

Understanding digital engagement in waste management: The role of traffic sources in website performance

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Abstract

Purpose: This study examines how different traffic sources influence engagement quality on waste management websites. While previous research primarily focused on technological, organizational, and policy aspects of waste management systems, limited attention has been devoted to understanding how users access digital platforms and how these access channels influence engagement behaviour. The study aims to identify patterns of traffic acquisition channels with website performance indicators.

Design/methodology/approach: A quantitative analysis was conducted using aggregated website traffic data obtained from the Similarweb platform. Website performance was evaluated through engagement metrics, including pages per visit, visit duration, and bounce rate. Analytical procedures combined correlation analysis, Welch's t-tests for group comparisons, and Random Forest modelling to identify key drivers of website performance across traffic sources.

Findings: The analysis indicates that engagement quality differs across traffic acquisition channels, with some sources consistently associated with stronger interaction than others. Results suggest that traffic volume alone does not guarantee deeper engagement and that certain access channels contribute more effectively to website interaction. Multivariate modelling further highlights the uneven contribution of individual traffic sources to engagement outcomes.

Research limitations/implications: The study relies on aggregated third-party traffic estimates and a cross-sectional dataset, which restricts causal interpretation and long-term assessment. Future research could integrate first-party data, long-term observations, and specific performance indicators to extend understanding of digital engagement dynamics.

Practical implications: The findings guide waste management organizations and public institutions in prioritizing digital communication strategies that enhance website engagement, rather than focusing solely on traffic acquisition. Strengthening certain traffic sources and adjusting website content to user expectations may improve digital service accessibility and communication effectiveness.

Social Implications: Improved digital engagement with waste management platforms may contribute to public awareness, more effective communication of environmental initiatives, and enhanced participation in sustainable waste management practices.

Originality/value: This study contributes to research on digital communication in sustainability sectors by empirically demonstrating that traffic acquisition channels function as digital assets that influence the

quality of engagement on waste management websites. By linking website analytics with sustainability communication, the study extends current understanding of how website access patterns shape interaction with environmental services.

Keywords: Waste management, Website traffic, Traffic sources, User engagement, Digital communication

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1. Introduction

Digital communication has the power to significantly influence the value created in the circular economy, reverse logistics activities, recycling, redistribution, and remanufacturing. Digital innovations positively stimulate internal coordination and communication within organisations and with the external environment in waste management organisations (Kolade et al., 2024). The use of digital channels for communication and information dissemination is now a standard practice in most companies, and a lack of such communication can lead to the loss of a competitive advantage. Following its success in business practice, such communication has also spread into socially responsible segments and nonprofit organizations, such as waste management and the circular economy. Digital solutions improve information dissemination and exchange and positively influence the development of communication models of waste management websites (Arantes & Ferreira, 2025). Waste management companies and organizations operate in a demanding competitive environment in which consumer education, digital innovation, and effective communication are needed to strengthen their market position and increase consumer conversion. Integration of digital technologies and automation into all processes within the provision of services increases the accessibility of waste management solutions to customers (Svetlik & Lastuvka, 2022). Digitalization should also be present in information and communication technologies, which serve as the primary means of communication for the services provided. Digital communication nowadays represents a key component for planning, managing, and predicting demand for waste management systems. Digital solutions support monitoring of waste collection, optimizing disposal processes, and improving recycling management (Singh, 2022). From a governmental point of view, digitalization and the proper organization of waste management systems positively influence transparency, which in turn has a direct effect on the effectiveness of such systems. Evidence from cities with high transparency in waste management indicates that such cities tend to be larger and wealthier and to have better-organized separation infrastructure (Rodríguez Martín et al., 2022). Local governments are ideally positioned to facilitate and coordinate cooperation between public and private actors in the area (Saputra et al., 2025). Examples in some particular cities illustrate how legislation, technological processes, and public engagement contribute to successful waste management. For example, San Francisco is highly rated in the area of recycling thanks to the coordinated implementation of technological and legislative measures supporting waste management (Braga & Ribeiro, 2023). However, dependence solely on technological infrastructure without the support of public awareness and behavioral change is insufficient. Research shows that awareness is crucial to achieving effective waste management practices. For instance, Malaysia has experienced limited environmental awareness caused by insufficient promotion of individual responsibility for waste management, which has resulted in a poor waste management environment (Zulkipli et al., 2022). Research evidence from Vietnam confirms this importance, showing that awareness positively influences vendors' waste management behaviours through attitudes and willingness to pay for waste management (Thi Thanh Huyen et al., 2025). High willingness to pay for waste management services across various income groups is highly connected to education, awareness, and effective policies (Etim, 2024). Governmental support for waste management awareness significantly improves households' waste management practices (Widyatmika & Bolia, 2024). However, every household participant has different perceptions and

preferences; it is important to effectively tailor campaigns for different target groups (Etim et al., 2024). Digital platforms play an important role in awareness development and the coordination of waste management practitioners. Empirical studies show that digital platforms connect people with municipalities and waste management service providers, reducing barriers for knowledge exchange and value co-creation (Mersico et al., 2026).

Previous research on waste management communication has mainly focused on technological infrastructure, governance and public policies. Much less attention has been paid to how users interact with the digital channels through which they access waste management information. This study addresses this gap by combining knowledge from digital analytics and sustainability communication. Specifically, it examines traffic sources not only as categories used to describe website visitors, but also as digital assets that influence how users interact with website content. Rather than simply confirming known relationships between traffic sources and user behaviour, the study identifies which acquisition channels are most effective in generating engagement with waste management websites. To the best of our knowledge, this perspective has not yet been systematically explored in the sustainability communication literature.

