# THE USE OF NETWORK ANALYSIS FOR THE DETECTION OF CORRUPTION IN PUBLIC PROCUREMENT: THE BULGARIAN CASE AS A TESTING GROUND

**Mario Rusinov[1], Sofia University "St. Kliment Ohridski"**

**Abstract**

*This article uses Bulgaria as a case study to explore the application of network analysis to detect corruption in public procurement. Based on procurement data from 2016 to 2022, the study constructs bipartite graphs to analyze patterns of supplier concentration, single-tender tendering, and network stability across political cycles. The findings reveal persistent high-risk sectors - such as construction, medical supplies, and fuels - characterized by closed supplier networks and limited competition. While general network structures remain stable under changes in government, the disappearance of specific high-profile nodes suggests politically driven market reconfigurations. These results demonstrate the potential of network analysis as a policy tool to enhance anticorruption efforts.*

**Keywords:** *political corruption, Bulgaria, public procurement, network analysis.*

## INTRODUCTION

Network Analysis and Social Network Sciences (SNS) aim to reveal patterns, dependencies, and interrelationships within a network of entities. (Borgatti et al., 2009: 893), They also identify clusters or more closely related parts of the network and detect hidden connections between entities. Nowadays, network analysis has diverse applications in various fields, including public health management and national security, such as combating organized crime and terrorism.

This paper examines the effectiveness of using Social Network Analysis (SNA) to identify alleged corruption and collusive behavior in tender procedures—an emerging yet promising approach. SNA is especially potent in backgrounds where a political family, as conceptualized by B. Magyar (2016), creates, boosts, or sustains economic groups to reinforce clientelist relations due to favored economic clusters. By employing this novel approach, researchers can more effectively address the challenges posed by the elusive nature of corruption.

Public procurement is of the utmost importance for providing public goods and infrastructure. OECD countries are measured to spend an average of 13 percent of their expenditures through this mechanism (OECD, 2022). This percentage increases to as high as 30 percent in developing countries. (UN Environment Programme, 2020) The significant financial

[1] Mario Rusinov is a PhD candidate at Sofia University. His research focuses on (anti-) corruption, clientelism, and election fraud, particularly emphasizing corruption in public procurement, e-mail: mario.rusinov@phls.uni-sofia.bg.

resources involved present an incentive for illicit and corrupt practices. According to GIACC (2023), corruption equates to US$ 5 trillion per annum of global stolen funds.

Corruption and political favoritism in procurement lead to higher prices, reduced value for money, the provision of low-quality or unsafe works, and reduced competition (Dávid-Barrett, Fazekas, 2020). They are also the basis of ineffective public institutions (Fukuyama, 2018) and challenge democratic values and practices, as well as economic growth. (Ortega et al. 2016).

In the context of systemic corruption, political power is sustained through a mechanism whereby procurement providers embezzle funds by setting aside a portion to secure the favour of politicians at both local and national levels in exchange for collusion and access to future contracts (Chiappinelli, 2020). In addition, the misuse of companies in public procurements is often a vehicle for funneling illegal money into political campaigns and vote buying (Luna-Pla, Nicholas-Carlock, 2024).

Countries with systemic corruption are characterized by an 'our turn to eat' approach (D'Arcy, Cornell, 2016); thus, traditional public-agent models are ineffective in addressing widespread corruption, and a change in power does not necessarily lead to a decrease in it.

A thorough examination of corruption in procurement is crucial for identifying systemic inefficiencies and developing strategies to promote transparency, accountability, and fair competition.

The case of the Bulgarian public procurement market will be used, as it has been identified as a procurement market with a high corruption risk in the past compared to other EU countries (Pashev, 2011; Mungiu-Pippidi, 2015), and it has well-structured open data. Furthermore, as Ateljevic and Budak (2010) argue, the situation in the Balkans in the 1990s resulted in weak national legal structures, providing fertile grounds for the emerging class of the 'entrepreneur-oligarch', which led to corruption in public procurement.

## LITERATURE REVIEW AND DEFINITIONS

For definition of corruption in Public Procurement, the definition of Fazekas, Tóth, and King (2013, 2) is employed: "*In public procurement, institutionalized grand corruption refers to the allocation and performance of public contracts by bending universalistic rules of open and fair access to government contracts to benefit a closed network while denying access to all others.*" Specific indices of such corruption can be defined as follows:

1. Conflict of interest – as defined in the Public Procurement Act: "A conflict of interest exists when the contracting authority, its employees, or external individuals engaged by the authority who are involved in the preparation or awarding of the public procurement—or who may influence its outcome—have an interest that could result in a benefit as defined in Article 72 of the Anti-Corruption and Forfeiture of Illegally Acquired Assets Act, and which could be deemed to impair their impartiality and independence concerning the procurement process." (amend. SG No. 7/2018, amend. SG No. 84/2023, in force as of 06.10.2023).

2. Imposing discriminatory conditions in technical specifications, or "unjustified restriction of access to public procurements aimed at benefiting a specific participant in the competitive procedure" (Fazekas, Kocsis, 2020, 1), as well as the deliberate inclusion of

subjective criteria in evaluation methodologies to allow discretionary judgment by evaluators and reduce competition.

3. Discretion in evaluating technical criteria set out in the tender documentation.
4. Launching procedures via direct award when unnecessary, to deliberately restrict competition.
5. Trading in influence.
6. Deliberate non-compliance with transparency procedures, including setting unreasonably short deadlines or otherwise obstructing potential bidders.

