



DETERMINING THE CONTRIBUTION OF THE INTEGRATION OF DATA FROM OPEN STATE REGISTERS AND THE PROZORRO SYSTEM TO MULTI-CRITERIA EVALUATION OF PUBLIC PROCUREMENT PARTICIPANTS

Electronic public procurement platforms publish large volumes of open data, and recommender components of e-government systems increasingly rely on multi-criteria evaluation of procurement participants, which makes the actual availability of the required attributes in open sources a matter of direct empirical verification. A reproducible computational pipeline has been developed that links Prozorro tender records with two open state registers – the Unified State Register of Legal Entities (EDR) and the Unified Register of Debtors (ERB) – by the national identifier (EDRPOU), builds a decision matrix and applies the TOPSIS and weighted sum (WSM) methods under equal, CRITIC and Gini weighting; the inference is based on rank correlations with confidence intervals and a bootstrap over participants. The experiment covered 45 open tenders of 2024 in one classification division (computer and office equipment) with 50 unique participants, of which 36 are legal entities and 14 are sole proprietors. It has been established that the open EDR file covers 100 % of legal entities (36 of 36) and, by structure, none of the sole proprietors (0 of 14), while several theoretically relevant attributes are empirically absent on this market: active debt in the ERB and terminated contracts were recorded for none of the participants, and offered prices are not comparable across tenders. It has been determined that the TOPSIS and WSM rankings almost coincide (Spearman 0.996; 95 % confidence interval [0.992, 0.998]; Kendall 0.965) and remain stable across the weighting schemes (Spearman 0.887-0.990). It has been quantified that procurement records alone collapse the 36 legal entities into only eight distinct score levels, with 21 participants sharing a single level, whereas adding one register attribute – company age from the EDR – resolves all 36 into unique scores while reordering the ranking moderately (Spearman 0.825; 95 % confidence interval [0.682, 0.908]). It has also been established by a bootstrap over participants (2,000 resamples) that the final ranking is statistically stable, with a median rank correlation of 0.985 and a 95 % interval of [0.909, 0.999]. The findings demonstrate that register integration materially increases the discriminatory power of open-data-based participant evaluation, and the released pipeline enables full reproduction of the results.

Keywords: record linkage; TOPSIS; CRITIC; decision support; e-government recommender system.

Introduction / Вступ

Public e-procurement platforms have become a primary channel for the transparent allocation of public funds, and Ukraine's Prozorro system is a widely cited example of open contracting in practice [17]. In open tenders the award decision is predominantly price-driven; however, a substantial body of work argues that evaluating a participant – a supplier – on a broader set of criteria such as past performance, reliability and formal status supports better decisions and reduces risk, and that such multi-criteria evaluation is a natural component of an e-government recommender system [1, 12]. In work [16], the use of artificial intelligence in risk analysis in public procurement was examined, which further motivates data-driven evaluation of procure-

ment participants as a component of such analytical systems. The data required for such evaluation are, in principle, openly published: procurement histories in Prozorro and supplier attributes in national state registers.

Two questions, nevertheless, remain open. The first concerns availability: how much of the information needed to populate a multi-criteria model is actually obtainable from open data for real participants, given war-time restrictions and the structural limits of each register? The second concerns contribution: does integrating external registers add discriminatory power beyond what procurement data alone provide – that is, does it help a recommender separate participants that would otherwise be indistinguishable? Both questions are empirical, and the analysis of recent re-

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search and publications below shows that they have not yet been answered on real Ukrainian open data.

Relevance of research – amid a large-scale reform of public procurement in Ukraine and steady growth of open contracting data, the reliance of award decisions on price alone is being questioned in both policy debate and academic literature, and multi-criteria evaluation of procurement participants is emerging as a natural component of e-government recommender systems. The technical prerequisites for such evaluation formally exist – procurement histories are openly published in Prozorro, and additional supplier attributes are available in state registers – but the practical feasibility of building an evaluation model from these open sources, and the actual contribution of state-register integration to its discriminatory power, have not been measured on real Ukrainian data. Without such an empirical assessment, the design of open-data-based supplier-evaluation components rests on assumptions rather than evidence, which motivates the present study.

Object of research – the process of multi-criteria evaluation of public procurement participants in a recommender component of an e-government system.

Subject of research – which will make it possible to establish, on real open data, the practical feasibility of open-data-based multi-criteria evaluation of procurement participants and to measure the marginal contribution of state-register integration to its discriminatory power.

The purpose of the research – to determine the contribution of open state register integration to the discriminatory power of multi-criteria assessment of public procurement participants on real open data, the results of which will provide a justified basis for designing recommender components of e-government systems.

To achieve this *purpose*, the following main *research objectives* are identified:

- develop a reproducible record-linkage pipeline that integrates Prozorro tender records with the EDR and ERB registers by the national identifier. This will enable end-to-end assembly of the decision matrix from open sources and full reproduction of every reported result;
- measure the availability of open data per source and per evaluation criterion. This will give an opportunity to establish which theoretically relevant attributes are actually usable on a real market segment;
- rank the participants with the TOPSIS and WSM (weighted sum model) methods under the equal, CRITIC and Gini weighting schemes and assess method agreement and weight sensitivity. This will ensure that the resulting ranking is not an artefact of a single aggregation method or weighting scheme;
- quantify the marginal contribution of a register-derived attribute to the resolution of the ranking. This will help to measure, on real data, the discriminatory power that register integration adds beyond procurement history.

