DOI: 10.55643/fcaptp.6.65.2025.5082

INCREASING FINANCIAL TRANSPARENCY IN THE USE OF INTERNATIONAL TECHNICAL ASSISTANCE UNDER MARTIAL LAW: THE DIGITAL AND ANALYTICAL CAPABILITIES OF PROZORRO

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Received: 24/11/2025
Accepted: 19/12/2025
Published: 31/12/2025

ABSTRACT

The article is devoted to researching opportunities for improving the financial transparency and effectiveness of international technical assistance (ITA) in Ukraine during martial law conditions by improving the Prozorro public procurement system tools. The authors emphasise that during a full-scale war, the role of ITA increases significantly, as it provides funding for critical infrastructure, humanitarian needs, and institutional development. At the same time, corruption risks and restrictions on procurement transparency significantly affect the trust of international partners. The article proves the necessity of introducing automated digital financial control solutions to improve the analytical capabilities of Prozorro and strengthen the public procurement results audit system. The use of two text mining algorithms is proposed – Latent Dirichlet Allocation (LDA) and BERTopic – for analysing large amounts of tender documentation, identifying structural patterns, and identifying anomalous topics which may indicate atypical financial expenses of recipients, abnormal pricing, and misuse of funds. Practical testing on Prozorro data shows that LDA forms generalized thematic clusters that reflect the areas of expenditure of international technical assistance funds, while BERTopic allows for detailed subtopics, to detect atypical text patterns, and to identify purchases with increased financial risks. The results of the study prove that integrating the proposed models into the Prozorro system can significantly strengthen anti-corruption and financial control, reduce potential losses of budget and donor resources, optimize the system of using international technical assistance, and contribute to building a higher level of trust between Ukraine and its international partners in the process of military and post-war reconstruction.

Keywords: international technical assistance, public procurement, financial control, financial risks, Prozorro system, LDA model, BERTopic model, text mining, anti-corruption monitoring

JEL Classification: C45, D73, H6

INTRODUCTION

Being at the doorstep of 2026, Ukraine is on the brink of the fourth year of a full-scale war, which, of course, affects not only all fields of society but also radically transforms them. In parallel with the economic, social, political, military, and international fields, the legal, spiritual, and technological spheres have also undergone upheavals. At the same time, despite the daily human loss, reduction of energy capacity, damage to civil and industrial infrastructure, and reduction of agricultural areas, Ukraine manages not only to maintain national security, but also to continue implementing the European integration development vector. Of course, during the war, state budget revenues are predominantly directed to ensuring the defence capability of Ukraine, while the requirements of innovative, humanitarian development, and modernization of social institutions are financed from external sources. In this context, the international technical assistance (ITA) becomes of primary importance, becoming the main tool for financing the devel-

opment of the digital economy, implementing projects to restore entrepreneurial activity, and updating the healthcare and education systems. Projects implemented within the ITA not only cover the costs associated with the restoration of critical infrastructure and economic development, but also provide for requirements related to the supply of equipment, the introduction of technologies, and expert support. In addition, funds under the ITA are directed to financing the population's needs for medicines, food, housing, and other humanitarian supplies.

The data presented in Table 1 confirms the radical transformation in the dynamics of international technical assistance volumes directed to Ukraine. In 2017-2019, Ukraine consistently ranked around 30th among the ITA recipient countries, with its share in the global volume of technical assistance amounting to about 1%. In 2020–2021, the volume of international technical assistance attracted by Ukraine showed moderate growth, which ensured the rise of the country in the global ranking of recipients (entering the top 20) and an increase in the share of the ITA received to over 1.6% of its global volume. At the same time, the decisive growth in international technical assistance for Ukraine was observed during the period of full-scale war. In 2022-2023, Ukraine became the largest recipient of the ITA in the world, confidently ranking first in this indicator. The share of international technical assistance provided to Ukraine exceeded 28% of the total global volume, which indicates an unprecedented concentration of international financial resources and their decisive role in supporting the functioning of state institutions, restoring the economy, and stabilising the financial system.

Table 1. Dynamics of indicators characterising the ITA directed to Ukraine for 2017-2023. *(Source: developed by authors based on (Our world in data, 2025))*

Indicators	Year						
	2017	2018	2019	2020	2021	2022	2023
Volume of international technical assistance, USD billion	1.29	1.27	1.17	2.34	2.13	28.7	36.89
Share of the volume of international technical assistance provided to Ukraine in the total volume of international technical assistance for countries worldwide, %	1.09	1.09	1.02	1.68	1.61	18.98	22.97
The place of Ukraine among the countries of the world in terms of the volume of international technical assistance	32	28	31	17	19	1	1

Considering active support of Ukraine by the international community (namely, in 2024, at least 14 international technical assistance projects were implemented (Ministry of Finance of Ukraine, 2025a), and according to the results of 2025, within the Ukraine Facility, it is expected to attract EUR 30.6 billion of budget support (Ministry of Finance of Ukraine, 2025b), aimed at improving processes related to European integration, energy stability, budget transparency, improving the tax system, financial system stability, institutional capacity, as well as the functioning of small and medium-sized businesses, it can be argued that ITA forms the foundation for the sustainable, both war and post-war development of Ukraine.

All projects launched in 2024-2025 are long-term with annual phased funding. This not only builds confidence among project implementers regarding financial stability, but also ensures the development of the country's socio-economic infrastructure for years to come.

In parallel with the above-mentioned, guarantees of further cooperation with Ukraine within the ITA and full financing of projects depend on the level of transparency and objective accountability of domestic recipients. Currently, the huge number of corruption risks in Ukraine increases donors' sensitivity to continued cooperation, which, in turn, increases reputational losses and leads to a potential reduction in ITA amounts. In this context, the use of digital tools that ensure objectivity and minimize the influence of the human factor on decision-making is of particular importance. Presently, Ukraine operates a national e-procurement system, called Prozorro, which is gradually becoming a platform for analyzing the efficiency of the state resources.

This trend is confirmed by the performance indicators of the Prozorro system in the pre-war and during war years (Table 2).