Regarding the methodologies for measurement of corruption, Hlatshwayo et al. (2018) argue that there are three distinct waves in their development:

1) Measuring Corruption—Such surveys include the Transparency International (TI) Corruption Perceptions Index and the World Bank's Corruption Control Index. However, they are criticized for their inaccuracy. (Pozsgai-Alvarez, 2024, 5)
2) Measuring anti-corruption and integrity - This generation attempts to address the limitations of the perception-based approach. For this purpose, second-wave research uses two types of empirical data: victimization surveys and institutional capacity assessments. Examples of institutional capacity surveys include the Global Integrity Index and the Public Integrity Index, among others. Notably, legislation audits and anti-corruption bodies' performance do not directly measure corruption. Forensic data has not significantly impacted international corruption metrics due to theoretical and empirical concerns about the validity of legal cases as an indicator of actual corruption.
3) The third generation has been labelled "big data approaches" (Hlatshwayo et al., 2018, 8). These include data from crowdsourcing projects, procurement databases, and media sources.

This paper was created in the latter tradition. The efforts to objectify the presence of corruption, with methodologies, such as **red flagging of public procurement** (Decarolis, Giorgiantoniom, 2022), (Fazekas, Kocsis, 2022), **network analysis of suppliers** (Fountoukidis, Antoniou, Varsakelis, 2023), (Carneiro, Veloso, Ventura, Palumbo, 2020), **discrepancies of public spending and the quality of provided services** (Picci, Escresa 2017), (Lehne, Shapiro, Eynde 2018) seem to address most of the criticisms of the former approaches. Due to the general universality of data, they also enable comprehensive and comparative analysis[2].

The author comprehensively analyzed the existing scholarly literature on the topic to systematize the previous academic efforts. This was achieved by executing the query "Public Procurement" AND "Network Analysis" in Scopus, Mendeley, and Google Scholar web search engines. The results are supplemented by the findings of the bibliographic article Public procurement research: a bibliometric analysis (2024).
A few general approaches for the study of corruption in Public Procurements were outlined:

[2] Especially in the European Union, where the joint platform "Tenders Electronic Daily" is used. (TED) website, where all tender procedures above certain thresholds are listed. TED publishes more than676 thousand procurement notices a year, including 258 thousand calls for tenders worth approximately 670 billion euros.6

**Machine Learning and Factor analysis** (Lopez, Sanz, 2017), (Nai, Meo, Morina,, Pasteris, 2023), (Ovsyannikova, Domashova, 2020); **Measuring Party Favoritism and Dynamics in the Suppliers** (Mironov, Zhuravskaya, 2016), (David-Barrett, Fazekas, 2019), **Red flagging of Tender Procedures** (Kenny, Musatova, 2011)**, (**Ferwerda, Deleanu, Brigitte, 2016), (Fazekas, King 2019), **Network analysis** (Carbone, Calderoni, Jofre 2024), (Fountoukidis, Antoniou, Varsakelis, 2023), (Wachs, Fazekas, Kertész, 2021), (Waxenecker, Prell, 2024)

## BENEFITS AND APPROACHES IN SOCIAL NETWORK ANALYSIS

De Domenico (2019) argues that the use of network analysis has the following advantages: (1) Complex systems are usually composed of multiple interacting elements, each having different types of interactions; (2) The structure of complex systems can be represented as a network of interactions and relationships;(3) Complex systems often exhibit collective and nonlinear dynamics, which makes them unpredictable.

Thus, network analysis can be leveraged to provide a comprehensive understanding of the complexity of corrupted interactions and the significant number of agents and participants involved in such acts.

Generally, studies employing network analysis (NA) can be classified along two main dimensions:

First, based on the subject of the study, (a) some focus on detecting collusive behavior and bid-rigging **among firms** by identifying patterns of similarity between suspected collaborators (e.g., Carbone, Calderoni, Jofre, 2024), while (b) others examine corrupt interactions between **public agencies and private firms**. (e.g., Wachs, Fazekas, Kertész, 2021; Fazekas, Poltoratskaia, Tóth, 2023 )

Second, based on their analytical scope: (a) some adopt a bird's-eye view of the entire supplier network to identify systemic tendencies and hidden clusters, whereas (b) others conduct case-by-case analyses to uncover the specific corruption mechanisms in individual instances.

## METHODOLOGY AND CHALLENGES

The study examined seven years of public procurements from 2016 to 2022. These include the governance of three regular[3] and four caretaker[4] governments and two cycles of municipal elections. The selected period strives to balance enabling a comparison of the evolution of procurement networks under different authorities and ensuring data availability. To conduct the analysis, data from the Public Procurement Register[5], the Commercial Register, the

[3] Respectively, the second (2014-2017) and third (2017-2021) cabinets of B. Borrisov, and K. Petkov's cabinet (2021-2022).

[4] Respectively, O.Gerdzhikov's (2017), first (2021) and second (2021) S. Yanev's and G. Donev's (2022) cabinets.

[5] Contracts and Contract Amendments – 2022 (data from CAIS EOP). https://data.egov.bg/data/view/b6ec0598-8dfd-4338-8756-a679420c2cd0, Contracts and Contract Amendments – 2022 (data from ROP) https://data.egov.bg/data/view/db3e39ba-37f9-44bf-847f-75f36acee513, Contracts and Contract Amendments – 2021 (data from CAIS EOP) https://data.egov.bg/data/view/523c7c16-1a36-4935-a66a-4ad8bd1a4713, Contracts and Contract Amendments – 2021 (data from ROP) https://data.egov.bg/data/view/a03748c9-bb31-4cce-b350-b8e06b63c7c9, Contracts and Contract Amendments – 2020 (data from CAIS EOP) https://data.egov.bg/data/view/c5404069-668a-4cd2-ab43-a1cdc26e03c6, Contracts and Contract Amendments – 2020 (data from ROP) https://data.egov.bg/data/view/b97eec73-e091-47c5-a1c7-582d38d1758d, Contracts and

CENTRALIZED AUTOMATED INFORMATION SYSTEM "ELECTRONIC PUBLIC PROCUREMENT" (CAIS), and data from the Bulstat Register (where the consortia applying for public procurement are registered) were used. Despite the partial availability of open data, gathering and assembling the data was highly challenging. Refer to Annex 1 for further details.