Analysis of recent research and publications. In study [2], the authors proposed a comprehensive framework for supplier selection that combines several multi-criteria methods with an extensive sensitivity analysis of the resulting rankings. The work demonstrates that the reliability of a supplier ranking should be verified against changes in weights and methods rather than assumed; however, the attributes of the evaluated suppliers are taken as given, and the question of whether such attributes can be obtained from open sources is not raised.

In work [6], a comparison of multi-criteria decision-making techniques for managing public procurement tenders

was carried out, and it was shown that different aggregation methods may produce close but not identical award decisions. The study concentrates on the award phase of procurement and on the methodological side of aggregation, while the data describing the tenderers are assumed to be complete and readily available.

In study [10], the application of multi-criteria decision analysis to the most economically advantageous tender approach was examined on real procurement practice, and it was established that price still dominates the awarding even when non-price criteria are formally declared. This finding motivates evaluation models that draw non-price attributes from sources external to the tender itself, which is the direction developed in the present article.

In work [14], an assessment system of the public procurement efficiency was developed, and it was shown that non-price dimensions of procurement performance require dedicated indicators drawn from external sources. This conclusion further motivates the participant-level, register-based evaluation adopted in the present study, in which non-price signals about a supplier are obtained not from the tender document itself but from the state registers.

In the monograph [8], the TOPSIS method was introduced together with the family of multiple attribute decision-making procedures, and in study [5] the CRITIC method of objective weighting was proposed, which derives criterion weights from the variability of and correlation between criteria. These two works form the methodological core used in the present study, since objective weighting removes the need for expert judgement at the demonstration stage.

In study [7], machine learning models were trained on open procurement records to provide early warnings of contract malfeasance, and it was demonstrated that open contracting data alone carry a measurable predictive signal. At the same time, the work does not integrate external state registers, so the marginal value of register attributes over procurement history remains unmeasured.

In the systematic review [11], network-analytic approaches to detecting fraud, corruption and collusion in public procurement were summarised, and it was concluded that the quality and completeness of open data are the principal practical constraints of such analytics. This conclusion supports treating data availability as an object of study rather than as an assumption.

In work [12], multi-criteria evaluation was applied to the management of open government data, and it was shown that the usefulness of open data portals varies considerably across attributes and use cases. The study addresses open data in general, without linking procurement records to state registers at the level of an individual supplier.

Summing up, the analysis of recent research shows the following. In the reviewed studies, the methodological toolkit of multi-criteria evaluation is mature and supported by accessible open software [2, 5, 6, 8, 9, 10], yet the published applications concentrate on the award phase, the sensitivity of the resulting rankings is examined only in some of them [2, 6, 10], and the availability of the attributes required by the models is assumed rather than verified [2, 6, 12]. For Ukrainian open data – the Prozorro system combined with the state registers – no quantitative assessment of the feasibility of such evaluation, or of the contribution of register integration to its discriminatory power, has been published so far [1, 7, 11]. This gap directly motivates the aim and the tasks of the present research.

Materials and methods of research. The study uses three open sources read as a June 2026 snapshot: the Prozorro public API, the open-data file of the Unified State Register of Legal Entities (EDR) and the Unified Register of Debtors (ERB), linked by the national identifier (EDRPOU). The sample comprises 45 open tenders of 2024 in classification division 30 with 50 unique participants (36 legal entities, 14 sole proprietors). Rankings are computed with the TOPSIS and WSM methods under equal, CRITIC and Gini weighting; statistical processing relies on Spearman and Kendall rank correlations with two-sided tests and Fisher-transform confidence intervals, and on a bootstrap (a computer-intensive statistical method based on repeated re-sampling from the observed data).

Research results and their discussion / Результати дослідження та їх обговорення

Data sources and sample. The sampling frame was open ("aboveThreshold") tenders whose item classification (DK 021:2015, the national CPV variant) falls in division 30 (office and computer equipment and supplies) with a tender creation date in 2024; all three sources are openly reusable with attribution [1]. Collection proceeded backwards through the Prozorro modification feed, retrieving full records and filtering locally, until 50 unique participants had been accumulated. This yielded 45 tenders and 50 participants, of which 36 are legal entities (eight-digit identifier) and 14 are sole proprietors (ten-digit individual tax number). Anonymised participant identifiers (P01-P36) are used throughout the figures so that no individual supplier is publicly ranked by name.