DOI: 10.55643/fcaptp.6.65.2025.5082

Table 2. Dynamics of Prozorro system performance indicators for 2021-2024. *(Source: developed by authors based on (Ministry of Economy, Environment and Agriculture of Ukraine, 2023; Ministry of Economy, Environment and Agriculture of Ukraine, 2025))*

Indicators	Year			
	2021	2022	2023	2024
Number of announced purchases, million units	5.37	2.95	3.55	3.44
Value of concluded contracts, UAH million	966	484	794	889
Number of customers, units	34516	29610	28302	27949
Number of suppliers, units	261920	181000	197400	188274
Average number of proposals at auction, units	2.06	1.85	2.03	2.37

Thus, based on the data presented in Table 2, it is fair to say that in 2022, compared to 2021, the use of the Prozorro system significantly decreased, which was associated both with a decline in business activity at the beginning of the war and with legislative weakening of public procurement. At the same time, it should be noted that over the three years of the wartime, the public procurement sector has shown positive developments, restoring both the volume of contracts concluded through the Prozorro system (the value of contracts concluded in 2024 is only 8% less than the corresponding figure in 2021) and the level of competition among suppliers (the average number of bids in 2024 is higher than in 2021).

Focusing on financial control of all transactions within the framework of international technical assistance projects using the Prozorro system, we note that at the current stage of public procurement development, significant progress is being made in this area. An example is the international procurement module in the Prozorro system, which, based on the flexible "constructor" principle, provides the ability to adapt tender procedures to the specific requirements of each donor. This allows you to form the parameters of the tender in accordance with the project requirements within the ITA, namely to determine the expected cost, auction conditions, currency of offers, and also to use various evaluation criteria – from price to quality and technical characteristics (Prozorro, 2023).

At the same time, the issues of public financial control and independent monitoring of the ITA by both society and executive authorities within the Prozorro system remain unresolved. Systematic and continuous improvement of the Prozorro system modules is the key to shaping the image of Ukraine as a reliable partner and gaining the trust of international investors.

LITERATURE REVIEW

Focusing on research into existing scientific achievements in the field of ITA use, we note that Ukrainian scientists, for the most part, consider the role of the ITA through the prism of its dynamics, structure, and priorities of donor countries. Therefore, the analysis of key aspects of Ukraine's cooperation with international organizations is based on the information dating back to the time of independence (Medvid, 2017). Researchers pay attention to identifying further vectors of international cooperation within the implementation of the ITA projects based on an analysis of the connection between the number of international projects and the socio-political situation in Ukraine during 1992-2014. In turn, the increase in the volume of the ITA in Ukraine in 2020 allows for research to be conducted in terms of the number of projects by development partners and sectors, as well as forms of assistance (Sysoenko & Karliuka, 2022). The results obtained determine the directions for further transformation of the internal monitoring system of the ITA in order to preserve the image of Ukraine as a reliable partner. The defining shifts in the socio-economic life of Ukraine also did not go unnoticed by international support (Shkurat et al., 2022). So, the implementation of the decentralization reform in Ukraine at the state and regional levels took place with the active participation of the ITA programs, which allowed creating a system of administrative services that was as close as possible to the population.

In turn, foreign researchers focus on narrower aspects of the impact of the ITA on socio-economic processes in recipient countries. Thus, the decisive role of MTB has been identified in the transformation processes of the healthcare systems of countries such as China and Georgia (Huang et al., 2024). It is through the effective use of the ITA that these countries have been able to lay the foundation for the long-term financial stability of their national healthcare systems. In Latin America, international technical assistance was used to improve the effectiveness of judicial reform, with the aim of achieving further positive economic effects and strengthening the democratisation of society (Ciurlizza, 2000). Despite the significant role of political compromise in all state processes, some Latin American countries have nevertheless managed to improve the rule of law and strengthen human rights. Another interesting study examines the impact of international

organisations through the ITA on the domestic investment policy of recipient countries through official development assistance (Berge & Fauchald, 2023). It is also worth noting that changes in national legislation have been chosen as the instrument of influence on investment activity in the country.

Scientific research related to the role and significance of military technical assistance for Ukraine during a full-scale war deserves special attention. These studies focus on determining the impact of ODA on stabilising the economy and strengthening defence capabilities, as well as strategic planning of military operations aimed at Ukraine's victory (Tkach, Slobodianyk & Makoshenets, 2024). In addition, an analysis is conducted of changes in the directions of the ITA, the main donors, and the level of effectiveness of each programme. Considerable attention is paid to analysing the transparency of the use and rational distribution of foreign aid during the war, as well as systematic reporting on international projects (Bezzubko & Bezzubko, 2022). In addition, in terms of researching the level of effectiveness of the use of international technical assistance and identifying ways to improve these procedures during the war and post-war years, some researchers emphasise the analysis of ethical standards and visual content policy in working with international technical assistance (Hordieieva, 2023); Others focus on the fight against corruption, the need for systemic reform of the budget system, and increasing the level of trust in the authorities (Vatamaniuk-Zelinska & Bund, 2023); some researchers are already highlighting the issue of establishing a transparent oversight and control system that would ensure a high level of investor confidence (Martynovych, Boichenko & Dielini, 2023).

Research devoted to identifying the main determinants of the distribution of the ITA among donors is also worthy. The model developed allows us to establish the strength of the influence of relevant indicators on both the desire to help Ukraine and the amount of aid (Schmidt, 2024). Another novel study examines EU security policy through the prism of the need for long-term ITA for Ukraine (Genini, 2025). It has been determined that only through a common foreign policy (cooperation between European donors and Ukraine) and a supranational security policy (improvement of the voting mechanism, centralisation of financial resources, formation of defence competences) can EU countries counter military threats.

Focusing on research into the specifics of public procurement in Ukraine, we note that this topic has become particularly relevant during the war. Thus, not only have scientific works on compliance with transparency standards, strengthening control over compliance with legislation, and the adequacy of confidentiality requirements for defence projects (Nefodova et al., 2025; Pavliuk et al., 2025; Smentyna & Fialkovska, 2023), but also research on changes in the average purchase price, online activity of participants, speed of service provision, and level of competition after the Russian invasion (Klymak & Vlandas, 2024). These studies provide a basis for forming an information base for effective management decisions in the field of public procurement in the post-war period and creating a flexible system to counter various shock situations, from pandemics and financial crises to war.

