

CHANGE IN WEB ACCESSIBILITY OF MUNICIPAL WEBSITES (2024–2025) AND THE ROLE OF POPULATION SIZE: EVIDENCE FROM BULGARIA

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Abstract: The purpose of this study is to assess the level, structure, and temporal dynamics of web accessibility in Bulgarian municipal websites, and to examine whether accessibility outcomes are associated with municipal size or demonstrate systematic improvement over time. The analysis is based on an almost complete national coverage of 264 out of 265 municipal websites, which allows the study to describe the actual structural state of accessibility rather than infer trends from a sample. Accessibility was evaluated in two consecutive years (2024 and 2025) using the automated WAVE assessment tool, with official population data incorporated as a proxy for municipal capacity. Given the highly skewed and zero-inflated nature of accessibility error distributions, non-parametric statistical methods were employed, including Wilcoxon signed-rank tests to assess temporal change and Spearman rank correlations to examine associations between municipality size and both accessibility levels and their dynamics. The results indicate no statistically significant improvement in overall web accessibility at the national level, even after controlling for extreme outliers, and no consistent relationship between municipality size and either the level or rate of change in accessibility. Although the number of websites with zero detected errors increased over time, this improvement was counterbalanced by stagnation or deterioration among a substantial proportion of municipalities, resulting in increased dispersion and institutional inequality. Domain-specific analyses show that the most prevalent and harmful accessibility barriers – particularly those related to contrast, navigation, and text alternatives – remain structurally stable and widespread, while observed changes are largely confined to technical domains such as ARIA and empty interactive elements and affect only a limited subset of websites. The study concludes that web accessibility in the municipal sector is characterized by institutional inertia and fragmentation, driven more by ad hoc technological updates than by coordinated governance or policy implementation, highlighting the need for stronger institutional accountability, systematic monitoring, and capacity-building to advance digital inclusion in the public sector.

Keywords: web accessibility, municipal websites, WCAG compliance, public sector, digital inclusion

1. INTRODUCTION

Web content accessibility is a key component of digital inclusion and equitable access to public services and information in an increasingly online society. It refers to the extent to which people, including those with sensory, cognitive, or motor impairments, are able to perceive, understand, navigate, and interact with web content and functionality (W3C, 2018). A lack of accessibility not only restricts individual participation but may also conflict with legal and human rights frameworks that safeguard equal access to information and services (UN, 2006).

In the context of public administration, municipal government websites serve as primary access points to information and services, including documentation, announcements, e-government services, and tools for public participation. Ensuring web accessibility on these platforms is therefore not merely a matter of technical design, but also one of public accountability and social inclusion (Youngblood & Mackiewicz, 2012). Previous research across a wide range of national contexts has consistently demonstrated low levels of accessibility in public sector websites, as well as the presence of systemic barriers that disproportionately affect users with disabilities (Gambino et al., 2016; Ismailova & Inal, 2018; Karaim & Inal, 2019; Inal, Mishra & Torkildsby, 2022, Valtolina, Fratus 2022, Akgül, 2022, Fernández-Díaz et al., 2023, among others).

At the European level, the regulatory framework for the public sector is clearly defined by Directive (EU) 2016/2102 on the accessibility of the websites and mobile applications of public sector bodies, which obliges Member States to ensure that public digital services comply with harmonised accessibility standards. The Directive links the technical reference framework to the harmonised European standard EN 301 549, which, with regard to web content, is based on the requirements of the Web Content Accessibility Guidelines (WCAG) developed by the World Wide Web Consortium (W3C) (Caldwell et al., 2008). WCAG define testable success criteria for accessibility, organised around four principles: perceivability, operability, understandability, and robustness.

In practical evaluations of public sector websites, WCAG requirements are frequently operationalised through automated tools designed to detect common types of violations, such as missing text alternatives, contrast issues, empty controls, incorrect ARIA references and others, all of which are associated with measurable barriers for end users. Automated tools such as WAVE are widely used in quantitative accessibility assessments due to their consistency and reproducibility (Vigo et al., 2013). Although automated evaluations do not capture all accessibility

barriers – particularly those requiring human judgement – they are valuable for longitudinal and comparative analyses when applied consistently over time (Acosta-Vargas et al., 2018).