Record-linkage pipeline. Participants were linked across sources by the national legal-entity code (the identifier carried in Prozorro under scheme UA-EDR). The pipeline comprises three components released as small scripts for reproducibility. The collector reads the Prozorro feed with server-side pre-filtering by procurement method to avoid downloading the full record of non-relevant procedures, applies local filtering by classification prefix and date, uses polite rate limiting with retry and back-off, and checkpoints progress to allow resumption. The EDR component performs a streaming parse of the legal-entity XML dump, extracting the registration date (converted to age), the activity status and the presence of a disclosed ultimate-beneficial-owner; it tolerates the malformed numeric character references and control bytes that occur in the dumps and respects the declared encoding. The ERB component detects the debtor-code column by name and, as a fallback, by content, with automatic encoding (Windows-1251) and delimiter detection, and counts active enforcement proceedings per identifier. A structural consequence of the open data is that sole proprietors carry no register-side code in the open EDR file and are not reliably matchable in the ERB; register-derived attributes are therefore available for legal entities only, which is reported as a coverage result rather than treated as missing data to be imputed.

Criteria and collinearity reduction. Participant-level features were aggregated from the raw tender records: number of submitted bids, active awards (wins), rejected awards (disqualifications), cancelled awards, award-level complaints, and contract counts by status, together with attributes from the registers (company age, activity status, beneficial-owner disclosure, active debt). Two feature pairs were near-collinear and were de-duplicated to avoid double counting:

wins versus active-contract count (Pearson $r = 0.94$, $p < 0.001$; identical for 34 of 36 legal entities) and cancelled-award versus cancelled-contract count ($r = 0.79$, $p < 0.001$; identical for 34 of 36). One member of each pair was retained. Features that were empty or near-constant in the sample (Section "Results") were excluded from the ranking model and reported under availability. The retained criteria are listed in Table 1.

Table 1. Retained evaluation criteria, their optimisation direction, data source and availability ($n = 50$ participants; the register-derived age is available for the 36 legal entities only) / Відібрані критерії оцінювання, напрям їх оптимізації, джерело даних і доступність ($n = 50$ учасників; реєстрова ознака віку доступна лише для 36 юридичних осіб)

Criterion	Direction	Source	Available for
Wins	benefit	Prozorro	all 50
Disqualifications	cost	Prozorro	all 50
Cancelled contracts	cost	Prozorro	all 50
Company age, years	benefit	EDR	36 legal entities

MCDM model. The decision matrix was normalised with min-max normalisation, which admits the zero values present in count criteria [15]. For a benefit criterion the normalised value is:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, i = \overline{1, n}, j = \overline{1, m}, \quad (1)$$

for a cost criterion:

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, i = \overline{1, n}, j = \overline{1, m}, \quad (2)$$

where m and n is the number of rows and columns in the decision matrix.

Two aggregation methods were applied. The weighted-sum model (WSM) computes:

$$S_i = \sum_{j=1}^m w_j r_{ij}, i = \overline{1, n}. \quad (3)$$

TOPSIS [8] forms the weighted matrix:

$$v_{ij} = w_j r_{ij}, i = \overline{1, n}, j = \overline{1, m}, A^+ = \{\max_i v_{ij}\}, A^- = \{\min_i v_{ij}\}, \quad (4)$$

deal A^+ and anti-ideal A^- vectors, the Euclidean distances D_i^+ and D_i^- of each alternative to them, and the closeness coefficient:

$$D_i^+ = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^+)^2}, D_i^- = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^-)^2}, i = \overline{1, n}. \quad (5)$$

Three weighting schemes were used: equal weights as a baseline, and two objective schemes – CRITIC [5], which is scale-invariant and accounts for inter-criterion correlation through:

$$C_j = \sigma_j \cdot \sum_{k=1}^m (1 - \rho_{jk}), w_j = \frac{C_j}{\sum_{k=1}^m C_k}, j = \overline{1, m}, \quad (6)$$

and a Gini-based scheme as a robustness check. Shannon-entropy weighting was not used because its implementation requires strictly positive matrix entries, which is incompatible with the sparse count criteria; standard-deviation and variance weights were rejected because, computed on raw scales, they over-weight the years-scaled age criterion. All computations used the pymcdm library [9].

Analyses and sources of error. Four analyses were performed: data availability (coverage per source and informativeness per criterion); method agreement (Spearman, Kendall's τ and weighted Spearman r_w between TOPSIS and WSM); weight sensitivity (Spearman between weighting

schemes); and register contribution (a two-tier comparison between a Prozorro-only model and a register-enriched model on the same 36 legal entities). The authors note the principal sources of error: the registers are read as a current snapshot, not as the state at bid time; the ERB retains only active proceedings; the sample is one classification division and one snapshot; and there is no labelled outcome variable, so the study characterises the mechanism rather than its predictive quality.

Statistical processing. Primary data were processed statistically as follows. Criterion distributions were summarised by descriptive statistics (counts of informative values, ranges and medians). Linear dependence used for collinearity reduction was quantified with Pearson's correlation. Agreement between methods, sensitivity to weighting and the contribution of register integration were quantified with rank correlations – Spearman's ρ , Kendall's τ and weighted Spearman r_w – each reported with a two-sided significance test and, for Spearman's ρ , a 95 % confidence interval obtained through the Fisher z-transform. The stability of the final ranking was assessed by a non-parametric bootstrap over participants (2000 resamples), reporting the median and the 95 % percentile interval of the rank correlation between resampled and original rankings. Because the primary data are administrative records rather than measured observations with experimental replication, statistical inference is based on rank-correlation significance, confidence intervals and resampling, rather than on parametric comparison-of-means procedures (e.g., analysis of variance), which would not be appropriate for this design.