Scientists pay special attention to the Prozorro system as undoubtedly the most effective tool for ensuring the efficient, transparent, and accountable use of public funds. Despite certain shortcomings in the functioning of the Prozorro system, namely insufficient independent auditing and public monitoring, slow integration with other public services, lack of data on contract performance and disregard for the business reputation of contractors (OECD, 2023), researchers are unanimous in their conclusions that this service remains the most effective tool for combating corruption, provided that it is systematically improved (Tkachuk & Deineka, 2023). The most relevant trend in the development of the Prozorro system is its digital transformation in terms of synergy with project management systems, international aid platforms, and public control tools, which will create a space of trust between executive authorities, business entities, citizens, and international partners (Shvaiko, 2024).

Considering existing scientific achievements in the field of international technical assistance and public procurement systems, it is fair to note that during the war in Ukraine, research aimed at improving the Prozorro system has become particularly relevant, as it would ensure compliance with the basic requirements of financial donors regarding transparency in the use of funds received.

AIMS AND OBJECTIVES

The aim of the study is to increase the level of financial transparency in the use of international technical assistance in Ukraine during martial law through financial and economic analysis of public procurement based on text mining algorithms of the Prozorro system.

DOI: 10.55643/fcaptp.6.65.2025.5082

The objectives of the study are:

- to examine the dynamics of changes in the volume of foreign aid received by Ukraine and assess the state's financial dependence on this aid;
- to determine the volumes and key financial parameters of tender procedures in the Prozorro system;
- justify the effectiveness of using BERTopic and LDA algorithms for analysing tender documentation, reveal their potential in identifying semantic patterns, risky topics, and building automated indicators for monitoring the transparency of international technical assistance use.

The research hypotheses are:

1. Tenders containing textual anomalies (atypical requirements, overly detailed descriptions, disproportionate technical characteristics) are more likely to involve financial risks than tenders with a standard textual structure.
2. The process of using international technical assistance implemented through the Prozorro system demonstrates a higher level of financial transparency and lower risks of inefficient spending compared to similar purchases made outside the electronic public procurement system.

METHODS

The process of improving the Prozorro system using the latest digital solutions is proposed to be implemented using the text mining method. This is a set of sequential algorithms for automatic processing of large arrays of unstructured text information, the purpose of which is to search for patterns, interrelationships, and hidden structures (Shu & Ye, 2023). Text mining methods differ depending on the input array of information and the task set before the researcher.

Pre-processing methods include stemming (reducing words to their root form), collocation extraction (fixed word combinations), and frequency analysis to identify the most common terms in the text corpus by calculating absolute and relative frequencies.

To implement text clustering and classification, we use k-means and its variations (Fast Global, Global, Two-Level, etc.), hierarchical classification (Zangari et al., 2024) based on agglomerative clustering and divisive clustering, and clustering based on frequencies and distributions.

Among all text mining methods, the subclass of thematic modelling methods, which is particularly relevant to the objectives of our study, is worth focusing on: Latent Semantic Analysis (LSA), Latent Dirichlet Allocation (LDA), Non-Negative Matrix Factorization (NMF), and BERTopic (Bidirectional Encoder Representations from Transformers Topics).

LSA can scale documents according to a specified keyword dimension and study semantic relationships between words without manual control by the researcher. However, unlike dictionaries, this method does not always achieve a high level of sensitivity and reliability, as it evaluates the semantic proximity between words in a set. This shortcoming often leads to errors in evaluation (Watanabe, 2020). In addition, the limitations of the method include working with small text samples (Kondeti et al., 2022).

LDA is a probabilistic model based on unsupervised learning, which assumes that each document in the corpus is a random mixture of latent topics, and each topic has a probability distribution across all words in the vocabulary. LDA is based on the idea that each document contains several hidden topics, each of which contains a set of words related to the topic (Chauhan & Shah, 2021). The limitations of the method are the need to know the number of topics in advance and the requirement for a large text sample.

NMF is a dimension reduction method (Hosseinzadeh & Daryaie, 2021) that identifies semantic features from high-dimensional data. The disadvantage of this method is that it ignores the relationships between feature vectors, which does not allow for better factorisation for text clustering. The algorithm uses random initialisation, which can lead to rapid finding of local minima and, as a result, incorrect clustering.

BERTopic is a modern method of thematic text modelling that combines classical statistical approaches (as in LDA/NMF) with deep contextual understanding of language thanks to BERT (Ma et al., 2025). BERTopic doesn't work with a random set of words like LDA, but with vector representations of texts that already "understand the context".

However, this approach can be more resource-intensive, which slows down work with large text samples.

Considering all advantages and disadvantages of these methods, to achieve the research goal, we propose a simultaneous use of two topical modeling methods: Latent Dirichlet Allocation (LDA) (Pan & Xu, 2023) and BERTopic (Grootendorst, 2025; Keita, 2022), which are regarded as the most advanced and reliable in quantitative assessment of textual topics.

The LDA algorithm implementation is visualized in Figure 1.

According to Figure 1, five steps are proposed to identify topical clusters by calculating distances between them:

- Step 1. Selection of words N in documents. Here, the length of documents in the collection is determined.
- Step 2. Topical distribution within the observation scope is established according to the Dirichlet distribution. You establish the probability of a particular topic being present in a specific document.
- Step 3. Selection of a specific topic from a multinomial distribution of topics.
- Step 4. Selection of a word that represents the corresponding topic with calculated probabilities.
- Step 5. Calculation of observation probability in a data sample containing textual information.

Consequently, an assessment is made to determine how well and accurately the LDA model explains the processed collection of texts, based on which words are grouped into topical clusters. The end user can familiarize themselves with a summary of topics in the studied set of texts, while understanding the degree of their semantic proximity.

