems particularly useful for content audits and website's textual element audits in general.

Copilot AI broke the SEO audit down into two stages. First, it listed critical SEO components

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Table 13. ChatGPT SEO Audit Tool SEO audit results for G3

SEO quality attribute, measurement/reading result	Recommendations
Current Title Tag: Grybów – System Informacji Przestrzennej (Grybów – Spatial Information System).	Recommended Title Tag: GIS mapping Grybów or Geospatial data Grybów.
Current Meta Description: There appears to be no specific meta description when viewing the page source, which can negatively impact click-through rates (CTR) from search results.	Improve Meta Description. Recommended Meta Description (150–160 characters): Explore Grybów's interactive maps and spatial data with the official GIS platform.
Headings (H1, H2, etc.): It's unclear if the page uses a proper heading structure, as map-centric platforms often lack visible text.	Recommended H1: Grybów Spatial Information System; H2: Interactive Maps or GIS Data Tools etc.
Content Quality: The platform seems primarily focused on delivering maps with minimal textual content.	Recommendations: Add More Content. Adding descriptive text about the tools available.
Current URL: https://sip.gison.pl/grybow	Recommended URL: https://sip.gison.pl/grybow-map-services.
Internal Linking: Map-focused sites often lack internal links.	Recommendations: adding links to relevant services or pages (e.g., tutorials, FAQs, or specific GIS data) can improve user experience and SEO.
Page Speed Optimisation; Mobile-Friendliness: optimal.	Recommendations: additional verification with dedicated test applications.
Backlinks and Domain Authority: further tests needed. Without a detailed backlink analysis, it's hard to determine the website's current standing.	Recommendations: focus on getting links from relevant sources such as local government websites, geospatial organisations, or academic institutions.

G3: https://sip.gison.pl/grybow (accessed on 26 September 2024)
Source: original work based on ChatGPT SEO Audit Tool.

Table 14. Selected recommendations from the ChatGPT SEO Audit Tool regarding Local SEO

Audit result (current state)	Recommendations
No local keywords in the content, title, and page description.	Add keywords of local relevance to the title and meta description such as Grybów Geoportal – maps, spatial information, and plots. Page content: Increase the number of keywords in the page content by describing the geoportal's services, such as 'browse plots in Grybów', 'Grybów surveying information'.
The Grybów Geoportal most probably is not linked to any Google My Business profile or local online directories.	Create a Google My Business profile for the geoportal or Grybów Town Office to improve the website's search engine results page rank. Submit the geoportal to local online directories for local backlinks.
NAP (Name, Address, Phone) and local contact data: the website lacks a distinctive NAP for Grybów's location. It is critical for Google algorithms when composing local search results.	Make sure that details such as name, address, and phone number are exposed on the main page and on the contact page. Use them consistently across the website and other sources, such as Google My Business.
Load speed (no real-time measurement).	General recommendations: optimise graphic files, compress files, minify code.
Responsiveness and mobile friendliness (Mobile SEO) (no real-time measurement).	Responsiveness tests recommended.
Content and UX (User Experience) optimisation (no real-time measurement).	A general recommendation to optimise content and conduct UX testing.
Local backlinks (no real-time measurement).	A general recommendation: Collaborate with local institutions, media, and organisations to gain more backlinks.

Source: original work based on the ChatGPT SEO Audit Tool.

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(first-degree prompt, Technical SEO): loading speed, URL structure, content and keywords, meta tags, external links and backlinks, responsiveness, and security. A more detailed consideration of the response revealed that it did not contain audit results for G3 but a set of general and universal tips useful for optimising any website. The response to the second-degree prompt concerning content audit was more detailed. Still, in this case, the tool failed to provide insights based on actual measurements as well. It merely presented general qualitative characteristics advisable for online content. Hence, Copilot AI does not perform an audit defined under the employed research design as an actual measurement or evaluation. Instead, it provides generic information about components of the SEO audit and what can be done in terms of SEO.

Gemini promptly notifies the user about its limited SEO capabilities. The results are divided into on-page SEO and off-page SEO. Still, these are not test results. The system offers only general and universal recommendations. Its report additionally includes a list of potential problems and recommendations. These are not, however, linked to specific audits but a collection of the most common SEO mistakes and shortcomings. The user is also informed that to get a personalised report, they need to employ dedicated SEO tools. Similar results were achieved with Perplexity AI, which provided more specific advice on content SEO. The tool indicated the word 'Grybów' (G3) as critical for Local SEO (Primary Keyword) and a potential context and scope of its use, especially in Long-Tail Keywords.

DISCUSSION

The results of the ChatGPT SEO Audit Tool, considered a case study, demonstrate the potential of LLMs as a new class of tools for supporting Local SEO auditing. As opposed to traditional methods driven by technical metrics, LLMs can evaluate visibility from the user's perspective, taking into account content semantics, usability, and the local context of searches. The model's recommendations (Table 14) align with the applicable Local SEO guidelines and are adapted to the profile of a public institution. Hence, LLM-based tools can offer analytical and diagnostic services despite limited access to the website's back-end. If employed in future studies, this approach could help devise an automated model for evaluating geoportals based on AI-simulated user behaviour.

The results of the SEO audit seem inconclusive. SEOmator (T3) provided clearly higher values for the synthetic aggregate SEO Score metric. The excessively high results from this tool are significantly different than those from the other applications, suggesting that SEOmator may be less reliable. On the other hand, Website Grader (T5) provided comparatively good SEO results. Note that the synthetic measurement results depend on the component tests. The test applications differ in what component tests they employ, even though they have many common elements due to design standards. A thorough analysis suggests that high SEO Score values resulted from a modest test kit in T3 and T5, so the SEO audits with these applications are superficial. This means, in turn, that a high SEO score does not necessarily prove the website is of high quality. The result's reliability can only be evaluated after the component test kit is verified. Other studies corroborate this conclusion. A detailed report has been demonstrated to bring more value to technical SEO than an aggregate synthetic score (Król & Zdonek, 2020).