Implementation and reproducibility. Data collection requires no credentials, since only public read interfaces and open-data dumps are used. The collector stores both the raw retrieved records and an aggregated participant matrix, so that the feature aggregation, the collinearity reduction and every reported coefficient can be recomputed from the raw data without re-querying the source. The register parsers are deterministic given a fixed dump, and the snapshot date is recorded with the output.

Integration of electronic public procurement system data with open state registers and assessment of information accessibility. In the first stage, the integration of data from the Prozorro electronic system with open state registers was implemented. Following this integration, the actual accessibility of information was assessed for each source and each evaluation criterion.

The EDR covered 100 % of legal entities (36 of 36) and 0 % of sole proprietors (0 of 14); the coverage gap therefore equals exactly the share of sole proprietors, a structural consequence of the open EDR file not exposing an identifier code for them (Fig. 1,a). Among the procurement criteria, informative (non-zero) values were present for wins in 52 % of participants, for disqualifications in 20 % and for cancelled contracts in 16 % (Fig. 1,b). Two theoretically relevant signals were empirically absent: contract terminations (0 of 50) and active debt in the ERB (0 of 36 verifiable legal entities; non-verifiable for sole proprietors). Offered prices were available but are not comparable across tenders of different subject matter and were therefore not used as a ranking criterion. These null findings are reported for the sample and are not generalised.

Consistency Analysis of Multi-Criteria Ranking Methods. To verify the applicability of the integrated data, a multi-criteria ranking of procurement participants was performed using the TOPSIS and WSM methods.

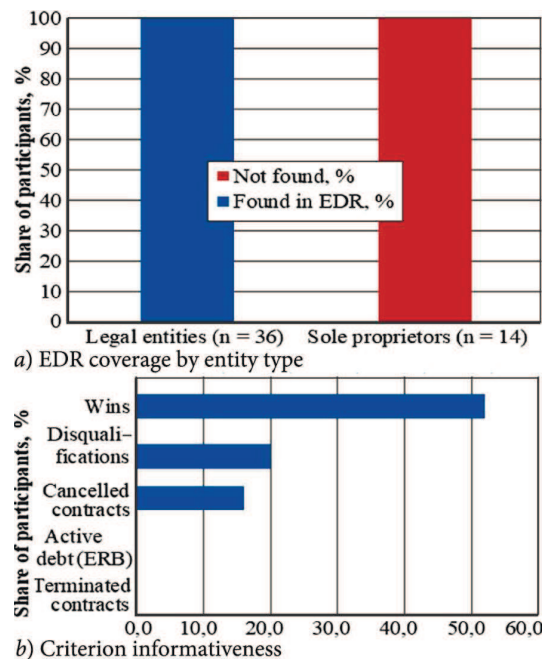


Fig. 1. Open-data availability for participant evaluation ($n = 50$) / Доступність відкритих даних для оцінювання учасників ($n = 50$): (a) share of participants found in the EDR by entity type – 100 % of legal entities versus 0 % of sole proprietors / частка учасників, знайдених у ЄДР, за типом суб'єкта; (b) share of participants with a non-zero value per criterion / частка учасників з ненульовим значенням за кожним критерієм

Table 2. Informativeness of candidate criteria in the sample (LE – legal entities). Empty or near-empty criteria were excluded from the ranking model and reported here / Інформативність критеріїв-кандидатів у вибірці (LE – юридичні особи); порожні та майже порожні критерії вилучено з моделі ранжування

Criterion	Non-zero (of 50)	Non-zero (of 36 LE)	Range
Wins	26	18	0-2
Disqualifications	10	7	0-2
Cancelled contracts	8	6	0-1
Terminated contracts	0	0	0
Active debt (ERB)	0	0	0
Company age, years	–	36	2.0-33.1 (median 12.5)

TOPSIS and WSM produced almost identical rankings under all three weighting schemes (Table 3, Fig. 2): Spearman 0.99 (0.996 for CRITIC weights; two-sided $p < 0.001$; 95 % CI [0.992, 0.998]), Kendall's τ 0.96-0.97 ($p < 0.001$) and weighted Spearman r_w 0.99 (Table 6). The ranking is therefore not an artefact of a single aggregation method.

Table 3. Agreement between TOPSIS and WSM rankings of the 36 legal entities under three weighting schemes (rank-correlation coefficients) / Узгодженість ранжувань TOPSIS і WSM для 36 юридичних осіб за трьох схем зважування (коефіцієнти рангової кореляції)

Weighting	Spearman	Kendall τ	r_w
Equal	0.994	0.968	0.991
CRITIC	0.996	0.965	0.996
Gini	0.993	0.965	0.996

Sensitivity Analysis of Ranking Results to Variations in Criteria Weights. To verify the robustness of the model, the impact of various schemes for the objective determination of criteria weights on the ranking results was investigated.