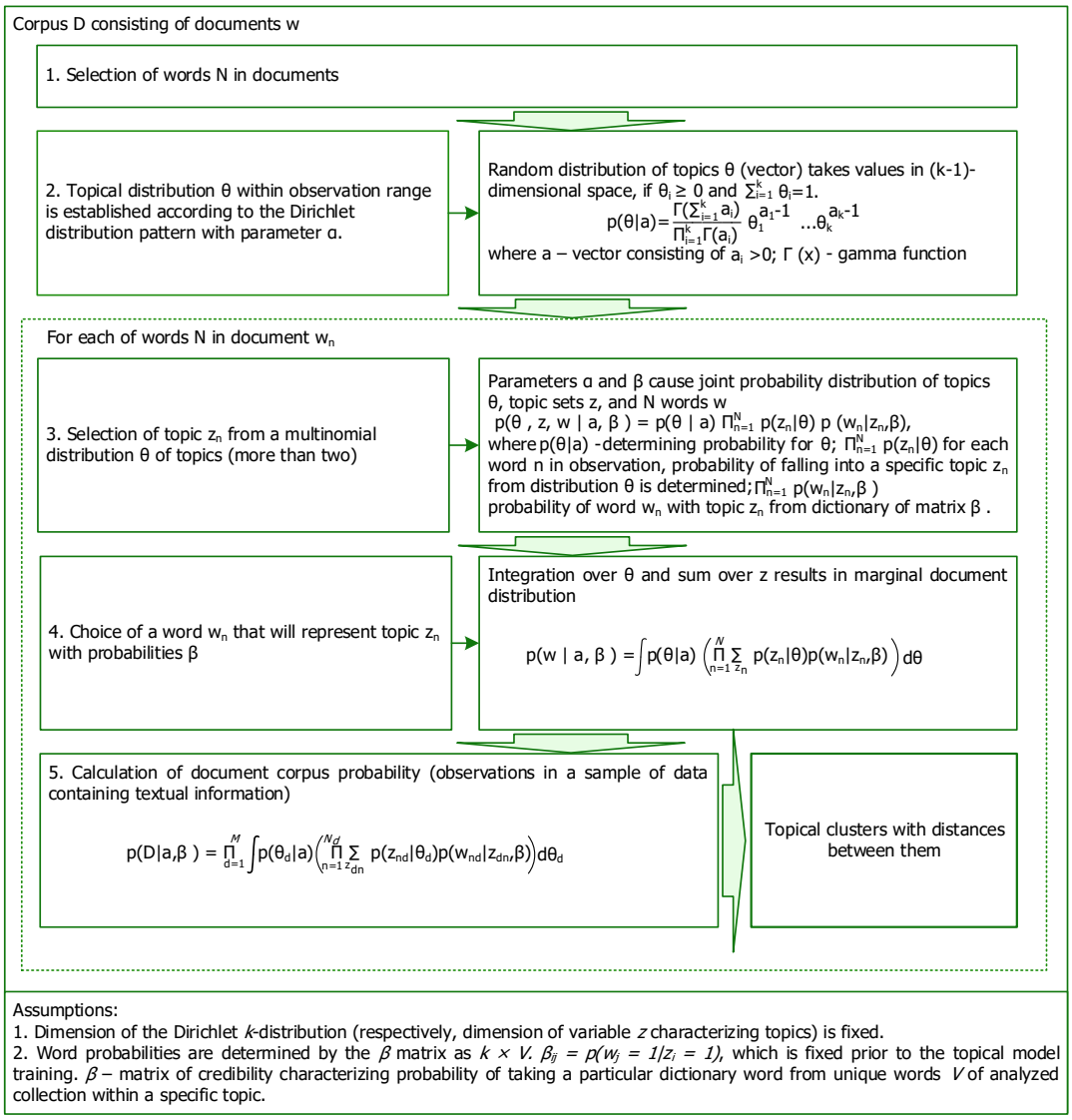

Figure 1. The Latent Dirichlet Allocation Algorithm Diagram. *(Source: developed by the authors based on (Pan & Xu, 2023; Chauhan & Shah, 2021; Kondeti et al., 2022))*

An additional method of analyzing textual context is the BERTopic algorithm. It is visualized in Figure 2.

DOI: 10.55643/fcaptp.6.65.2025.5082

Focusing on the features of the BERTopic implementation algorithm, we note that Step 1 of the algorithm is the text conversion into a numerical expression. The conversion task is the transformation of sentences (Sentence Transformers Documentation, 2025) into a vector space, which will allow for high-quality text clustering. It is proposed to use paraphrase-multilingual-mpnet-base-v2 (Sentence transformers, 2025), as the largest trained language model, which was trained on a large number of Cyrillic texts, including texts in the Ukrainian language.

Step 2 – Reduce the dimensionality of numerical representations. When clustering high-dimensional data, the difficulty in separating groups increases (Karanam, 2021), since the resulting data points will look like equidistant values, which will make clustering impossible.

Step 3 – density-based data clustering. It is proposed to use the method HDBSCAN (Hierarchical Density-Based Spatial Clustering of Applications with Noise), which will ensure the division into distinct groups. In the context of thematic modeling, this means that the clarity of the topic described by a certain group of words as a result of building the model is higher. This exceeds the potential results that can be obtained, for example, by k-averaging.

Step 4 – tokenization (breaking a continuous text into words for further division into thematic clusters). At this stage, a set of words is formed from which it will be determined later which words will represent the corresponding topic. Based on metric c-TF-IDF, the words are defined that are typical for one cluster and don't affect any other cluster.

Step 5 – topic formation. Topics are presented as lists of words, divided by relevance. Received groups and frequencies will allow us to make a decision on the popularity of the topic in public procurement.