The 'shortcomings of component test kit' constituting SEO Score are offset under the employed research design by using several test tools as a form of cross-validation. Cross-validation means a quality audit with at least two test tools. Component test kits of each tool partially overlap, which makes them complementary. This way, the auditor can identify more design details in need of SEO action. Preferably, results from various tools should be similar. This would support the synthetic score.

A detailed analysis of a list of backlinks found that for all the geoportals, the main websites linking to them were those of the respective municipalities, which is only to be expected. The rest of the backlinks are most often found on general-purpose geoinformation

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websites, directories, or content warehouses. These links offer limited Local SEO values. Therefore, it is recommended to include global websites with strong top-level domains like .gov or .edu and 'local Internet' websites in one's link building strategy.

Universal Recommendations

The responses from the AI tools make up a 'typical geoportal' SEO specification. It contains characteristics of the geoportal and SEO recommendations based on the audit results.

A typical geoportal is designed to provide maps with a minimum of text. The primary medium is the map and its components. They contain very limited text and usually do not use headers (H1–H5). However, the map as the centrepiece does not preclude text or headers. Therefore, SEO audit reports often advise adding texts with keywords (focused on Local SEO) and headers to the geoportal's landing page. In addition, being a map service, the geoportal usually has little to no internal links. Consequently, audit reports frequently mention linking to services or subpages (such as tutorials, FAQs or thematic geodata). Moreover, geoportals are typically responsive: they adapt the interface to the display. They also load fast regardless of the device on which they are viewed. In most cases, they are available under SSL-protected URLs. Unfortunately, the URLs are often not SEO-friendly because of strings of characters users do not understand. It is another common recommendation to adapt the URL to SEO principles. In addition, geoportals usually have no support in the global online ecosystem. Increasing their social media presence or posting links on third-party websites is often recommended. This way, editors can use their available resources to effectively pursue optimisation strategy for municipal geoportals in the context of local search results (answer to Q1).

Considering the results, a number of optimisation efforts are recommended to improve the visibility of local government geoportals on SERPs, particularly regarding Local SEO. The primary intervention area is standardisation and improvement of metadata, including the <title> and <meta name="description"> tags, which should contain local keywords and reflect the actual content structure of the website. The data structure should follow schema.org guidelines (such as LocalBusiness, Organization), for better content indexation and a greater chance for rich snippets.

Another important technical domain to be improved is to optimise the website's performance, particularly loading time and interface responsiveness on mobile devices, according to the Google PageSpeed Insights. The NAP data (Name, Address, Phone) should be complete and consistent. It is recommended that they follow a standardised format and be placed in an easily visible part of the page. Regarding off-page SEO, it is advisable to complete the institution's profiles on Google Business Profile and similar directories, and register with industry-specific map directories, which reinforces local visibility within the online ecosystem. Next, the internal links architecture should be improved and supported with reliable backlinks from local and institutional domains. When combined, these actions could improve geoportal visibility among organic search results and user experience.

Additionally, the backlinking strategy should be considered especially carefully. It was the least developed component of the investigated geoportals. Local government geoportals would preferably build their backlink profile using local, institutional, and thematic sources. It is recommended to establish cooperation with other public administrations, local media, NGOs, and universities whose websites enjoy high domain authority and are relevant to the geoportal's function. Another worthwhile angle is to place backlinks on official city and regional portals and local directories, which can substantially impact the website's position on geolocal SERPs. These efforts should be regular and in line with Google guidelines to ensure durable linking performance and prevent website downrating due to quality infringements.

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CONCLUSIONS

The study sheds new light on the position of geoportals in the global online ecosystem and SEO auditing methods using Large Language Models (LLMs). It has revealed that the tested geoportals have untapped potential for conversion, image, and brand building and receive no SEO support from the local public administrations to which they belong. This is the case for both off-page SEO and on-page SEO, especially regarding link building and properly composed metadata. It is evident from relatively small numbers of referring domains and backlinks, but also low values of global quality indicators revealed by the study. Metadata analysis has also confirmed this because local search engine optimisation of metainformation is required. In addition, the study demonstrated that:

1. Artificial intelligence tools employed in the study were only slightly useful for assessing geoportal quality under the employed research design (answer to Q2). ChatGPT by OpenAI exhibits the best capabilities here (on 4 October 2024). This tool has a component dedicated to evaluating website quality, the ChatGPT SEO Audit Tool (DIAP Media). Still, it is also limited.

2. The tested AI tools (LLMs) do not perform an SEO audit in real time because of their technical and logical design. This limits their capability of delivering accurate and specific SEO audit results. Instead, they can perform a 'theoretical SEO audit' in the form of a list of good practices based on analyses of large (textual) datasets. This means that input (measured values) is necessary for them to generate a detailed SEO report. They can also employ dedicated crawlers (auxiliary LLM components) that verify a website's content or test it under controlled conditions. Such Large Language Models as ChatGPT can be useful when describing or interpreting results of measurements.

3. An SEO audit report generated in response to an LLM prompt is, in fact, a summary of universal recommendations. It contains generic principles, tips, and examples of good SEO practices. Moreover, the study shows that more detailed prompts yield the same information but rearranged. This means that increasing prompt accuracy fails to stimulate more detailed SEO audit results.

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