2. Literature Review

2.1. Digital Communication in Waste Management

Website traffic is directly dependent on content production and dissemination across different and various digital communication channels. The type and form of content are crucial. Waste management communication frequently utilizes functional, practical information focusing on usability of the information; however, it lacks an emotional and social dimension, which can cause limited engagement (Repovienė & Pažėraitė, 2023). Recent studies show that even social media algorithms support green and environmental information dissemination and enhance the visibility of such information. Studies examining zero-waste initiatives demonstrate a significant enhancement in visibility of content with environmental topics and content encouraging citizen waste management participation (Gong et al., 2022). Technical competence is standard in specialized waste sectors, such as radioactive waste management; however, proper communication should also be standard. Current advanced analytical tools and genAI tools can significantly help to spread technical information in a suitable form to support communication with the public and policymakers (Khaydarov, 2025). Household and community studies show that waste management problems and low frequency of usage are connected to a limited understanding of individual responsibilities, which supports the importance of awareness and educational programs (Kala & Bolia, 2021). It is necessary to distinguish between technological solutions and behavioral adoption of the communicated topic, especially in the waste management area, where stakeholders' perception significantly impacts the successful integration of the process into practice (Liao et al., 2023). Communication style and information dissemination channels nowadays serve as intangible assets, which, especially in the waste management sector, serve as a crucial tool for the implementation and adaptation of waste management approaches into everyday lives. Dissemination channels, in literature and practice named digital touchpoints, such as organic search results, paid search results, direct website access, social media, referral network etc. are created and optimized gradually and gain communication and economic value over time strengthening organizations' position. User journey over different digital touchpoints follows identifiable patterns, which individuals follow to reach desired information (Moore & Hastie, 2025).

2.2. Traffic Source As an Intangible Digital Asset

Traffic sources are intangible assets, which reflect brand or topic positioning, familiarity, and trust in the digital environment. Different digital touchpoints have different, however direct influence on website key performance indicators. Website KPIs may vary depending on where the user came to the website (Filippou et al., 2024). Except for where to communicate, it is important what to communicate. Content quality significantly influences website traffic and engagement with a website (Liu & Xu, 2025). The information search process and decision-making process significantly vary depending on the user's patterns of information suppression. This has an impact on engagement behavior with a website (Miao et al., 2025). A lot of organic and performance-oriented website traffic strategies exist, and they influence each other; for instance, branded search visits positively increase direct website access (Filippou et al., 2025). Research uncovered, that almost all traffic sources

consequently influence also direct traffic and repeated website visits (Zhao et al., 2022). Since direct traffic is the strongest and the most desired one, it is a positive finding (Jiang et al., 2021). Besides content quality and digital touchpoints used as entry points to the website, devices play a crucial role in website KPIs. Website traffic from emails and paid search frequently contribute to significant website visits on both desktop and mobile (Gaur et al., 2026). Content quality can be enhanced by personalization, where recommendations appear as very effective during the exploration stage of information seeking, while price-based information is more effective in the user stage with a particular goal (Ding et al., 2025).

This approach is based on the resource-based view of digital marketing, which perceives digital touchpoints (such as search volume, referrals, and repeat direct visits) as intangible resources that can generate competitive advantage, similar to brand equity (Armstrong et al., 2025). At the same time, engagement generated by traffic source is influenced by users' intent and information goals, meaning that a channel's value depends on individual preferences of the users it attracts (Miao et al., 2025; Ho, 2021). This study combines insights from digital assets theory and user behaviour theory and explains how users interact with communication in the sustainability area. Instead of focusing only on differences in website traffic, it examines why some digital touchpoints are better at attracting users and encouraging them to engage with waste management content. There is a conceptual distinction between traffic sources as they are observed and the intangible resources that produce them. What web analytics records is a channel: a classified entry path through which a session begins. The channel itself is not the asset, because it can be neither owned nor accumulated; it is a measurable trace of an underlying resource that the organisation has built over time (Homburg & Wielgos, 2022). Organic search traffic is the visible output of accumulated content quality, topical authority and technical site condition. Direct traffic reflects brand recall and habitual return, that is, the memory that users hold of the organisation. Referral traffic is the trace of relational capital embedded in partnerships with municipalities, institutions and media. Email traffic expresses permission-based audience capital, a consented relationship with identified users. Social traffic reflects community capital, the audience an organisation has assembled on platforms it does not own. Paid search and display advertising occupy a different position: they are purchased rather than accumulated, they generate no residual value once spending stops, and they are therefore better understood as expenditure that may build intangible resources indirectly, through awareness and recall, than as assets in their own right (Kannan & Li, 2017). This distinction has two implications for the present study. It explains why channels differ systematically in engagement quality, since each is generated by a different resource and each resource attracts users with different levels of prior familiarity and intent. It also clarifies what the engagement metrics measure: they are indicators of the strength of the underlying resource, observed at the moment when it converts into a visit. Traffic sources are consequently treated in this paper as observable proxies for intangible digital resources, and not as the resources themselves.

These findings support the conceptualization of traffic sources as cumulative digital assets influencing website acquisition patterns, engagement quality, and overall website performance.