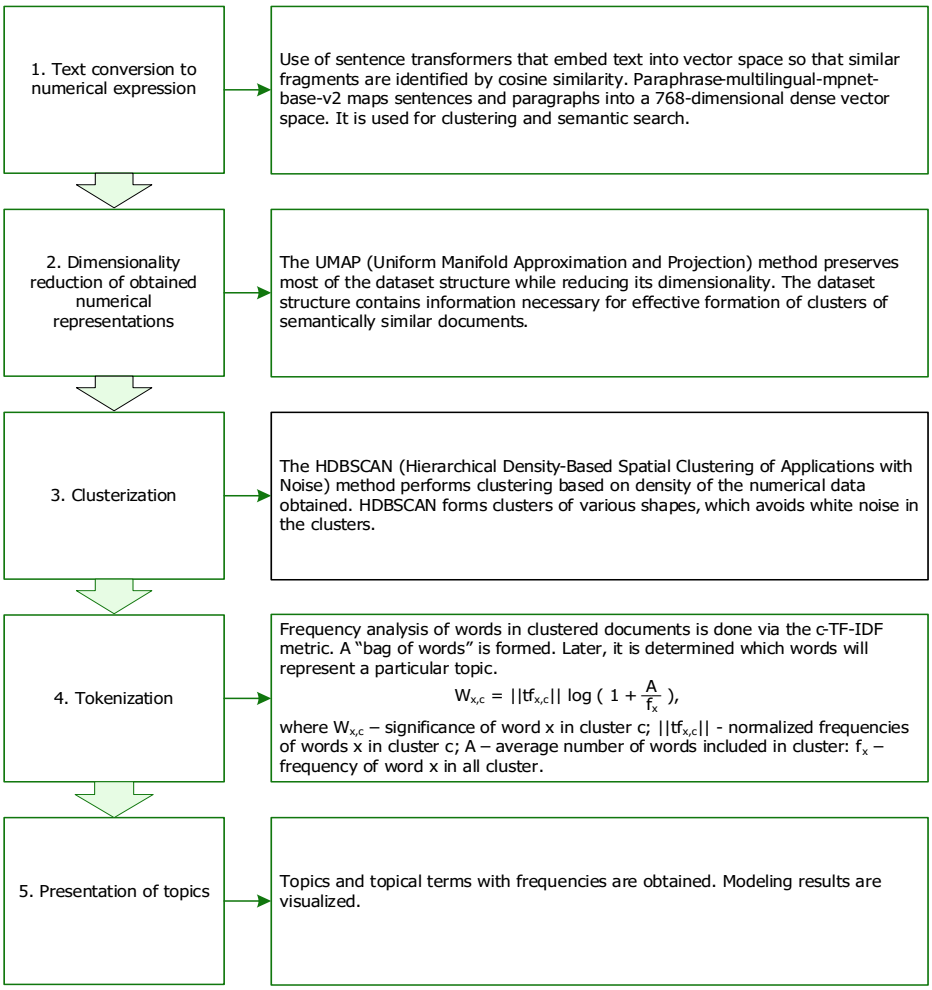

Figure 2. BERTopic Algorithm Diagram. *(Source: developed by the authors based on (Ma et al., 2025; Grootendorst, 2025; Keita, 2022; Sentence Transformers Documentation, 2025; Sentence Transformers, 2025; Karanam, 2021))*

The key difference between the BERTopic algorithm (Reaves, 2022) and the previous LDA is that it uses already trained language models of varying sizes, whereas LDA works with the available text sample. BERTopic also supports semi-controlled, dynamic topic modelling and modelling with a tutor. In turn, it is fair to note that the parallel use of these algorithms to identify the necessary patterns in the text is the basis for obtaining reliable results.

RESULTS

The practical implementation of the LDA and BERTopic algorithms was performed based on a sample of procurement data obtained from the Open Procurement API of the Prozorro system. The calculations were performed using the Python programming language.

Thus, within the BERTopic model, 1,422 topics were automatically identified, while for the LDA model, 44 topics were identified. This is because the latter model focuses on achieving the highest possible level of word coherence and, therefore, the maximum coincidence of features in lexical meaning structures or their equivalence.

Below are maps showing the distances between topics for BERTopic and LDA models (Figures 3 and 4).

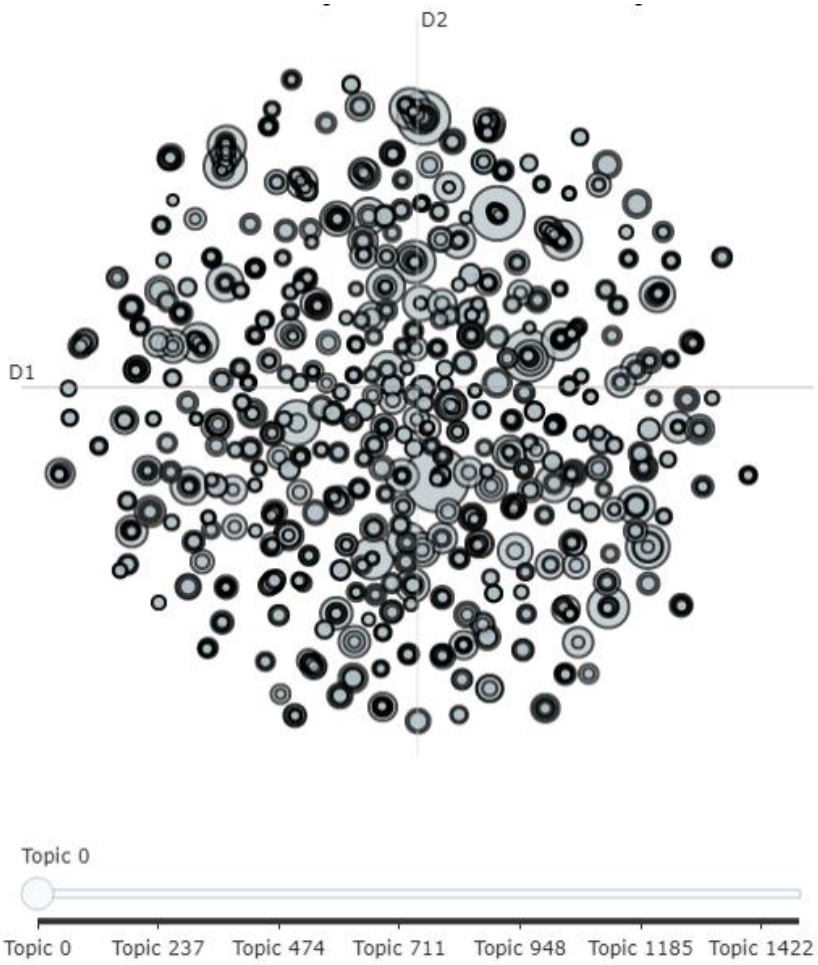

Figure 3. Topics Distances Map across dimensions D1 and D2 of the BERTopic Model. Note: D1 and D2 are dimensions between the topics studied. *(Source: developed by the authors using Python on Prozorro tenders data)*

The assumption regarding the LDA model is that it provides a more comprehensive but generalised view of the range of procurement items whose announcements were included in the sample data from Prozorro. This may be useful for analysing the needs within the sectors of the national economy of Ukraine and its socio-economic system.