The tenders were analyzed to identify changes in the procurement networks, pinpoint clusters of surprising winners and losers, and possible hotbeds of corruption. The analysis tested the following hypotheses.

H1) **Some parts of the procurement network (sectors) have significantly higher corruption risk.** They are identified by a concentration of a relatively closed network of suppliers, winning tenders through a single bid.[6]

H1.1) **Some parts of the network (sectors) keep this risky behaviour over time**.

H2) **The network of contractors changes significantly following shifts in political leadership.** If substantial changes occur in the networks, this will strongly suggest the presence of favoritism and potential corruption within the tendering process. The assumption is that in a market with transparent and "by-the-book" tenders, the companies with winning bids should be diversified, chosen on objective criteria, merit-based, and thus unbound by the political climate. Conversely, such changes can serve as a proxy indicator for potential irregularities.

To test that an approach similar to that used by Fazekas, Poltoratskaia, and Tóth (2016) is employed. A bipartite graph is created between suppliers and the contracting authority. Supplier-individual networks are also tested for further clustering and uncovering links that may not be apparent at first glance.

In contrast to the cited research, the edge weights in this study represent the number of single-bid tenders awarded to a specific supplier by a particular Contracting Authority within a given year. Edges are colored red if the supplier has won over 75% of tenders through single bidding, thus showing a continuous risky behavior. Furthermore, the graphs are drafted on a one-year rather than a three-year basis to highlight more subtle changes within the network. Finally, using tenders from only awarded and executed contracts diminishes the place for error, which is present in some former studies. However, it should be noted that, unlike the complex Corruption Index proposed by Fazekas, the current study employs a simpler proxy for corruption - single bidding.

The Fruchterman-Reingold, ForceAtlas, and ForceAtlas 2 (Jacomy, Heymann, Venturini, and Bastian, 2012) algorithms were tested. The latter yielded the best result. Then, modularity is calculated, and clusters are formed based on that.

The graphs were created using Python's NetworkX library. Subsequently, the software Gephi was used to visualize the networks.

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Contract Amendments – 2019, https://data.egov.bg/data/view/83e02856-b460-4ec8-bf5e-b23ae6e267ca, Contracts and Contract Amendments – 2017, https://data.egov.bg/data/view/5a06c9b5-4db6-4213-8c7a-df9bb9c94c55, Contracts and Contract Amendments – 2016 https://data.egov.bg/data/view/5d588198-c9e5-40df-86a6-698dbf69dbf7

[6] Single bidding is adopted as a red flag for corruption in Public Procurement. Special report 28/2023: Public procurement in the EU (no date) European Court of Auditors. Available at: https://www.eca.europa.eu/en/publications/SR-2023-28 (Accessed: 02 May 2024).