2.3. User Intent and Engagement

There are two key optics on website performance: total traffic volume and engagement quality with a website and its elements. There are many key performance indicators regarding engagement quality, and particular selection depends on the goals of website providers. Widely monitored engagement metrics are average visit duration, pages per visit, bounce rate, average time spent, and many more. Existing research demonstrates that different digital touchpoints influence engagement behavior. Different traffic sources, such as email, social media advertising, and display advertising, stimulate engagement with a website differently (Lütjens et al., 2022). Also, websites with user-centric design and transparent communication enhance website engagement and trust in the offer on the website (Usas & Streimikiene, 2025). Studies also indicate that comfort while consuming content on a website significantly influences engagement with a website. Fully responsive and mobile-adapted websites enhance engagement with digital recycling systems, highlighting user-friendly solutions (Mugerwa et al., 2025). Traffic source can also explain variability in user behavior on a website (Filippou et al., 2024). Design of a website directly influences engagement and satisfaction with website content consumption, underscoring the importance of website interaction and user-friendly website structure (Lun et al., 2024). Traffic source influence also determines the type of user who will visit a website. Paid search often lures the attention of goal-directed

users and display advertising triggers the curiosity of exploratory users (Ho, 2021). Advertising value and flow experience influence engagement behavior on a website (Chen et al., 2025). Content procession and elements on a website are crucial to stimulate engagement on a website, since interactivity and engagement increase perceived value, and irritation negatively influences engagement. Device type also plays a significant role, where firm-initiated traffic sources perform better on PC and direct and organic traffic perform the same on all devices (De Battista et al., 2025). Display advertisement loses performance due to the banner blindness phenomenon in case a user performs focused tasks on the internet (Nam & Cho, 2026). Email communication focused on relationship creation, creating emotional value, and positively influencing engagement with email and also landing pages from email (Rodriguez & Sangle-Ferriere, 2023). Different traffic sources influence search and engagement behavior through different user approaches (Bhatnagar et al., 2022). Website traffic can be perceived as a significant intangible asset since it is possible to predict revenue and profitability based on the traffic of an organization (Armstrong et al., 2025). Social media campaigns influence website traffic and engagement at high intensity, although product type also plays a role (Dolega et al., 2021). It is recommended to think strategically of resource allocation regarding paid and organic traffic sources, since they have different impacts on website performance (Vukovic et al., 2026). Social media marketing further enhances brand awareness, triggering user interaction (Al-Hujri et al., 2025). Communication channel effectiveness varies across audiences. Within middle-income target groups, the direct mail channel often outperforms traditional offline communication forms, such as newspaper advertisements, since it offers the option of personalization and flexible communication (Kala et al., 2020). The type of content used for communication also influences engagement with a website. Existing studies emphasize the importance of digital communication and stakeholder engagement in waste management. However, little attention is devoted to analyzing how users approach waste management websites and how they interact with them. Existing studies indicate differences in traffic and engagement quantity and quality on waste management websites.

3. Methodology and Research Methods

This paper examines identified web traffic performance indicators for waste management websites to assess how different factors influence overall quantity and quality of website traffic. The research utilizes a quantitative research design focused on comparative analysis across traffic sources and device types.

3.1. Data and Sample Selection

A dataset of 41 websites related to waste management services was identified from an initial pool of 55 identified websites. The websites represent a mix of waste management service providers, institution websites, and information websites. The identified and analysed websites operate primarily in the United States and other developed countries. Websites were identified using a combination of two approaches:

1. curated sources – Google Search was used to identify relevant websites using relevant keywords such as “waste management”, “waste management website”, etc., and
2. AI search processes – Chat GPT was prompted to create a list of waste management websites.

Some of the identified websites from both sources were duplicated. These duplicities were excluded to ensure data consistency.

It should be acknowledged that combining keyword searches with AI-generated suggestions introduces some subjectivity into the sample, as neither method guarantees that all relevant waste management websites are identified. As a result, the sample may not fully represent the entire population of waste management organizations and may be difficult to reproduce exactly. Therefore, the dataset should be viewed as an illustrative rather than a comprehensive sample of the sector. At the same time, the sampling strategy is consistent with the exploratory objective of the study. Justification of utilized sample selection is, that no official register or comprehensive directory of waste management websites exists, and the sector combines public institutions, municipal operators, private service providers and information portals, so any sampling frame has to be constructed by the researcher rather than drawn from an existing list. The combination of keyword-based search and AI-generated suggestions was therefore chosen because it reproduces, as closely as possible, the two routes through which users themselves currently discover waste management websites, namely search engines and

conversational AI assistants. The resulting sample is heterogeneous in ownership, size and function, which is appropriate for the research question addressed here: the aim is not to estimate population parameters for the waste management sector, but to examine whether engagement quality varies systematically with the channel through which users arrive at a website. The findings should accordingly be read as evidence that such variation exists and follows an identifiable pattern, and as an illustration of an analytical approach for studying it, rather than as precise estimates of channel performance that can be generalised to all waste management organisations.

In the next steps, performance and engagement data about identified websites were collected. For the collection, the enterprise version of the Similarweb analytical tool was used. The tool aggregates traffic data about websites using various data streams including web browser extensions, panel data and publicly available data. The data were collected at the domain level. Two types of data were collected:

- A) Traffic source data – (1) Direct traffic – user accesses the website by entering the URL address directly to a browser or via bookmarks. (2) Organic search – users visit the website from unpaid search engine results. (3) Paid search – traffic generated through paid search advertising. (4) Referral traffic – visits from hyperlinks on external websites. (5) Display advertising – traffic generated by banner or display ad. (6) Social traffic – visits generated from social networks. (7) Email traffic – users coming to websites via email campaigns or newsletters.
- B) Engagement data – (1) Total visits – overall traffic on a website, (2) Monthly visits – average website visits per month. (3) Monthly unique visitors – estimated number of particular users per month. (4) Deduplicated audience – consolidated user estimates across devices. (5) Device share – desktop and mobile share of visits. (6) Average visit duration – average time spent on the website. (7) Pages per visit – average number of pages visited during one visit. (8) Bounce rate – percentage of visits with no interaction after visiting a website.

Similarweb data are based on aggregated third-party sources, such as browser extensions, panel data and statistical estimates, rather than internal website data. As a result, reported traffic and engagement metrics may not be fully accurate, especially for websites with lower traffic volumes. This limitation should be considered when interpreting the results and is discussed further in the Limitations section.