According to Figure 3, the topics are evenly distributed among four quadrants formed in a two-dimensional space (D1 and D2). Each circle represents a topic with a specific set of phrases. If the circles intersect, the phrase belongs to both topics. The size of the circle corresponds to the number of phrases in the topic. The qualitative characteristic of this distribution is uniformity, which characterises the diversity of tenders in Prozorro. Accordingly, this confirms the opinion that additional tools are needed to analyse purchases through Prozorro, since the usual parameters of a "cut-off" search do not work.

According to the LDA model, the keywords defining the largest cluster (cluster 1, containing 4.5% of all tokens) reveal a distinct thematic concentration. From a financial and economic perspective, this result suggests the presence of substantial and stable budgetary flows directed toward the maintenance of infrastructure facilities, as such expenditures are typically regular and less sensitive to economic fluctuations. From the standpoint of promoting transparency in public procurement,

DOI: 10.55643/fcaptp.6.65.2025.5082

the identification of such dominant thematic areas makes it possible to determine where the largest portion of public funds is actually allocated, without relying exclusively on formal classifications or extensive manual document reviews. In contrast, the smallest cluster – cluster 44 – appears to correspond to a relatively infrequent or fragmented topic within procurement activities. Detecting such small clusters also contributes to enhancing transparency in public procurement by bringing to light irregular or atypical procurement patterns that may otherwise remain obscured in the absence of automated topic modeling tools.

The lexical composition of Cluster 1 indicates that it pertains to topics related to public utilities and the material and technical infrastructure required for their operation. The housing and utilities sector is a critical component of the economic system – providing enterprises with resources such as water, gas, and electricity – as well as of the social domain, ensuring comfortable living conditions for the population. Given this essential role, a high share of public procurement in this sector is expected to persist. In this context, the application of the LDA model enhances the accountability and transparency of public procurement by illustrating whether the scale of procurement in the utilities sector aligns with its societal significance or, conversely, by uncovering disproportionalities and instances of excessive expenditure.

Moreover, the fact that larger clusters encompass a greater share of tokens indicates that the LDA model can effectively reflect the structure of public spending: the greater the number of tokens within a cluster, the more procurement transactions and financial operations are associated with that thematic area. Consequently, clusters can be interpreted as indicative "spending centres" within the budget, thereby reinforcing transparency by offering an independent means to verify actual financial flows and their correspondence with declared fiscal priorities.

Additionally, Clusters 7 and 3 exhibit a strong thematic proximity to Cluster 1, as they concern the maintenance and development of the Ukrainian housing stock. From a financial and economic standpoint, this proximity may signify interrelated segments of expenditure – specifically, capital investment in the housing and utilities sector alongside ongoing operational spending on its upkeep. Regarding procurement transparency, this relationship enables a more comprehensive analysis that extends beyond individual tenders. It facilitates the identification of structural linkages between procurement activities, thereby supporting the detection of duplicated costs, inefficient spending patterns, or potential corruption risks in areas characterized by high volumes of budgetary operations.

Figure 4. Topics Distances Map across PC1 and PC2 of the LDA Model. Note: PC1 and PC2 are dimensions between the topics studied. *(Source: developed by the authors using Python on Prozorro tenders data)*

The results of the BERTopic model should be considered using specific topics as examples. Nine topics were selected from 1,422 generated topics to provide a relevant representation of the results.

According to Figure 5, it can be seen that the BERTopic model generates topics based on key phrases according to the relevance of their mentions. A significant portion of tenders corresponds to the areas of financing of the ITA. In our selected example, these are topics 317, 275, 607, 171, 177, 125, and 611. These topics cover construction. (technical supervision, major repairs, project documentation, contract works, building materials), energy supply (technical supervision, major repairs, project documentation, contract works, building materials), supporting communications with IT (telephone, optical cable, router, mobile communication, internet, server, monitor, switch, storage device, computer equipment), and medicine (bandage, medical spirit, insulin, syringe, gloves). In addition, the model allows you to highlight topics that are not related to the ITA (topic 413). This characterises the described model as a universal tool for additional analysis of tenders, which will allow tracking the effectiveness of the use of ITA, improving the efficiency of identifying abuses, and strengthening the transparency of public procurement.

The diagrams show the five most frequent phrases in each topic, sorted by descending relative frequency. Accordingly, by delving deeper into the analysis of each topic, suspicious patterns of system abuse can be identified. The analysis showed that it is more expedient to use the proposed algorithms for specific categories, filtering the input data array.

Figure 5. Topics and terms of BERTopic. Note: The x-axis shows the relative frequencies of phrases in the topic.

Based on the above, it can be concluded that BERTopic is useful for a more detailed analysis of subtopics. This may be useful for controlling corruption risks, stimulating optimisation and redistribution of budget funds in wartime conditions, etc.

The models built can be used for different purposes. The LDA model is suitable for analysing demand trends, while BERTopic is suitable for analysing abnormal activity.