## RESULTS AND DISCUSSION

**Fig. 1. Procurement Market in Bulgaria, 2016**

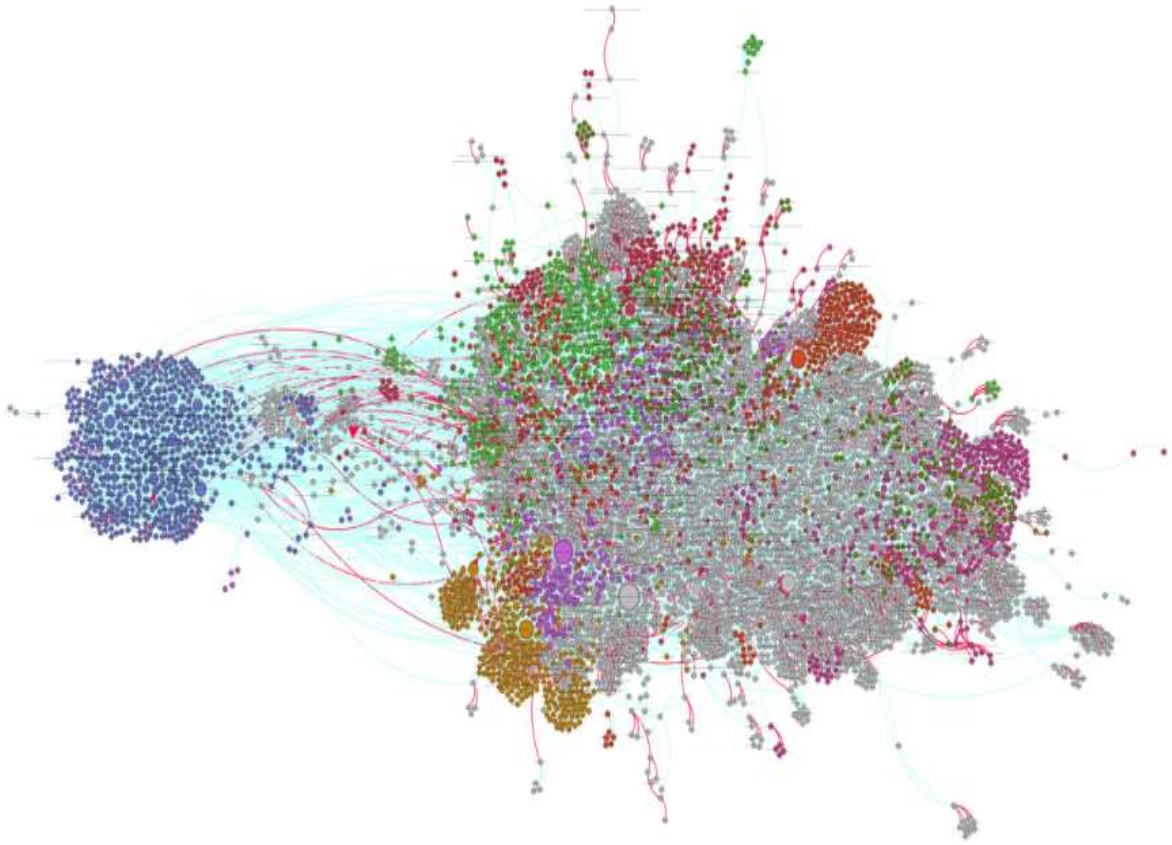
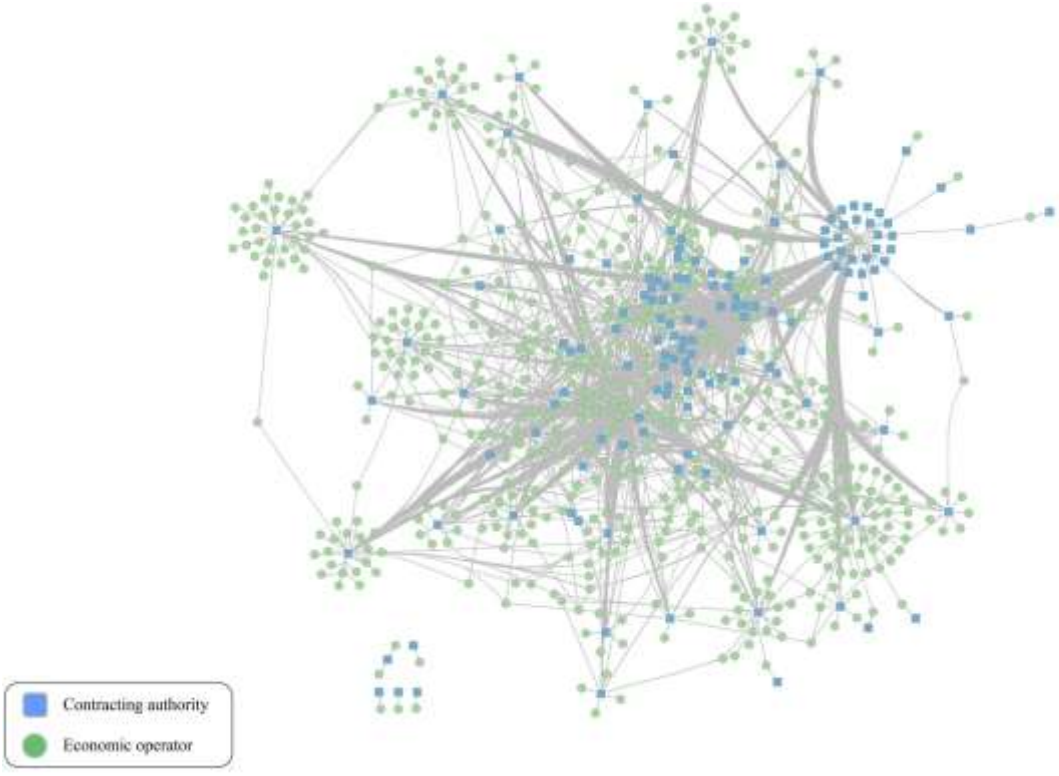


**Fig. 2. The Greek Procurement Market, according to Pliatsidis's analysis (2024)**



As evident by the results, the network analysis of the suppliers' network in Bulgaria shows that clusters in specific sectors are more prone to corruption than others. This aligns with the conclusions of Pliatsidis's analysis (2024). Figures 1 and 2 illustrate the similarity between the economic clusters from both studies. Such trends are especially evident in the sectors of medical supplies, construction, and fuels, which align with the findings of the Center for the Study of Democracy (Galev, T. et al., 2021).

A significantly isolated cluster is also evident in the field of school supplies, marked by significant corruption risks. Most of the edges are colored red, indicating a single bid. Similar high modularity is also evident in construction.

Such highly closed clusters are also evident in the EU Market, according to a study by Fountoukidis, Antoniou, and Varsakelis (2023), who employed measures of market entropy and clusterization to identify signs of preferential treatment in specific parts of the network.

Notably, a correlation exists between the centralization of public procurement markets and corruption risks, as determined by network analysis and corruption risk (CRI) (Wachs, Fazekas, Kertész, 2021).

In another study, Fazekas, Poltoratskaia, and Tóth measure the level of state capture in public procurement in Bulgaria through a combination of their corruption risk analysis and network analysis. They distinguish four types of networks: (a) clean networks, (b) corrupt but not captured networks, (c) partially captured networks, and (d) fully captured networks.

Fazekas and Toth (2013) used a combination of indicators to calculate the Corruption Risk Index and Network analysis to estimate the risk of state capture in Hungary and the elite configuration. The indicators included single bid, lack of publication, type of procedure, eligibility criteria, length of the submission period, evaluation criteria, etc. By clustering the CRI and centralization, they measured how each organization’s ego network fits the hypothesized homogeneous or heterogeneous corruption patterns. They identified four types of capture: Clean organizations, Occasionally Corrupt Organizations, Partially Captured Organizations, and Fully Captured Organizations.