Despite these regulatory and technical advances, empirical evidence on national-level dynamics of web accessibility in public sector websites remains limited, particularly in Eastern Europe. This study addresses this gap by conducting a longitudinal assessment of municipal websites in Bulgaria – a context in which digital public services are legally required to comply with EU accessibility standards, yet where systematic comparative analysis remains scarce.

Using automated WAVE-based assessments for 254 out of 265 municipal websites across two consecutive years (2024 and 2025), the study examines not only the level of accessibility barriers, but also their structural composition and temporal change across specific WCAG-related error domains. In addition, official population data are incorporated to explore the structural relationship between municipal “size” and the level of reported accessibility errors. This relationship is relevant from the perspective of institutional capacity – financial, organisational, and expert – for maintaining and developing web presence, and has direct policy implications.

The study seeks to answer three main research questions:

- Is there a statistically significant change in the accessibility of municipal websites over time?
- Is municipal size associated with the level or dynamics of web accessibility?
- How is the internal composition of accessibility errors across key WCAG domains structured, and does this structure change over time?

The findings contribute to broader debates on the effectiveness of web accessibility policies, institutional capacity, and digital inclusion in the public sector.

2. METHOD

Data and scope

The study covers the websites of 264 out of the 265 municipalities in Bulgaria, representing almost the entire population of municipal websites. One municipality was excluded due to the technical impossibility of assessing its website in 2024. As a result, the analysis is based on a national census rather than a sample and describes the actual structural state of web accessibility at the municipal level.

The homepage of each website was evaluated in two consecutive years (2024 and 2025) using the automated accessibility evaluation tool WAVE. For each website, the total number of detected accessibility errors was recorded, along with detailed data on specific error categories corresponding to key areas of WCAG 2.1.

Municipal population data were obtained from the National Statistical Institute and used as an indicator of institutional capacity (NSI, 2025). As municipal population changes only marginally over a one-year period, a single population measure was used as a time-invariant structural characteristic. To account for the strongly skewed distribution of municipality size, population was logarithmically transformed using the natural logarithm (ln).

Accessibility evaluation tool

Accessibility assessments were conducted using WAVE, a widely adopted automated tool aligned with WCAG requirements and applied in numerous empirical studies (Lazar et al., 2013; Vigo et al., 2013 and others). WAVE identifies a range of WCAG-related error types – such as contrast errors, missing alternative text, form label issues, broken ARIA references, and others – and generates error counts that serve as indicators of potential accessibility barriers encountered by users with disabilities. Although automated tools do not capture all accessibility barriers (Vigo et al., 2013), the systematic reporting of quantitatively measurable errors by WAVE provides a reproducible basis for longitudinal and comparative analysis.

Variables

Three groups of variables were analysed:

- Overall accessibility indicators: (a) the total number of WAVE-detected errors in 2024 and in 2025, serving as the primary indicator of accessibility performance; and (b) the change in errors between the two years ($\Delta\text{errors} = \text{errors}_{2025} - \text{errors}_{2024}$), capturing the direction and magnitude of temporal change in accessibility.
- WCAG-related error types: Counts of specific categories of errors – such as contrast errors, missing alternative text, missing form labels, empty links, empty buttons, and ARIA-related errors – for both 2024 and 2025. These categories are used in descriptive analyses to illustrate the composition of accessibility problems but are not the primary focus of the main inferential models. For all error types, year-to-year differences were also calculated.

- Structural variable: $\ln(\text{population})$, representing the official population size of each municipality by the end of 2024. Population was log-transformed to address skewness and to allow more interpretable associations in non-linear contexts (Tabachnick & Fidell, 2013).

In addition, proportional indicators were constructed to capture the internal structure of accessibility failures. For each municipality and each year, the share of each error category was calculated as:

$$\text{Share}_{\text{type,year}} = \text{Errors}_{\text{type,year}} / \text{Total Errors}_{\text{year}}$$

This approach prevents large websites with high absolute numbers of errors from dominating national patterns and allows each municipality to contribute equally to the structural analysis.

Distributional properties and robustness

The number of accessibility errors exhibits strong right skewness and excess zeros across all variables, violating the normality assumptions required for parametric tests (Cameron & Trivedi, 2013). Shapiro-Wilk tests confirmed non-normal distributions ($p < 0.001$ for all primary variables), thereby justifying the use of non-parametric methods.