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The practical application of these models can be implemented within the following vectors of financial analysis:

1. *Identification of potential corruption risks.* If a specific supplier or brand is repeatedly mentioned within a single topic, this may indicate that undue preferences are being given to a particular company. Such practices usually lead to inflated procurement costs and, consequently, excessive financial losses and inefficient spending of international donor funds.
2. *Identifying possible misuse of international technical assistance.* If phrases related to international technical assistance appear alongside descriptions of goods or services that cannot be financed by international technical assistance under the law (e.g., the purchase of luxury items) within the same topic, this may indicate misuse or improper use of donor funds.
3. *Improving the system of state financial control.* Thematic templates generated by LDA and BERTopic can be used by regulatory authorities to identify tenders with atypical or questionable conditions. Such anomalies often indicate financial manipulation, misuse of resources, or corrupt practices. Thus, the models can form a targeted analytical basis for making management decisions regarding enhanced financial control.

DISCUSSION

The full-scale war in Ukraine has significantly exacerbated the problems of ensuring the effectiveness and integrity of the public procurement system. Accordingly, it is becoming increasingly important to achieve two critically important goals simultaneously: transparency of procedures and maximum strengthening of the state's defense capabilities. As a result, this leads to a forced narrowing of openness, which during peacetime was considered a key indicator of anti-corruption resilience. The return to direct contracts and the classification of a significant portion of military procurement as confidential were responses to military challenges, but at the same time represented a departure from the principles of accountability on which the Prozorro architecture was built, as confirmed by OECD analytical assessments and Transparency International Ukraine.

International organisations, including the World Bank, OECD, and Transparency International Ukraine, insist on further improving the Prozorro system, viewing it not only as a tool for transparency but also as a foundation for trust in Ukraine as a recipient of international aid. There is also an urgent need to harmonise the Ukrainian procurement system with international standards and strengthen the analytical component for risk management. (World Bank, 2023; OECD, 2023; TI-Ukraine, 2022). However, even with broad international support, any structural reforms in public procurement traditionally face resistance from an overly bureaucratic administrative apparatus, which significantly slows down the implementation of innovative solutions.

Focusing on the work of researchers who have attempted to solve the problems of public procurement, we note that some of them share our opinion on the vectors for improving Prozorro, namely: expanding the functionality of Prozorro and introducing automated risk analysis systems (Nadtoka, 2024), but they stop at merely declaring their ideas in theory. At the same time, it is fair to note that recently, practical tools for using artificial intelligence to improve the public procurement monitoring system have become widespread (Ivanitskyi & Kroshnyi, 2025; Pakhachuk & Volkov, 2025; Lazar & Popescu, 2023). However, given that artificial intelligence has been used in practice for risk management in the defence sector, we believe that national systems such as Prozorro should have their own automated financial control developments. This will ensure a high level of cybersecurity and minimise dependence on external technological solutions.

Paying attention to researchers who used BERTopic and LDA models to solve scientific research problems, we note that none of them used them to improve public procurement. The models have been widely used by the scientific community to solve medical problems (Ma et al., 2025), analyse social networks (Rachel J. et al., 2024), and address general economic issues (Rejeb A. et al., 2025). At the same time, we fully agree with the positions of these authors, since text analysis models can be applied in various areas of research.

Therefore, it should be noted that scientists actively try to implement intelligent data analysis technologies in the Prozorro procurement system, but the authors have not yet attempted to implement text analysis to identify thematic structures in public procurement.

In this context, the integration of text mining tools – LDA and BERTopic – proposed in the study creates new opportunities for strengthening the public procurement monitoring system. Algorithms enable the automatic analysis of large volumes of tender documentation, the identification of key themes, the detection of recurring patterns of behaviour among suppliers

and customers, and the identification of potential anomalies that may indicate risks of corruption or misuse of international technical assistance. (Basel Institute on Governance, 2024).

Based on the thematic blocks obtained, it is possible to form an integrated information base for ex-post audits, as well as for ex-ante identification of risky procurements even before the tender is held. When modelling focuses on procurement related to ITA, the analytical system allows for the identification of substantive deviations, non-compliance with donor requirements, or manipulative practices. At the same time, the use of thematic modelling in public procurement requires a separate analytical unit or the expansion of the existing functions of control institutions. The processing of large text arrays, the correct interpretation of thematic clusters, and the integration of results into the management decision-making process require specialised methodological expertise, which is currently underdeveloped in the public sector.

In the long term, BERTopic and LDA can be considered as a separate risk-oriented monitoring module or as an add-on to Prozorro, strengthening its anti-corruption potential. This is particularly critical in the post-war period, when transparency in the use of international funds takes on not only technical but also political significance: it determines the level of trust that international partners have in Ukraine, the speed of investment attraction, and the stability of international technical assistance flows in the long term. At the same time, as the OECD emphasises, long-term donor support depends not only on the transparency of procedures, but also on the country demonstrating systemic dynamics in reducing corruption risks. Automated algorithms that record step-by-step changes in the structure of risks and transparency can form the basis of such a 'long-term trend' of trust.

In parallel with the above, it is fair to note that potential limitations of the research results may be due to both the peculiarities of the models used and the extremely large volume of input information on public procurement. The LDA and BERTopic text models work more effectively when the data has been properly pre-processed, but analysing all tender documentation without prior filtering can lead to excessive variability in thematic clusters and a loss of analytical clarity. It is therefore advisable to narrow down the sample in advance using relevant criteria.

In particular, the following are promising:

1. Time restrictions – analysis by month or quarter allows tracking the dynamics of abnormal patterns in the short term.
2. Spatial restrictions – differentiation of purchases by region of Ukraine allows identifying territorial differences in the risk structure.
3. Focus on the needs of regulatory authorities – forming a sample in accordance with the jurisdiction or functional competence of specific state institutions increases the practical value of the results for financial monitoring and auditing.

This targeted narrowing of the data set ensures more accurate modelling and allows for more valid conclusions to be drawn about the effectiveness of international technical assistance use.

Notwithstanding the above, let's emphasize that the proposed approach is fully consistent with the UNDP and EUACI framework recommendations on the need to strengthen digital transparency tools in the field of reconstruction and international resource management.

Therefore, systematic reduction of corruption risks, supported by digital tools for automated analysis, can create a sustainable positive trend in cooperation between Ukraine and international donors. As a result of implementing the proposed algorithms, it can become a key tool for rebuilding the state, improving the effectiveness of international technical assistance, and strengthening economic stability in the post-war period.