3.2. Analytical Framework

To ensure a comprehensive analysis of user behaviour on waste management websites and to deduce implications for traffic source strategies in the waste management sector, multiple analytical methods were employed. The analytical framework combines statistical testing with machine learning techniques, allowing both hypothesis identification and verification and exploratory identification of key drivers of website performance.

3.2.1. Correlation Analysis

To discover potential relationships between selected performance and engagement metrics, Spearman's rank correlation coefficient was used to perform a correlation analysis. This non-parametric measure was chosen due to its robustness to non-normal distributions and its suitability for ordinal or skewed web analytics data. Spearman's correlation coefficient ranges from -1 to $+1$, where -1 indicates a perfect negative association, 0 indicates no monotonic relationship, and $+1$ indicates a perfect positive association (Wu & Lin, 2022).

$$r_{xy} = \Sigma(x_i - \bar{x})(y_i - \bar{y}) / \sqrt{\Sigma(x_i - \bar{x})^2} \times \sqrt{\Sigma(y_i - \bar{y})^2} \quad (1)$$

The analysis focused on identifying statistically meaningful associations between examined metrics. This step provided an initial understanding of how different dimensions of website performance relate to each other. Key Performance Indicators (KPIs) were identified on the basis of these findings. In the next step, comparison of traffic source categories was performed. KPIs primarily reflected engagement quality rather than total visit amount.

3.2.2. Key Performance Indicators and Group Comparison

A Welch t-test was conducted to test hypotheses concerning the mean values across traffic sources. This test was applied instead of the standard t-test because digital traffic sources represent a heterogeneous data sample, and

the test applied here does not assume equal variances between compared groups (2). The Welch t-test was used to evaluate the null hypothesis that the mean values of selected KPIs are equal between different traffic sources.

H0: mean values of selected KPIs are statistically significantly equal across different traffic sources.

H1: mean values of selected KPIs are not equal across different traffic sources.

The calculated results within the t-statistic were compared against the critical value of the t-distribution with adjusted degrees of freedom (3). When the absolute value of the test statistic exceeded the critical threshold $|t| > t$, the null hypothesis of equality of the mean values of the two samples was rejected ($H_0: \mu_1 = \mu_2$).

$$t = (\bar{x}_1 - \bar{x}_2) / \sqrt{(s_1^2/n_1 + s_2^2/n_2)}, \quad (2)$$

$$df = (s_1^2/n_1 + s_2^2/n_2)^2 / [(s_1^2/n_1)^2/(n_1 - 1) + (s_2^2/n_2)^2/(n_2 - 1)], \quad (3)$$

*Where $\bar{x}_1$, $\bar{x}_2$ are the sample means, s_1^2 , s_2^2 are the sample variances, and n_1 , n_2 are the sample sizes (Ruxton, 2006).

This approach enabled comparison of traffic sources with respect to engagement metrics such as visit duration and bounce rate. The group comparison was carried out on subsamples created by splitting the dataset at the median value of each engagement KPI, so that each traffic source could be compared between websites with lower and higher engagement quality. Three considerations motivated the approach adopted here. First, the objective at this stage of the analysis is descriptive rather than predictive: the question is whether websites that achieve better engagement differ in the composition of their traffic, which is a comparison between two groups of websites rather than an estimation of marginal effects. Second, the traffic-source variables are strongly right-skewed and mutually correlated at a level of 0.96 and above, as reported in Section 4.1. With 41 observations, coefficient-based models estimated on such data are unstable and their individual coefficients are difficult to interpret, whereas a median split does not require variance to be attributed to nearly collinear predictors. Third, the median is a distribution-free splitting criterion that avoids the choice of an arbitrary threshold and produces subgroups of equal size, which suits the Welch test applied subsequently. It should be acknowledged that dichotomisation discards information and reduces statistical power, which makes the tests conservative and offers one plausible explanation for the fact that several p-values reported in Section 4.2 lie close to the conventional threshold. The Random Forest analysis described in the following subsection was included precisely in order to compensate for this loss of information, since it uses the engagement measures in their original continuous form.

3.2.3. Machine Learning Approach with Random Forest Analysis

To complement traditional statistical methods and capture non-linear relationships, a Random Forest model was also utilized. Random Forest is a learning technique that combines multiple decision trees, each trained on a bootstrapped sample of the data and a random subset of predictor variables at each split. Variable importance within the Random Forest model was assessed using the Increase in Mean Squared Error (Increase in MSE) metric. This measure evaluates the contribution of each variable by randomly permuting its values and observing the resulting deterioration in model performance. The logic of this approach is straightforward: if permuting a variable substantially increases prediction error, the variable is considered highly important in explaining the outcome.

$$Importance_j = (1/B) \times \sum_{b=1}^B (MSE_b^{permuted,j} - MSE_b^{baseline}) \quad (4)$$

*Where B denotes the number of trees, $(MSE)_b^{baseline}$ is the error on the original out-of-bag (OOB) data, and $(MSE)_b^{permuted,j}$ is the error after permutation of variable j.

The models were estimated in R using the randomForest package. A separate regression forest was grown for each of the three engagement KPIs, namely bounce rate, visit duration and pages per visit, each of which entered its model as the dependent variable, while the shares of the seven traffic sources together with the

desktop and mobile shares of visits served as predictors. Each forest consisted of 500 trees; the number of predictors sampled at each split was set to one third of the available predictors, which is the default for regression forests, and the minimum node size was left at the default value of five. Because the dataset contains only 41 websites, the data were resampled with replacement before estimation in order to stabilise the out-of-bag error estimates, and the values reported in Section 4.3 are averages over repeated runs with different random seeds. Variable importance was computed as the permutation-based increase in mean squared error on the out-of-bag observations, as defined in equation (4). The resulting importance measure is relative and unsigned: it captures a predictor's contribution to predictive accuracy rather than the direction or magnitude of its effect. Moreover, because correlated predictors may share predictive information, small differences in importance rankings should not be over-interpreted. The rankings in Section 4.3 are therefore used to identify channels that consistently carry predictive information and are interpreted alongside the correlation results reported in Section 4.1.