One municipality displayed an exceptionally high number of errors (over 8,000) relative to all others. This case was treated as an extreme outlier and subjected to robustness checks. All primary analyses were conducted both with and without this observation, in accordance with standard recommendations for handling influential cases in applied research (Field, 2018). The substantive results were unaffected by its exclusion, confirming that the findings are not driven by isolated anomalies.

Statistical methods

Because the dataset represents the full population of municipalities rather than a sample, statistical tests are employed to assess structural regularities and temporal dynamics rather than to estimate uncertainty with respect to an external population. Given the absence of normality and the ordinal or count-based nature of most variables, the following procedures were applied:

- Wilcoxon signed-rank tests were used to assess changes between 2024 and 2025 in the total number of errors, in specific WCAG-related error categories, and in proportional error shares. This non-parametric test is appropriate for paired census data with non-normal distributions (Hollander, Wolfe & Chicken, 2014).

- Spearman's rank correlation was employed to evaluate the association between municipality size ($\ln$ population) and: (1) error levels in each year; and (2) year-to-year changes in errors (Δerrors and $\Delta\text{error}_{\text{type}}$). Spearman's rho was selected because it does not assume linearity or normality and is robust to outliers and skewed distributions.

Structure of proportional errors

To examine the internal composition of accessibility failures, category-specific error shares were calculated for each municipality. This approach is consistent with recommended practices in comparative accessibility research, where proportional measures are used to avoid domination by extreme values and to reflect relative rather than absolute burdens, as demonstrated in related studies on web accessibility performance profiles.

Together, these methods allow the study to distinguish between: overall stagnation or change; structural inequality by municipality size; and shifts in the internal composition of accessibility failures.

Instrument validity and limitations

The WAVE accessibility evaluation tool detects a substantial range of relevant errors, particularly those that can be assessed automatically (e.g. contrast issues, missing alternative text, empty ARIA elements). As documented in prior research, automated tools cannot identify all accessibility barriers, especially those requiring human judgement, such as the appropriateness of alternative text or logical reading order. Consequently, the results should be interpreted as estimates of the lower bound of accessibility problems, capturing systematic and objectively detectable violations rather than the full spectrum of barriers encountered by users. This limitation is inherent in all large-scale automated accessibility assessments and does not introduce bias in temporal or cross-municipality comparisons, as the same tool and procedures were applied consistently across both waves.

Temporal comparability

All municipal websites were assessed using the same tool and configuration in July 2024 and August 2025, ensuring measurement invariance across waves. Observed changes therefore reflect genuine differences in website implementation rather than changes in the measurement instrument.

Population-level inference

Because the dataset covers nearly the entire population of Bulgarian municipalities, statistical tests are not used to generalise to a larger population but to assess structural regularities, temporal stability, and internal differentiation within the national system. In this context, non-significant p-values indicate the absence of systematic structure rather than insufficient statistical power.

Use of previously published data

Parts of the empirical dataset used in this study have been published previously. Accessibility assessment for Bulgarian municipal websites from 2024 were reported in a peer-reviewed chapter (Hristova, 2025), while the 2025

assessment were included in a monograph authored by the present researcher, which also contains accessibility data for healthcare institutions, schools, and universities (Hristova, 2026).

In the present study, these datasets are reused exclusively for municipal websites and combined into a two-wave longitudinal design. The analytical contribution of this article lies not in the individual annual measurements themselves, but in their systematic temporal comparison, the integration of population-based structural indicators, and the domain-specific decomposition of WCAG error types – none of which were undertaken in the earlier publications. Only methodological elements necessary to support these new analytical objectives are described here, while the original data collection procedures are documented in the respective earlier works (Hristova, 2025; Hristova, 2026).

3. RESULTS

The empirical analysis covers 264 out of 265 Bulgarian municipalities, effectively representing the entire population of municipal websites. Consequently, the results describe not a sample-based trend but the actual structural state of accessibility across municipal websites in the country.