Similar observations can be drawn from the current paper. Although sectors appear to have relatively stable levels of corruption risk, some changes occur over time, which supports H1 and H1.1. A blatant example is the medical supply sector, which experienced a significant increase in single bidding during and after the COVID-19 pandemic (see Fig. 3 and Fig. 4). In line with the findings of Thomann, Marconi, Zhelyazkova (2023)

**Fig. 3. The Medical Supply Sector Tenders in 2022; red signifies that the supplier won more than 75% of single-bid tenders**

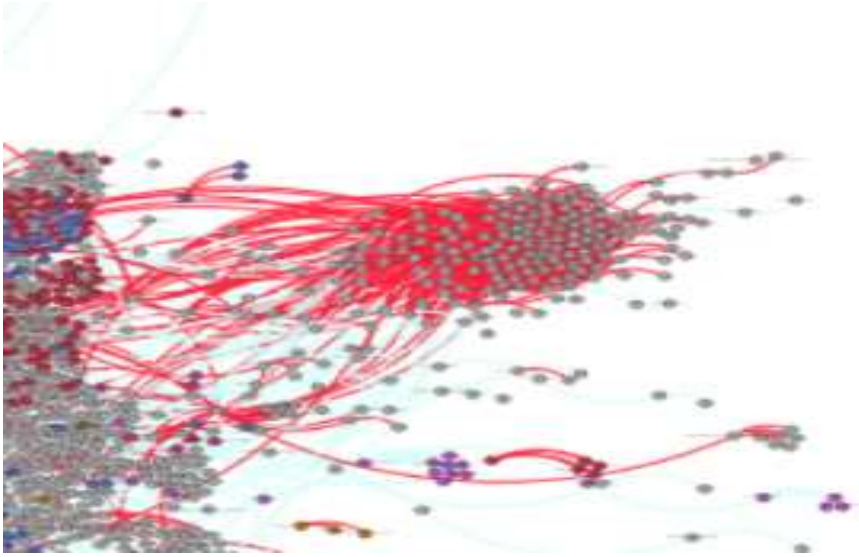
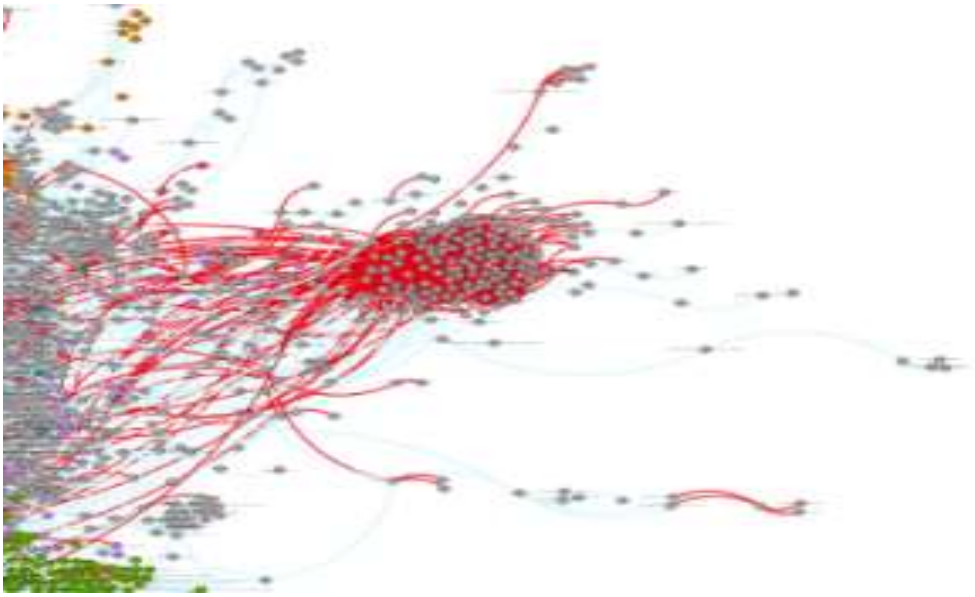


**Fig. 4. The Medical Supply Sector Tenders in 2021; red signifies that the supplier won more than 75% of single-bid tenders**



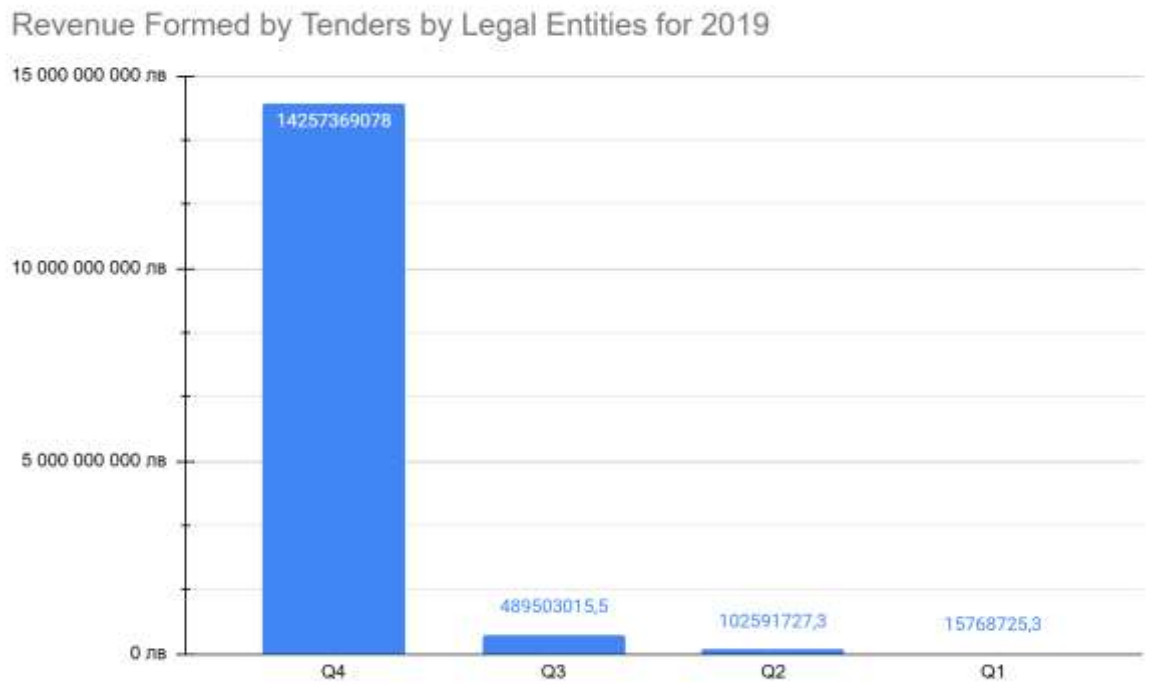
Unlike the initially formed hypothesis, no swift changes in the network can be observed with the change of government at the national level. Notably, the caretaker governments should not account for the procurement network changes due to their short cycle, which does not coincide with the procurement calendar[7]. De facto, we observe a single power shift between the third cabinet of B. Borrisov and K. Petkov's cabinet during the studied years. An interpretation of data suggests that perhaps Petkov's cabinet did not have the time or capacity to change the market drastically. Future studies can include more cabinets to capture a fuller picture.