The three methods were used as complementary steps rather than as separate analyses. First, correlation analysis was used to explore the data and identify the three key performance indicators (KPIs) for further analysis. Next, Welch's t-test tested whether these KPIs differed significantly between traffic sources. However, because this test only compares group means and may not capture more complex relationships, Random Forest modelling was used as a complementary method. Unlike Welch's t-test, Random Forest can identify relative importance of different traffic sources without assuming linear relationships or a specific data distribution. Together, the three methods provide a more comprehensive analysis, with each method addressing the limitations of the others.

The combined research approach strengthens the methodological frame of the study and supports both academic and practical outputs of the paper.

4. Results

4.1. Correlation Patterns Between Traffic Sources and Engagement

Figure 1 presents a correlation matrix illustrating the relationships between traffic sources, device usage, and key traffic and engagement metrics across the analysed waste management websites. The visualisation highlights the strength and direction of associations, providing an overview of how different access channels and user behaviours interact.

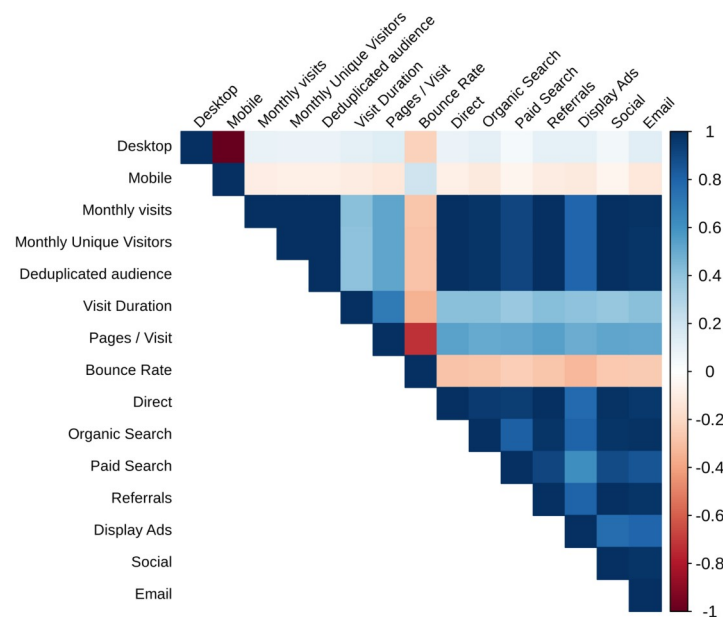


Figure 1. Correlation matrix of all measured indicators

The correlation matrix reveals several patterns in user behaviour on waste management websites. Mobile access shows negative correlations with other metrics. In contrast, desktop access is mostly neutral, suggesting that

mobile users engage less deeply with website content and use all website traffic sources at a lower frequency. The only higher correlation with smartphone usage is bounce rate, which confirms the weak interest of users using mobile phones in waste management websites.

Stronger differences are revealed in engagement metrics (visit duration, pages per visit, bounce rate) than for traffic volume metrics (monthly visits, unique visitors). Bounce rate has a negative correlation across all traffic sources (around -0.27), which confirms its relevance as a core indicator of engagement quality.

Engagement metrics such as pages per visit and visit duration show only moderate positive correlations with traffic size (approximately 0.40 – 0.53), suggesting that higher visit volumes do not automatically translate into stronger engagement.

A very high correlation between traffic sources themselves (≥ 0.96) was revealed, suggesting that individual channels contribute to overall traffic proportionally.

Based on the identified findings, three Key Performance Indicators (KPIs) were selected: (1) pages per visit, (2) bounce rate, and (3) visit duration.

- Referral traffic achieved the strongest engagement performance, generating the highest average pages per visit (0.547), the longest visit duration (0.427), and a significantly negative bounce rate (-0.279).
- Direct traffic performs similarly across all three engagement indicators, indicating high user intent.
- Organic search exhibits stable engagement levels, while also representing the largest share of overall traffic.
- Traffic from email and social media achieved moderate engagement performance across the observed KPIs.
- Paid search traffic shows weaker engagement relative to organic and direct channels.
- Display advertising records the weakest associations across all three identified and observed key performance indicators.

4.2. Comparison of Engagement Metrics Across Traffic Sources

Tables 1, 2, and 3 represent the results of hypothesis tests on the equality of mean values across traffic sources. Every table represents a different identified key performance indicator. The dataset of every KPI was divided into subsamples at the median value of a particular indicator. To compare the identified groups, Welch's test was used. This approach allowed comparison without assuming equal variances across subsamples. Results will provide information on whether there is a statistically significant difference in engagement indicator across traffic sources when conditioned by selected KPIs.

Channel	Mean_Low	Mean_High	p_value
Display Ads	19122.86	1568.35	0.0772
Direct	2649649.05	270793.95	0.1114
Referrals	217172.43	43170.30	0.1157
Social	129611.43	21752.55	0.1227
Organic Search	1528119.19	371523.70	0.1433
Paid Search	187549.52	10101.70	0.1603
Email	1699.76	500.70	0.2033

Table 1. Bounce rate and differences in mean values across individual traffic channels

There is no statistically significant difference for the bounce rate KPI across monitored traffic sources. Based on the observed p-values, the null hypothesis of equal mean values cannot be rejected at the 0.05 significance level. This means that the bounce rate does not differ statistically significantly between individual traffic sources and cannot be considered higher or lower in any specific channel.