Descriptive overview of accessibility errors

Across the 264 municipal websites included in the assessment, substantial variation is observed in the number of accessibility errors detected by WAVE in both waves of evaluation. The number of websites with no reported accessibility errors shows a notable improvement. In 2024, only 18 websites were assessed as fully compliant with web accessibility requirements, whereas in 2025 this number increased to 50 websites. When extreme values are excluded (specifically, the website of the municipality of Garmen municipality, which exhibited an exceptionally high number of errors), the total number of errors rises from 10019 to 11195, representing an increase of approximately 12%. After excluding extreme values, the mean number of errors per website increases from 38 in 2024 to 42 in 2025. This indicates that although some websites have improved – as reflected in the increased number of error-free sites – the quality of web accessibility for a large proportion of municipal administrations has deteriorated or remained unchanged.

The decline in the median number of errors from 24 to 17.5 suggests increasing polarisation: one group of websites shows substantial improvement (a reduction in errors), while another group deteriorates or continues to exhibit numerous shortcomings. This pattern is further supported by the standard deviation, which nearly doubles from 52.00 to 89.87. This large dispersion indicates growing inequality between individual municipal administrations in terms of accessibility quality, constituting a clear example of institutional-level digital stratification.

The minimum and maximum values further demonstrate that while some websites are entirely free of detected errors, others remain in a state of extreme inaccessibility, which seriously undermines the overall effectiveness of public digital communication.

In terms of error composition, the most frequent error types in both years relate to missing alternative text for images, contrast issues, empty or improperly labelled interactive elements, and ARIA-related problems. These categories correspond to core WCAG principles of perceivability, operability, and robustness, highlighting that accessibility problems are not merely cosmetic but affect fundamental aspects of assistive technology usability.

Overall accessibility dynamics

Paired comparisons of the total number of accessibility errors detected by WAVE between 2024 and 2025 reveal no statistically significant change (Wilcoxon signed-rank test, $p = 0.605$; $p = 0.525$ after excluding the extreme outlier). This indicates that, at the national level, the accessibility of municipal websites did not improve in any systematic way over the one-year period. The absence of change remains robust even after controlling for the extreme case with an unusually high number of errors, confirming that the observed stagnation is not driven by isolated anomalies.

Furthermore, municipality size, measured by population, is not associated with the number of accessibility errors in either year (Spearman's $\rho = 0.070$, $p = 0.260$ for 2024; $\rho = 0.007$, $p = 0.913$ for 2025), nor with changes in errors over time ($\rho = -0.066$, $p = 0.282$). This indicates that neither current accessibility performance nor its evolution is related to municipal capacity, as approximated by population size.

Taken together, these findings demonstrate that the system of accessibility across Bulgarian municipal websites shows neither improvement over time nor structural differentiation by municipality size. Consequently, accessibility outcomes are best characterised as institutionally unstructured and inert.

WCAG domain-specific dynamics

To examine whether stagnation at the aggregate level conceals changes within specific accessibility domains, individual WCAG-related error types were analysed.

“Contrast errors” showed no significant change between 2024 and 2025 (Wilcoxon $p = 0.805$) and were not associated with municipality size in either year ($\rho = -0.013$, $p = 0.833$ for 2024; $\rho = -0.034$, $p = 0.588$ for 2025). This indicates complete stagnation in one of the most fundamental and legally mandated accessibility criteria.

Errors related to “missing alternative text” likewise showed no significant change over time (Wilcoxon $p = 0.403$) and were not associated with population size ($p = 0.021$, $p = 0.733$ for 2024; $p = -0.027$, $p = 0.659$ for 2025). Analysis of the specific category “missing alternative text for images” also revealed no significant temporal change (Wilcoxon $p = 0.180$) and no relationship with population size ($p = 0.016$, $p = 0.791$ for 2024; $p = 0.013$, $p = 0.829$ for 2025). Thus, one of the most critical requirements for screen reader users remains persistently unmet.

Errors in form labels also did not change significantly over time (Wilcoxon $p = 0.828$). However, in 2024, larger municipalities exhibited significantly more such errors ($p = 0.187$, $p = 0.002$), a relationship that disappeared in 2025. Analysis of changes over time revealed only a weak and statistically non-significant tendency for larger municipalities to improve more ($p = -0.117$, $p = 0.057$). This suggests limited and unstable convergence rather than systematic improvement.