Rankings were stable across weighting schemes. The objective CRITIC weights were close to balanced (wins 0.288, disqualifications 0.219, cancelled contracts 0.234,

age 0.259), whereas the Gini scheme shifted weight towards the risk criteria (0.219, 0.320, 0.319, 0.142). Equal and CRITIC rankings agreed closely (Spearman 0.990, $p < 0.001$); the largest divergence occurred under Gini (Spearman 0.887-0.920, $p < 0.001$), affecting mainly the middle of the ranking (Fig. 3).

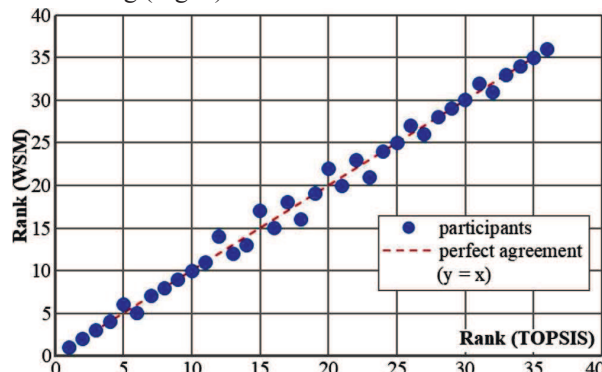


Fig. 2. TOPSIS versus WSM ranks for the 36 legal entities (CRITIC weights). Points lie on the diagonal; Spearman = 0.996 / Ранги TOPSIS і WSM для 36 юридичних осіб (вагомості CRITIC); точки лягають уздовж діагоналі повної згоди (пунктир), Спірмен = 0,996

Table 4. Criteria weights under the three weighting schemes (four criteria, 36 legal entities). CRITIC yields near-balanced weights; the Gini scheme shifts weight towards the two risk criteria / Вагомості критеріїв за трьох схем зважування (чотири критерії, 36 юридичних осіб)

Weighting scheme	Wins	Disqualifications	Cancelled contract	Company age
Equal (baseline)	0.250	0.250	0.250	0.250
CRITIC (objective)	0.288	0.219	0.234	0.259
Gini (objective)	0.219	0.320	0.319	0.142

Table 5. Sensitivity of the TOPSIS ranking to the weighting scheme: rank correlation between rankings obtained under different weights ($n = 36$) / Чутливість ранжування TOPSIS до схеми зважування: рангова кореляція між ранжуваннями за різних вагомостей ($n = 36$)

Pair of weighting schemes	Spearman (TOPSIS ranks)
Equal vs CRITIC	0.990
Equal vs Gini	0.920
CRITIC vs Gini	0.887

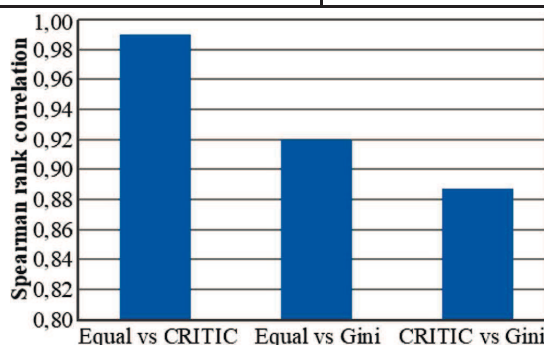


Fig. 3. Sensitivity of the TOPSIS ranking to the weighting scheme: Spearman rank correlation between rankings obtained under equal, CRITIC and Gini weights ($n = 36$) / Чутливість ранжування TOPSIS до схеми зважування: попарна рангова кореляція Спірмена між ранжуваннями за вагомостей equal, CRITIC і Gini ($n = 36$ юридичних осіб)

Quantitative Assessment of the Impact of Open State Register Data Integration on Enhancing the Model's Discriminatory Power. A key objective of the study was to determine whether the integration of open state registers enhances the discriminatory power of the model. To this end,

a comparison of the ranking results before and after the integration of registry data was performed.

Using procurement data alone, the 36 legal entities collapsed into only eight distinct score levels, with 21 of them sharing a single profile; 14 of the full 50 participants were entirely neutral. Procurement history alone therefore leaves most participants mutually indistinguishable. Adding a single register attribute (company age from the EDR) resolved all 36 into unique score levels, while reordering the ranking substantially but not arbitrarily (Spearman 0.825, $p < 0.001$, 95 % CI [0.682, 0.908], between the Prozorro-only and register-enriched tiers; Fig. 4). This is a direct, quantified demonstration that register integration supplies discriminatory power absent in the procurement data themselves. The resolution of register integration (or the resolution of register interaction) is a characteristic of a government or corporate electronic interaction system that determines the level of detail, accuracy and depth with which systems can match, identify and separate data from various basic and departmental information registers.