Channel	Mean_Short	Mean_Long	p_value
Display Ads	790.05	20817.80	0.0546
Email	196.43	2079.20	0.0569
Organic Search	202753.00	1763158.20	0.0599
Referrals	28752.19	241011.55	0.0672
Direct	174926.95	2869252.15	0.0859
Social	16602.62	140411.80	0.0913
Paid Search	8324.57	198287.90	0.1524

Table 2. Visit duration and differences in mean values across individual traffic channels

Similar results were obtained for the visit duration KPI, where the null hypotheses of equal mean values across traffic sources cannot be rejected. However, for display advertising, email, and organic search, the p-values are very close to the 0.05 significance threshold, indicating marginal differences that approach statistical significance. However, since p-values remain above conventional 0.05 threshold, this pattern should be interpreted as a suggestive / exploratory signal rather than confirmed evidence of difference between channels. This result requires validation with a larger sample.

Channel	Mean_Low	Mean_High	p_value
Organic Search	136038.10	1833208.85	0.0406
Referrals	17712.43	252603.30	0.0427
Email	154.38	2123.35	0.0464
Display Ads	677.00	20936.50	0.0519
Direct	121689	2925152.00	0.0738
Social	14635.38	142477.40	0.0811
Paid Search	6093.86	200630.15	0.1428

Table 3. Pages per visit and differences in mean values across individual traffic channels

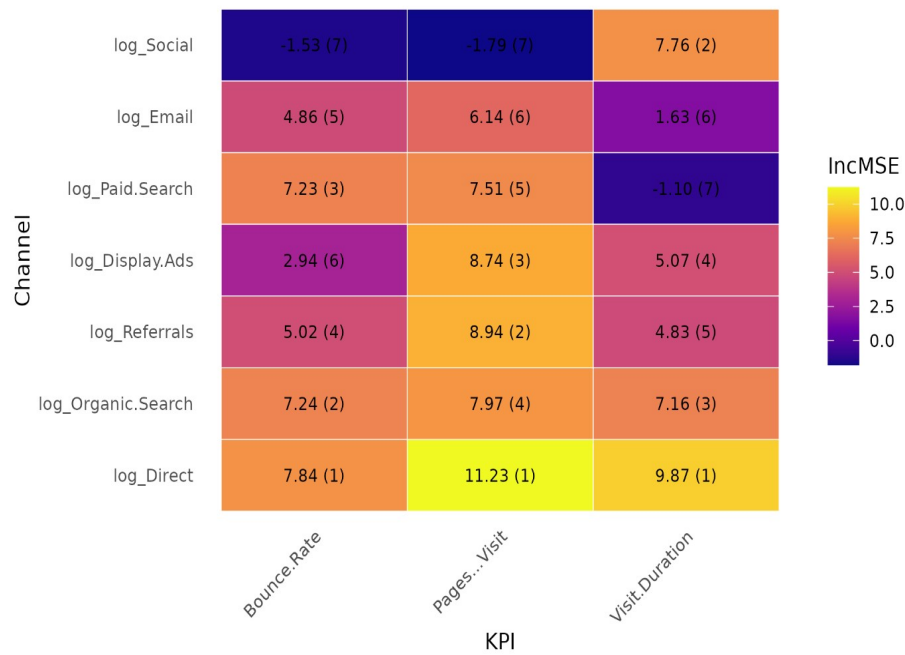
For KPI pages per visit, the null hypothesis of equal mean values is rejected for the organic search, referral, and email traffic channels, indicating statistically significant differences in user engagement across these sources. In the case of display advertising, the null hypothesis cannot be rejected, although the result lies very close to the significance threshold. While these differences are statistically significant, the relatively modest number of observations means that the estimated magnitude should be treated as indicative.

From a practical point of view, these findings suggest that efforts to increase the number of pages viewed per session should prioritise strengthening organic search, referral, and email channels, as these sources are more strongly associated with deeper interactions with a website during a visit.

4.3. Multivariate Analysis of Traffic Sources and Website Performance

A limitation of the above-processed Welch t-tests is the relatively small number of observations. Therefore, a multivariate analysis using the Random Forest approach was subsequently employed. Figure 2 presents the results of this analysis after resampling the original dataset.

The results of the Random Forest analysis, read together with the correlation patterns reported in Section 4.1, indicate that direct traffic is the most significant contributor to improvements in the analysed website performance KPIs. A higher volume of direct visits is statistically associated with a lower bounce rate and more pages viewed per visit. This suggests high user intent and familiarity with the website. On the other hand, organic search traffic is associated with an increase in bounce rate. This finding shows that, despite generating substantial traffic volumes, organic search also attracts users with weaker expectations for website content. Traffic from social media represents an important driver of longer visit durations, underscoring its role in sustaining the attention of users. Other traffic sources can be perceived more as complementary, contributing to website performance without strong or consistent effects across the examined KPIs.



*Note: Numbers in cells are IncMSE, with the rank in brackets.

Figure 2. Results of random forest multivariate analysis

The variable importance measures confirm the crucial role of direct traffic in website performance. Direct traffic achieved the highest Increase in Mean Squared Error (IncMSE) across all three observed KPIs. This indicates that excluding direct traffic leads to the greatest deterioration in the model's predictive accuracy. Organic and paid search rank next in terms of variable importance, particularly in relation to explaining variations in bounce rate. While display advertising and referral traffic do not emerge as dominant factors in the correlation analysis or in the group comparisons, their importance becomes more pronounced within the Random Forest framework. This pattern suggests a non-linear influence of these sources, especially with respect to visit duration and engagement depth. It is important to note that Random Forest importance rankings are exploratory and show predictive rather than causal relationships. Results for display advertising and referral traffic should be perceived as preliminary findings rather than confirmed effects because the model was trained on a limited number of observations. Future studies with larger samples should confirm these findings.