CONCLUSIONS

A study of the dynamics of international technical assistance for 2010-2023 allows us to conclude that there has been abnormal growth since the start of full-scale war in Ukraine in 2022. The results indicate the formation of a structural dependence of the state's financial security on the scale of international technical assistance involvement and the regularity of its receipt. Under the current conditions of recovery and transformation of the national economy, the development of most sectors of the economy critically depends on external financial support from international donors.

The dynamics and frequency of public procurement in the Prozorro system in 2021–2024 indicate that in 2023–2024, the volume of tenders will gradually return to pre-war levels. This confirms that the Prozorro system is the only option for ensuring financial transparency and accountability in the use of international technical assistance funds.

DOI: 10.55643/fcaptp.6.65.2025.5082

The BERTopic and LDA text mining algorithms proposed in the study can become an effective basis for improving the efficiency of the Prozorro system. The use of LDA allows for the formation of representative topics in tender documentation and the identification of systemic patterns in public procurement, while BERTopic provides more sensitive and context-oriented text grouping, allowing for the tracking of atypical patterns that may indicate risks of manipulation or non-transparent conditions.

The combination of these methods allows:

- to create a scalable information base of semantic patterns of tenders, reflecting the key characteristics of procurement related to ITA;
- to identify abnormal topics (e.g., atypical additional requirements, artificially narrowed specifications, 'noisy' product descriptions);
- to develop automated risk indicators that can be integrated into Prozorro as an additional monitoring module;
- to provide analysts from the State Audit Service and the National Agency for Corruption Prevention with tools to prioritise procurements that require manual verification.

In conclusion, it is fair to note that the introduction of BERTopic and LDA into the processes of analysing tender documentation for international technical assistance in Prozorro can enhance both the transparency of procurement and the reputational stability of Ukraine as a recipient of international technical assistance. The creation of an automated semantic monitoring system could be not only a technological step forward, but also a strategic one, strengthening accountability and resource management efficiency for the post-war reconstruction of Ukraine.

Based on the results of the study, it can be concluded that both hypotheses have been confirmed. The application of the BERTopic and LDA models has demonstrated the existence of a significant number of tenders with atypical text characteristics that require further analysis and may potentially be associated with increased financial risks. In addition, it has been established that further modernisation of the Prozorro system contributes to strengthening the confidence of international donors in the processes of using international technical assistance. This is ensured both by improving the effectiveness of financial monitoring mechanisms and by expanding opportunities for public control over the use of international resources.

Further research should focus on developing a unified financial and analytical methodology for identifying typical and abnormal patterns of international technical assistance use in public procurement. It is becoming increasingly important to develop an integrated system of indicators that combines: the financial structure of contracts, the parameters of competitive procedures, and the semantic characteristics of tender documentation as a source of hidden financial risks. Further research should focus on the application of combined methods of financial analytics and text modelling (in particular, LDA and BERTopic) to build integrated risk profiles for procurement. The results of such integration can be used to form a multi-level early financial warning system capable of automatically identifying deviations from normative behaviour and increasing the transparency and accountability of the use of international technical assistance in Ukraine.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

FUNDING

This contribution was undertaken as part of a research projects granted by the Ministry of Education and Science of Ukraine: «Cybersecurity and digital transformations of the country's wartime economy: the fight against cybercrime, corruption and the shadow sector» (registration number 0124U000544) and «Fundamentals of law enforcement agencies' activities in the field of control over the system of attracting and using international technical assistance: the globalisation dimension» (registration number 0124U000635).

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ПІДВИЩЕННЯ ФІНАНСОВОЇ ПРОЗОРОСТІ У ВИКОРИСТАННІ МІЖНАРОДНОЇ ТЕХНІЧНОЇ ДОПОМОГИ В УМОВАХ ВОЄННОГО СТАНУ: ЦИФРОВІ ТА АНАЛІТИЧНІ МОЖЛИВОСТІ PROZORRO

Стаття присвячена дослідженню можливостей підвищення фінансової прозорості та ефективності використання міжнародної технічної допомоги (МТД) в умовах воєнного стану в Україні через удосконалення інструментарію системи публічних закупівель Prozorro. Автори наголошують, що в період повномасштабної війни роль МТД значно зростає, адже вона забезпечує фінансування критичної інфраструктури, гуманітарних потреб та інституційного розвитку. Водночас корупційні ризики та обмеження відкритості закупівель суттєво знижують ефективність розподілу та перерозподілу фінансових ресурсів держави, а також упливають на рівень довіри міжнародних партнерів.

Автори доводять необхідність упровадження автоматизованих цифрових рішень фінансового контролю з метою вдосконалення аналітичні можливості Prozorro та посилення системи аудиту результатів публічних закупівель. Запропоновано використання двох алгоритмів текстового майнінгу – Latent Dirichlet Allocation (LDA) та BERTopic – для аналізу великих масивів тендерної документації, виявлення структурних закономірностей та ідентифікації аномальних тем, які можуть свідчити про нетипові фінансові витрати реципієнтів, аномальне ціноутворення й нецільове використання коштів. Практична апробація на даних Prozorro засвідчує, що LDA формує узагальнені тематичні кластери, які відображають напрями витрачання коштів МТД, водночас BERTopic дозволяє деталізувати субтеми, виявляти нетипові текстові патерни та ідентифікувати закупівлі з підвищеними фінансовими ризиками. Результати дослідження доводять, що інтеграція запропонованих моделей у систему Prozorro може суттєво підсилити антикорупційний і фінансовий контроль, скоротити потенційні втрати бюджету й донорських ресурсів, оптимізувати систему використання МТД й сприяти формуванню вищого рівня довіри між Україною та міжнародними партнерами в процесі воєнного й повоєнного відновлення.

Ключові слова: міжнародна технічна допомога, публічні закупівлі, фінансовий контроль, фінансові ризики, система Prozorro, модель LDA, модель BERTopic, текстовий майнінг, антикорупційний моніторинг

JEL Класифікація: C45, D73, H6

DOI: 10.55643/fcaptp.6.65.2025.5082