Table 6. Inferential statistics for the principal rank correlations ($n = 36$ legal entities). Two-sided p-values; 95 % confidence intervals for Spearman's ρ via the Fisher z-transform; the bootstrap interval is a 2000-resample percentile interval / Інференційна статистика основних рангових кореляцій ($n = 36$ юридичних осіб): двосторонні р-значення; 95 % довірчі інтервали для ρ Спірмена за з-перетворенням Фішера; бутстреп-інтервал – процентильний за 2000 ресемплів

Comparison (rank correlation)	Coefficient	p	95 % CI
TOPSIS vs WSM (Spearman)	0.996	< 0.001	[0.992, 0.998]
Prozorro-only vs +register (Spearman)	0.825	< 0.001	[0.682, 0.908]
CRITIC vs equal (Spearman)	0.990	< 0.001	-
CRITIC vs Gini (Spearman)	0.887	< 0.001	-
Bootstrap rank stability (median Spearman)	0.985	-	[0.909, 0.999]

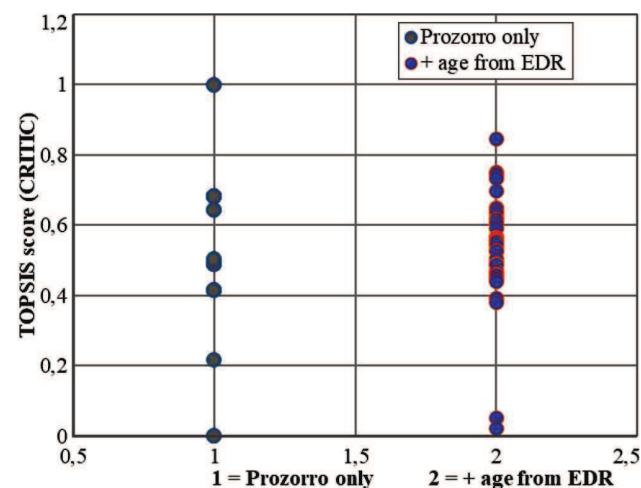


Fig. 4. Discriminatory power of register integration. Using Prozorro data only (left), the 36 legal entities take just eight distinct TOPSIS scores, with 21 sharing one level; adding company age from the EDR (right) resolves all 36 into unique scores. CRITIC weights / Розрізнявальна здатність реєстрової інтеграції (36 юридичних осіб; TOPSIS, вагомості CRITIC): лише за даними Prozorro (ліворуч) учасники мають вісім різних рівнів оцінки, причому 21 поділяє один рівень; додавання віку суб'єкта з ЄДР (праворуч) робить усі 36 оцінок унікальними

Statistical robustness. A non-parametric bootstrap over participants (2000 resamples; two resamples with a degenerate constant criterion were skipped) gave a median rank

correlation of 0.985 between the resampled and the original rankings, with a 95 % percentile interval of [0.909, 0.999]. The ranking is therefore statistically stable to sampling variation. Table 6 collects the inferential statistics for the principal rank correlations.

Results of the Multi-Criteria Ranking of Procurement Participants. Upon confirming the consistency of the methods, the robustness of the results, and the positive impact of registry data integration, the final ranking of procurement participants was established.

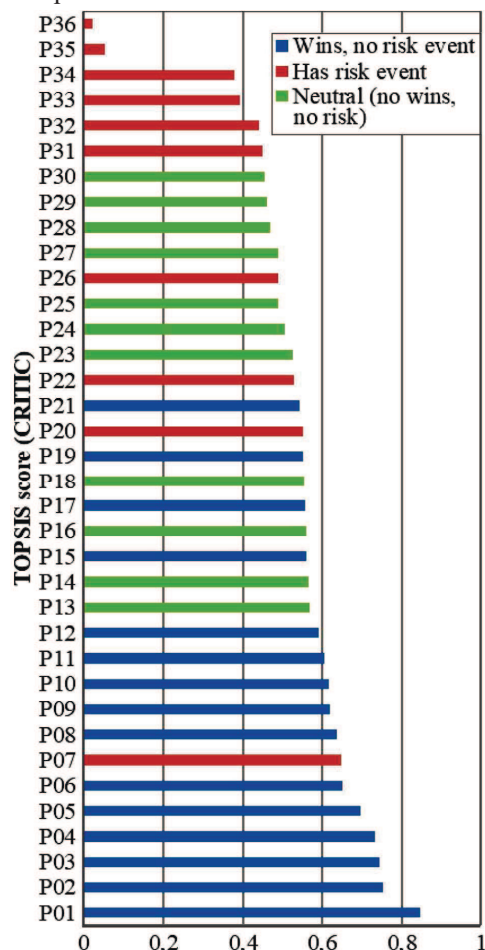


Fig. 5. Final TOPSIS ranking of the 36 legal entities (CRITIC weights; participants anonymised P01-P36). Colour encodes the presence of wins and of risk events (disqualifications or cancellations) / Підсумкове ранжування TOPSIS для 36 юридичних осіб (вагомості CRITIC; учасників анонімізовано P01–P36); колір позначає наявність перемог і ризикових подій

The register-enriched TOPSIS/CRITIC ranking (Fig. 5) is face-valid: the top positions are occupied by established legal entities with wins and no risk events, and the bottom positions by participants with no wins, multiple disqualifications and a cancelled contract. Because most participants have a thin procurement track, company age carries much of the separation in the resolved ranking; the risk criteria affect only the minority of participants with recorded events.