Overall, discovered results highlight the importance of prioritising direct traffic, while simultaneously optimising the quality of traffic generated through search engines and social media platforms.

5. Discussion

The research paper contributes to the existing and growing body of research focused on digital transformation, communication, and information dissemination in the waste management area. The shift from technological and legal infrastructure to a need for communication and education in the sector is evident. One of the strongest tools for such a need is a website, which, together with its traffic sources, serves in the current digital age as an intangible asset participating in business success and business value. Recent studies on the topic prioritize technological innovation, governance, and coordination of all stakeholders, and little attention is devoted to website performance from a digital touchpoint and engagement point of view. For further development of the waste management systems, it is necessary to devote attention also to understanding how consumers perceive waste management services in a digital environment and how they approach them. Therefore, this study provides important behavioral findings complementing existing technological and legal approaches.

The results confirm that traffic sources for the website serve as an intangible asset, which influences not only the total amount of visits to the website, but also engagement with website elements. This observation is in line with previous studies, which conceptualize digital touchpoints as cumulative resources shaping the digital presence of an institution and also in line with studies, which unveiled that different online channels influence

user behaviour unequally (Filippou et al., 2024; Bhatnagar et al., 2022). The analysis presented in this paper shows that engagement differs depending on how users arrive at the waste management website. One of the most consistent findings highlights the importance of direct traffic. Both correlation analysis and multivariate modelling identify direct visits as the strongest contributor to engagement performance across all examined KPIs. Users accessing websites directly achieved lower bounce rates, longer visit durations, and higher page-view counts per session. This pattern is in line with other studies, which connect direct access to the website to familiarity, brand awareness, and repeated visits. This confirms that accumulated digital presence and trust in the brand serve as assets. The result also corresponds with findings that performance-oriented digital campaigns and brand visibility frequency trigger search and direct website visits (Filippou et al., 2025). All of this led to the suggestion that it is more important to build long-term visibility rather than short-term visit volumes.

In contrast, organic search, representing the strongest traffic source, achieved mixed engagement effects. The Random Forest connects organic traffic to a higher bounce rate, indicating that this traffic source attracts users who might not be fully interested in the website content. This finding corresponds with other already conducted research, which indicates that traffic driven by search often represents exploratory behavior with no clear goal during the visit (Ho, 2021).

The results for organic search reveal an interesting pattern. Organic search generated the highest share of traffic, but it was also associated with higher bounce rates. This suggests that increasing organic visibility may attract more visitors, but not necessarily users who engage more deeply with website content. Therefore, traffic volume and user engagement should not be viewed as the same objective. The Random Forest analysis also unveiled that display advertising and referral traffic were more important than suggested by linear statistical tests. This indicates that their influence on user engagement may depend on other factors, such as device type, rather than performing independently. These findings highlight that relationship between traffic sources and user engagement is more complex than simple linear comparisons suggest and it should be explored further in future research.

These findings highlight the importance of topic relevancy and correspondence between search terms in search engines and content displayed on the landing page to secure not only traffic, but also meaningful engagement. Social media acts as a relevant mediator for longer visit duration. This observation supports studies that discovered that traffic from social media enhances environmental awareness and user engagement in sustainability initiatives (Gong et al., 2022; Al-Hujri et al., 2025). It is possible to deduce that social media plays a dual role: the first role is environmental content disseminators, and the second role is a source of deeper website content interaction. Referral traffic and email traffic show strong engagement and high pages per visit. This finding highlights the importance of traffic sources, which are considered by users as trusted partners. This aligns with research showing that familiar and personalized communication formats trigger perceived value and engagement even in a utilitarian context (Rodriguez & Sangle-Ferriere, 2023). Display advertisements consistently generate weaker engagement, supporting findings of banner blindness and low effectiveness of display ads in digital communication forms (Nam & Cho, 2026). This suggests that display advertisement might be a good source of awareness and brand building; however, it is a weak tool for generating traffic with strong on-site engagement, especially in services that need to explain and educate their target groups. An important observation is related to device usage. Users reaching websites from mobile devices show weaker engagement compared to users generating traffic from desktops. The key indicator here might be bounce rate, which is significantly higher in mobile users. This finding corresponds with studies supporting the need for usability and comfort during browsing of sustainability platforms (Mugerwa et al., 2025). The result suggests that mobile user experience optimization is a critical challenge for waste management websites.

Taken together, these results permit an interpretation that goes beyond confirming the presence of differences between channels. The observed pattern is consistent with a selection mechanism that operates before the visit begins. Channels differ in the amount of prior knowledge and intent that a user brings to the website, and the engagement metrics measured after arrival largely reproduce this pre-visit difference. Direct visits presuppose that the user already knows the organisation and has a specific reason to return, which is why they combine low bounce rates with depth of interaction. Referral and email visits presuppose an intermediary that has already