[7] The preparatioln of a tender usually takes a significant time and they are planned ahead.

However, fascinating observations can be made in the construction sector for the studied period. Although the network's structure does not change drastically, specific nodes gradually or rapidly disappear, providing quasi-evidence for H2. Those nodes can be responsible for significant public funds distributed through procurement[8]. Similar is the case of firms being publicly alleged to be connected to the business mogul and PEP Delyan Peevski, as well as the KTB bankruptcy scandal, including VodStroy 98, which experienced rapid growth and decline in revenue. The deliberate bankruptcy of one of the biggest banks in Bulgaria and its subsequent stripping of assets in favor of PEP-related persons or companies[9] should be studied as a new and separate stage of corruption behaviour in Bulgarian politics. Hence, the participation of companies' suppliers should also be further examined using an academic approach.

If we divide the suppliers into quartiles, based on revenue from tenders, there are giants within the Public Markets, mainly in the fuels, medical supplies, and construction sectors. The biggest quartile accounts for tens of times the revenue of the other quartiles. Those edges in the network can de facto get less revenue from tenders, which remain hidden on the graphic level, but are within the surprising losers, surprising winners assumption. The current network analysis does not consider the size and number of the awarded tenders, which can also be improved in future results. An in-depth analysis of the network sector by sector and specific queries and groupings, allowing for fewer nodes, can help capture such behaviour[10].

**Fig. 5. Revenue Formed**

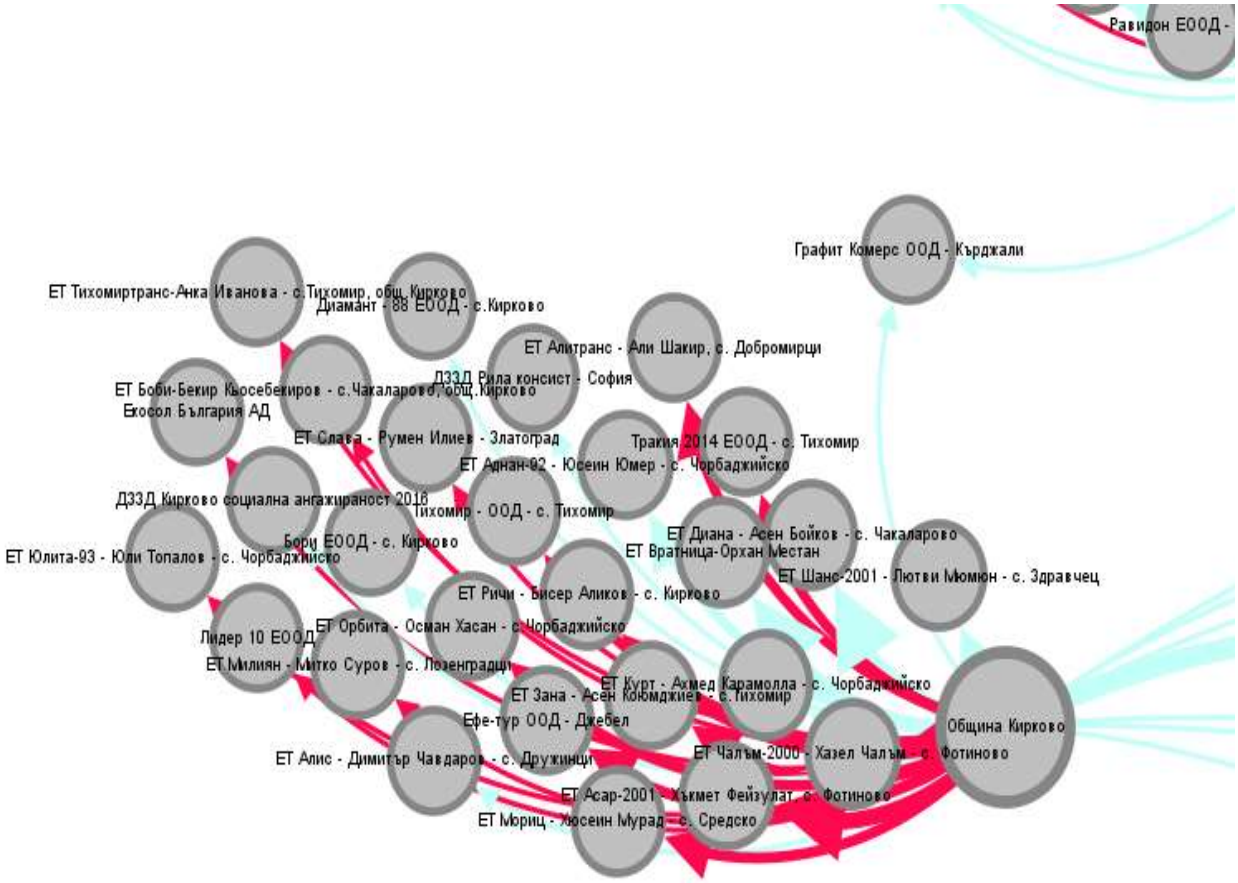



[8] The presented calculation does not consider the connection of legal entities, which makes for an even higher concentration.