The resulting ranking demonstrates that the integration of information from open state registers improves the differentiation of procurement participants while maintaining stable ranking behavior across various alternative weighting schemes and MCDA methods. These findings confirm the practical value of the proposed integration approach and justify its applicability as a decision support tool for the objective evaluation of procurement participants using heterogeneous open data sources.

Discussion of research results. In study [15], a benchmarking framework for multi-criteria methods was proposed, in which TOPSIS, VIKOR, COPRAS and PROMETHEE II were compared on simulated decision matrices and the similarity of the resulting rankings was measured with Spearman correlation coefficients. The results of the present study transfer this verification logic from simulated to real administrative data and further specify its outcome: on an actual procurement sample, the TOPSIS and WSM rankings agree almost perfectly (Spearman 0.996; 95 % confidence interval [0.992, 0.998]), so the reported ranking is demonstrably not an artefact of the chosen aggregation method.

In work [3], an experimental analysis of the theory of the TOPSIS method demonstrated that its outcome is sensitive to internal settings such as the normalization technique and the distance metric. The experiment conducted within the present paper complements this observation from the opposite side: with the min-max normalization fixed for the sparse count criteria, the ranking remained stable across three weighting schemes (Spearman 0.887–0.990) and across a bootstrap over participants (median rank correlation 0.985; 95 % interval [0.909, 0.999]), which localises the remaining sensitivity in the choice of weights rather than in the aggregation itself.

In study [13], the CRITIC method was applied to derive objective weights for ranking supply chain companies, and the stability of the resulting priorities was examined through a sensitivity analysis. The results of the present study are consistent with that design and extend it with an inferential layer: the objective CRITIC weights proved close to balanced on the procurement data, and the divergence between the objective schemes concentrated in the middle of the ranking while the top and bottom positions remained stable.

In work [4], machine learning tools applied to Italian calls for tenders identified quantitative red flags of corruption risk, including characteristics of the participating firms, and it was shown that broadening the set of indicators improves the predictive model. The availability analysis of the present study adds an empirical caution to this line of work for the open-data setting: on the studied market segment, several theoretically central firm-level indicators – active debt and contract terminations – turned out to be empirically empty, so the practically usable set of red-flag attributes must be established per data source and market rather than taken from a general catalogue.

In the systematic review [18], the application of multi-criteria decision analysis to public procurement was summarised, and it was concluded that the published models concentrate on the award phase, rarely report sensitivity analysis and rely on accessible software only in a minority of cases. The present study addresses all three of these gaps simultaneously: it shifts the evaluation from the award of a single tender to the participant level, reports method-agreement, weight-sensitivity and bootstrap analyses with confidence intervals, and releases the computation built on an open library.

Thus, the discussion of the research results confirms the relevance of conducting this study: the analysed contemporary works verify ranking robustness on simulated data [15], examine the internal settings of the aggregation method [3], apply objective weighting with sensitivity checks in other domains [13], extract risk indicators from procurement records [4] or summarise the field's methodological

gaps [16], whereas the present study quantifies, within a unified reproducible experiment on real Ukrainian open data, both the actual availability of the required attributes and the marginal discriminatory contribution of state register integration. The interpretation of the results is bounded by the design of the experiment: the registers were read as a current snapshot while the tenders belong to 2024; the ERB retains only active proceedings, so cleared historical debt is invisible and the debt signal is biased conservatively towards absence; the sample covers one classification division; and no outcome variable is used, so the study characterises the evaluation mechanism rather than its predictive quality.

So, based on the results of the work performed, it is possible to formulate the following scientific novelty and practical significance of the research results.

Scientific novelty of the obtained research results – the methodology for determining the contribution of the integration of data from open state registers and the Prozorro system to multi-criteria evaluation of public procurement participants has been further developed; unlike existing methodologies, it is distinguished by empirically measuring the contribution of a specific data source (state registers) to the discriminatory power of the evaluation on real open data of Ukraine through comparing rankings without and with register integration, and the results of its application will become a justified basis for developing recommender components of e-government systems.

Practical significance of the research results – can be applied when designing recommender components of e-government systems and open-data-based supplier evaluation models in public procurement, enabling practitioners to build the evaluation on sources and criteria whose actual availability has been empirically verified and to reproduce the entire computation from the released pipeline, code and data.

Conclusions / Висновки

Defined the contribution of open state register integration to the discriminatory power of multi-criteria assessment of public procurement participants on real open data, the results of which will provide a justified basis for designing recommender components of e-government systems. Based on the results of the research the following main conclusions can be drawn.