qualified the user's interest, whether a partner website or a subscription, and they behave accordingly. Organic search, by contrast, aggregates users with widely varying goals under a single label, from those seeking a collection schedule to those with a general interest in recycling, and its mixed engagement profile is therefore an arithmetic consequence of this internal heterogeneity rather than evidence of a deficiency in the channel itself. Display advertising sits at the opposite end of the same continuum, since the visit is initiated by the organisation rather than by the user and prior intent is largely absent. Read in this way, the ranking of channels by engagement quality is not a ranking of channel effectiveness but a ranking of the degree of user intent that each channel selects for. This interpretation carries a theoretical implication for the treatment of traffic sources as intangible assets. If engagement quality reflects the intent for which a channel selects, rather than something the channel does to the user after arrival, then the value of a digital touchpoint lies in its capacity to reach users who are already disposed to engage. The asset being measured is the accumulated relationship, that is, the familiarity, trust and prior consent that make such reach possible, and the engagement metric is its observable return. The same reasoning accounts for the apparent tension between the linear and the non-linear results. Display advertising and referral traffic gained importance in the Random Forest models while remaining weak in the correlation analysis, which suggests that their contribution is conditional rather than uniform: they matter for particular website profiles, most plausibly those in which the device composition or the type of content aligns with the channel. Conditional effects of this kind are by construction invisible to methods that assume a single average relationship, which is itself an argument for the combined analytical design adopted here. For the waste management sector specifically, the implication is that communication strategy should be formulated in terms of which audiences a channel can reach and with what predisposition, rather than in terms of the volume of visits it delivers.

From a broader point of view, the findings highlight the importance of integration of digital communication into waste management approaches. Previous research highlights that awareness campaigns and engagement of stakeholders are necessary to shift sustainability goals into behavioural change (Etim, 2024; Widyatmika & Bolia, 2024). This study enriches this knowledge by proposing the integration of website access pathways and optimization of digital touchpoints interaction into a strategic approach to waste management. In other words, even perfectly designed sustainability initiatives may fail to reach users effectively if digital communication channels and website experiences are not in line with user expectations.

This study also contributes methodologically by combining correlation analysis, hypothesis testing, and machine learning approaches to analyze website performance. While Welch t-tests provide insights into data group differences, Random Forest models capture more complex, non-linear relationships between traffic sources and engagement. The approach of combined data processing strengthens the robustness of conclusions.

Overall, viewing traffic sources as strategic digital assets rather than analytical metrics offers a clearer way to interpret these findings. The theoretical, methodological and practical implications of this perspective are presented in the Conclusion.

6. Conclusion

This study examined how traffic sources influence engagement with waste management websites, filling a gap in existing research that has largely focused on technological, policy, and organizational approaches to waste management, while limited attention was dedicated to digital user behaviour. By analysing website traffic and engagement metrics across waste management websites, the study highlights that differences in website performance are not connected solely to traffic volume but depend strongly on how users access digital platforms.

The findings confirm that traffic sources serve as digital assets that shape user interaction and engagement patterns. Direct traffic can be perceived as the strongest contributor to engagement across all analysed indicators, suggesting that user familiarity and repeated access to a website play a crucial role in website performance. Organic search remains essential for generating overall traffic, although its engagement quality varies. This highlights the importance of adjusting search visibility to relevant and informative content. Referral and email traffic show strong engagement metrics, while social media traffic contributes to sustainable user attention. In

contrast, display advertising achieved weaker engagement performance, suggesting that visibility does not guarantee interaction.

6.1. Theoretical and Methodological Implications

From a theoretical point of view, this study contributes to the digital communication and website analytics literature by demonstrating that engagement metrics are not in direct relation to traffic volume. It extends the conceptualization of digital touchpoints as assets that influence the digital performance of an organization. In the context of waste management, the results highlight that digital communication strategies are important for supporting sustainability initiatives by optimizing access to information and services. Methodologically, this study shows that combining correlation analysis, hypothesis testing, and Random Forest modelling provides a comprehensive way to analyse both linear and non-linear relationships. This approach can also serve as a useful template for future research.

6.2. Practical Implications

From a practical perspective, the findings suggest that waste management organizations should prioritize strategies that strengthen direct traffic sources, optimize organic search, and develop partnerships generating referral traffic. Investments in social media communication should focus on sustaining user attention rather than traffic volumes. Furthermore, improving the mobile experience remains critical, as mobile access currently shows lower engagement performance than desktop.

6.3. Limitations and Future Research

The study also has several limitations. The dataset includes a limited number of websites and represents a current snapshot rather than longitudinal user behaviour. Traffic volume and engagement data are based on aggregated Similarweb source rather than first-party analytics, which may cause measurement uncertainty. In addition to the limitations of the Similarweb data, this study has several other limitations. The sample of 41 websites is relatively small, which reduces the statistical power of the analyses and may explain why some results were not statistically significant. Also, the data were collected at one time, so it does not capture seasonality, marketing campaigns or changes in algorithms. Most of the analysed websites are from the United States and other developed countries, which limits the applicability of the findings to other regions. A further limitation concerns the interpretation of the random forest variable importance measures. Because traffic-source shares are correlated, predictive information may be distributed across related predictors, meaning that the importance attributed to an individual traffic source should not be interpreted as its isolated contribution or as the magnitude of an independent effect. Finally, because the study utilizes observational data, the identified relationships between traffic sources and user engagement should be interpreted as associations rather than evidence of causality.

Future research may therefore extend the analysis by utilizing long-term first-party data. Further studies could also examine how website design, content structure, and website functionalities influence engagement patterns. Future studies could use experimental methods, such as A/B testing of landing pages across different traffic sources, to better understand causal relationships.

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Authors' contributions

Martin Kuchta: Study conception and design, Data collection, Formal Analysis, Writing - original draft preparation, Writing - review and editing.

Roman Lacko: Study conception and design, Methodology, Formal Analysis, Investigation. Writing - review and editing.

Radúz Dula: Conceptualization, Supervision, Project Administration, Funding Acquisition.

Peter Drábik: Conceptualization, Supervision, Project Administration, Funding Acquisition.

Data availability

Data available upon request.

Use of Artificial Intelligence

During the preparation of this work, the authors used Grammarly to improve the English expression, grammar, and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the final text's accuracy and integrity.

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