[9] Both in a broader sense of a political family and de jure definitions.

[10] Currently, an average of around 6000 nodes are present in each graph.

**Fig. 6. The network of suppliers for the municipality of Kirkovo, red signifies that the supplier won more than 75% of single-bid tenders (2019)**




A concentration of risky tenders can be observed at the municipal level, where favoritism is also prevalent—an example given in fig. 6. Former studies suggest a high level of clientelism and vote buying in different municipalities. (ACF, 2022) For future studies, it is worth exploring the link between high corruption risk and such illicit election practices, as the assumption is that the latter need a significant amount of funds. Hence, there should be an illegitimate source for it. Logically, it could be sought in the processes of embezzlement of procurement.

This paper raises several policy implications. First, the persistence of closed procurement clusters and high levels of single bids, especially in key sectors, may serve as channels for state capture rather than as instruments of public value. Second, national and local procurement needs greater scrutiny, as they appear to be at a relatively high risk of corruption. Third, the big data approach, network analysis, and red flagging tenders show potential for discovering hotbeds of alleged illicit practices. As such, they are a policy instrument that can be part of national anti-corruption strategies, allowing real-time monitoring of procurement networks and early detection of collusion patterns. They provide insights for risk-based audits.

## CONCLUSION AND FUTURE RESEARCH

The current paper examined three hypotheses through the Bulgarian Public Procurement market:

H1) Some parts of the network (sectors) with significantly higher corruption risk-

H1.1) Some parts of the network keep this risky behaviour over time.

H2) The network of contractors changes significantly following shifts in political leadership.

H1 was confirmed by outlining specific sectors with traditionally higher corruption risk, notably the medical supply, construction, energy and fuel, and the school supply sectors.

As outlined in H1.1, most parts of the networks exhibit stable behavior, which can be further influenced (or worsened in terms of corruption risks) by outside factors, as illustrated by the state of the procurement market during the COVID-19 pandemic.

H2 is quasi-proven not by a change in the network itself but by a shift in nodes within the network. Certain PEP-related companies experience rapid growth and declining revenues, suggesting non-merit-based procedures. Further exploration of this hypothesis is needed.

The results showed that SNA is a valuable tool for detecting potential corruption and irregularities in public procurement. Researchers can identify surprising winners and losers by analyzing changes in contractors' networks after political changes and the unusual density of networks, suggesting favoritism and possible corruption.

Unlike the other methods, which are survey-based, this methodology relies on objective and quantitative data. In addition, red flagging, text mining, machine learning, and social network analysis can complement each other.

Future research can compare whether the in- and out-degrees of nodes and modularity levels are identical for different Contracting Authorities with common budgets and characteristics. This data can be cross-referenced with other variables, such as population size, economic factors, and political formations in power, to identify potential factors contributing to reduced competition and alleged corruption or collusive practices.