1. Developed a reproducible record-linkage pipeline that integrates Prozorro tender records with the open files of the EDR and ERB registers by the national identifier (EDRPOU), which enables end-to-end assembly of the decision matrix from open sources and full recomputation of every reported coefficient from the released code and data.
2. Established the actual availability of open data for participant evaluation: the open EDR file covers 100 % of legal entities (36 of 36) and none of the sole proprietors (0 of 14), while active debt in the ERB and terminated contracts are empirically absent on the studied market and offered prices are not comparable across tenders, so theoretically motivated criteria must be verified empirically per market segment.
3. Determined that the ranking is robust to methodological choices: the TOPSIS and WSM rankings almost coincide (Spearman 0.996; 95 % confidence interval [0.992, 0.998]; Kendall 0.965), and the rankings obtained under the equal, CRITIC and Gini weighting schemes agree with Spearman 0.887-0.990.
4. Quantified the marginal contribution of register integration: procurement records alone collapse the 36 legal entities into eight distinct score levels with 21 participants sharing a single level, whereas adding one register attribute – company age from the EDR – resolves all 36 into unique scores while reordering the ranking moderately (Spearman 0.825; 95 % confidence interval [0.682, 0.908]).
5. Established by a non-parametric bootstrap over participants (2,000 resamples) that the final ranking is statistically stable to sampling variation, with a median rank correlation of 0.985 and a 95 % percentile interval of [0.909, 0.999].
6. Future research may focus on prospective validation of the evaluation mechanism by fixing a register snapshot and observing subsequently maturing contract outcomes, on extending the analysis to other classification divisions, on incorporating expert-elicited weights alongside objective ones, and on adding further state registers where bulk access permits, treating their coverage as part of the analysis.

Statement on the Use of AI-Assisted Technologies.

During the preparation of this work, the authors used ChatGPT and Grammarly solely for grammar and spell checking, as well as for the paraphrasing and stylistic refinement of complex sentences. Following the use of these tools, the authors critically reviewed, revised, and edited the content, and accept full responsibility for the final context and conclusions of the publication.

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ВИЗНАЧЕННЯ ВНЕСКУ ІНТЕГРАЦІЇ ДАНИХ З ВІДКРИТИХ ДЕРЖАВНИХ РЕЄСТРІВ ТА СИСТЕМИ PROZORRO У БАГАТОКРИТЕРІАЛЬНЕ ОЦІНЮВАННЯ УЧАСНИКІВ ПУБЛІЧНИХ ЗАКУПІВЕЛЬ

Електронні системи публічних закупівель оприлюднюють великі обсяги відкритих даних, а рекомендаційні компоненти систем електронного урядування дедалі частіше спираються на багатокритеріальне оцінювання учасників закупівель, тож фактична доступність потрібних атрибутів у відкритих джерелах потребує прямої емпіричної перевірки. Розроблено відтворюваний обчислювальний конвеєр, який зводить записи системи Prozorro із двома відкритими державними реєстрами – Єдиним державним реєстром юридичних осіб (ЄДР) та Єдиним реєстром боржників (ЄРБ) – за кодом ЄДРПОУ, формує матрицю рішень і застосовує методи TOPSIS та зваженої суми (WSM) зі схемами вагомостей equal, CRITIC і Gini; статистичне опрацювання отриманих даних ґрунтується на рангових кореляціях з довірчими інтервалами та бутстрепі за учасниками. Експеримент охопив 45 відкритих тендерів 2024 року одного розділу класифікатора (комп'ютерна та офісна техніка) з 50 унікальними учасниками, з яких 36 – юридичні особи і 14 – фізичні особи-підприємці. Встановлено, що відкритий файл ЄДР покриває 100 % юридичних осіб (36 із 36) і, за структурою, жодної фізичної особи-підприємця (0 із 14), а низка теоретично значущих атрибутів на цьому ринку емпірично відсутня: активний борг у ЄРБ і розірвані договори не зафіксовано в жодного учасника, цінові ж пропозиції незіставні між тендерами. Визначено, що ранжування за методами TOPSIS і WSM практично збігаються (кореляція Спірмена 0,996; 95 % довірчий інтервал [0,992; 0,998]; кореляція Кендалла 0,965) і залишаються стійкими до зміни схеми вагомостей (Спірмен 0,887-0,990). Кількісно оцінено, що самі тільки закупівельні дані зводять 36 юридичних осіб до восьми різних рівнів оцінювання, причому 21 учасник поділяє один рівень, тоді як додавання однієї реєстрової ознаки – віку суб'єкта з ЄДР – робить усі 36 оцінок унікальними за помірного переупорядкування ранжування (Спірмен 0,825; 95 % довірчий інтервал [0,682; 0,908]). Встановлено також бутстрепом за учасниками (2000 ресемплів) статистичну стабільність підсумкового ранжування: медіанна рангова кореляція 0,985, 95 % інтервал [0,909; 0,999]. Отримані результати демонструють, що інтеграція реєстрів істотно підвищує розрізняльну здатність результатів оцінювання учасників на відкритих даних, а оприлюднений конвеєр забезпечує повне відтворення результатів.

Ключові слова: зв'язування записів учасників публічних закупівель; метод визначення порядку переваги за подібністю до ідеального рішення; метод визначення важливості критеріїв через міжкритеріальну кореляцію; підтримка прийняття рішень; рекомендаційна система електронного урядування.