“Empty links” showed no significant change (Wilcoxon $p = 0.737$) and were not associated with municipality size. “Empty buttons”, by contrast, exhibited a statistically significant change over time (Wilcoxon $p < 0.001$), although the median remained zero in both years, indicating that these changes were confined to a subset of websites. These changes were not associated with population size ($p = 0.008$, $p = 0.893$ for 2024; $p = -0.007$, $p = 0.905$ for 2025), pointing to dynamics driven by technological factors rather than policy interventions.

ARIA-related errors showed a statistically significant change (Wilcoxon $p = 0.007$), despite mean values of zero in both years. This indicates localised but systematic technical changes affecting a subset of websites. These changes were not associated with municipality size or rates of improvement, suggesting that they are more likely the result of technological updates than of accessibility governance.

Structural composition of accessibility errors

To understand why overall accessibility remains unchanged, the proportional composition of error types was analysed. Using municipality-level error shares, the national structure of accessibility errors was calculated. The analysis focuses on the most frequent error types, which collectively account for the majority of all detected violations, while less common categories have a limited relative share and do not alter the overall structural pattern.

In 2024, nearly 40% of all errors were related to contrast issues, followed by missing alternative text for images (14.5%), empty buttons (13.1%), and empty links (10.6%). In 2025, contrast-related errors increased to 43.2%, while missing alternative text for images (17.8%), empty links (13.3%), and form label issues (10.6%) also became more pronounced. Errors related to alternative text remained stable, whereas ARIA-related errors and empty buttons declined.

Despite these changes in raw proportions, Wilcoxon tests applied to all proportional variables indicate that, with the exception of empty buttons, none of these proportional changes are statistically significant. This demonstrates that the structure of accessibility errors is remarkably stable over time and continues to be dominated by fundamental visual and navigational barriers.

4. INTERPRETATION AND DISCUSSION

The combined findings reveal a highly consistent pattern: Bulgarian municipal websites do not exhibit systematic improvement in accessibility over time, nor is accessibility structured by institutional capacity. The most widespread and harmful accessibility barriers – related to contrast, navigation, and labelling – remain persistent and unmanaged. Observed changes are confined to technical domains such as ARIA and empty buttons and are best explained by platform or template updates rather than by deliberate accessibility policies or governance mechanisms.

From an institutional perspective, this suggests that web accessibility in the municipal sector is not managed as a coordinated objective of public policy but is instead left to fragmented, ad hoc technological practices. The outcome is a system characterised by inertia, a lack of convergence, and the persistence of fundamental accessibility barriers, despite the existence of binding European regulatory frameworks.

The results further demonstrate that between 2024 and 2025, web accessibility across Bulgarian municipal websites did not improve in a statistically significant manner, as measured by reductions in the total number of WAVE-detected errors. This constitutes a critical empirical indicator that, within the municipal public sector, there is no substantive dynamic towards improved compliance with web accessibility requirements. Such a pattern stands in clear tension with the objectives of Directive (EU) 2016/2102, which obliges Member States not only to establish a legal framework but also to achieve measurable improvements in the accessibility of public sector websites.

At the same time, the findings point to the presence of limited and uneven improvement. A substantial share of municipalities reduced the number of accessibility errors, while others maintained similar levels or experienced deterioration. This divergence indicates that regulatory pressure alone is insufficient to ensure homogeneous progress. In this sense, web accessibility emerges not merely as a technical issue but as an institutional one: although the formal requirements are uniform, the capacity to implement them effectively is not.

5. CONCLUSION

This study provides a large-scale longitudinal assessment of web accessibility across nearly all municipal websites in Bulgaria (with one exception), based on two consecutive measurement waves (2024 and 2025) and standardised WAVE indicators. The findings demonstrate that, despite the existence of a regulatory framework and isolated instances of improvement, web accessibility at the municipal level does not exhibit systematic progress over time and remains institutionally inert.

The analysis identifies no relationship between municipality size and either the level or the dynamics of accessibility, calling into question the assumption that institutional capacity alone leads to better compliance with accessibility standards. The most widespread and harmful barriers – related to contrast, navigation, and text alternatives – remain structurally persistent, while observed changes are confined to technical domains and affect only a small subset of websites.

More broadly, the results underscore that web accessibility in the public sector cannot be treated solely as a technical issue but requires sustained governance practices, institutional accountability, and effective policy enforcement mechanisms. Without such integration, there is a risk that regulatory requirements will remain formally satisfied yet functionally ineffective in advancing digital inclusion.

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