**Fig. 7. Procurement Market in Bulgaria, 2016**

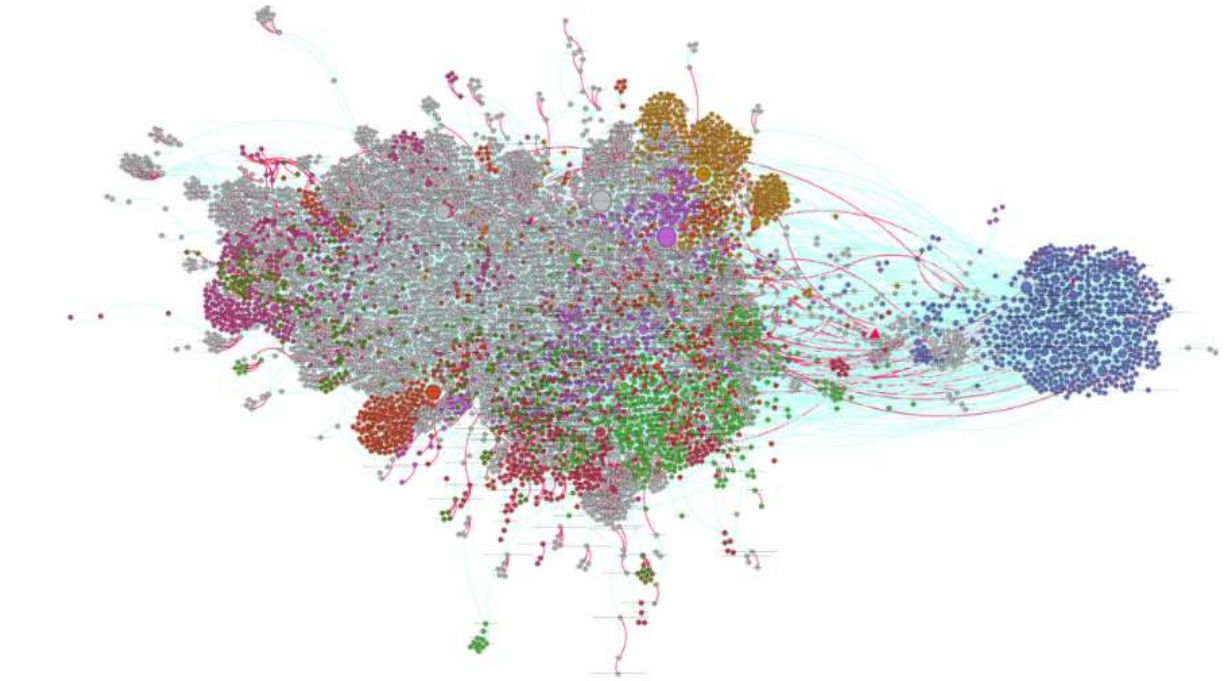


**Fig. 8. Procurement Market in Bulgaria, 2019**

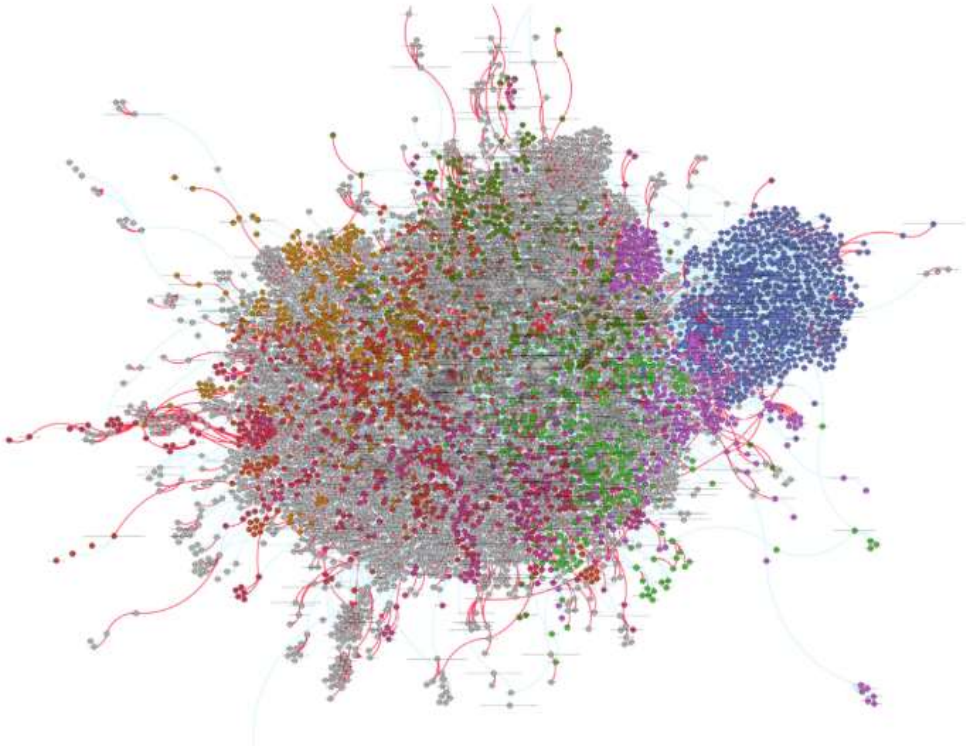


**Fig. 9. Procurement Market in Bulgaria, 2021**

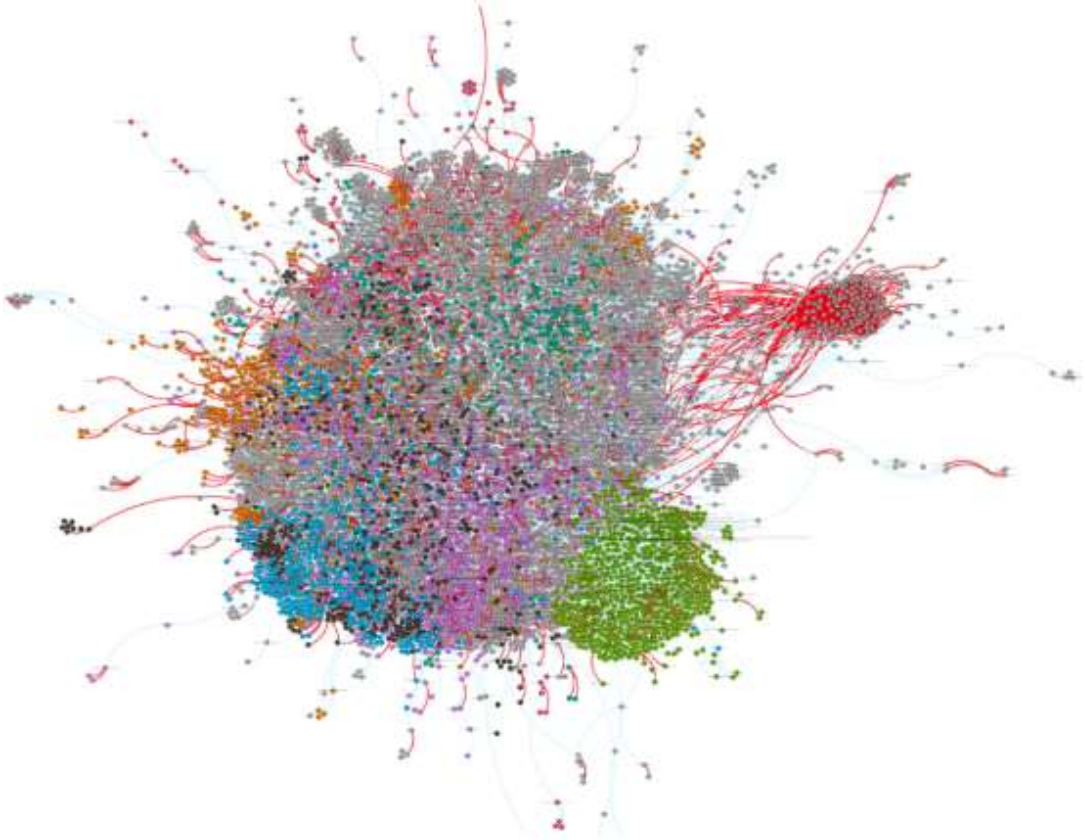
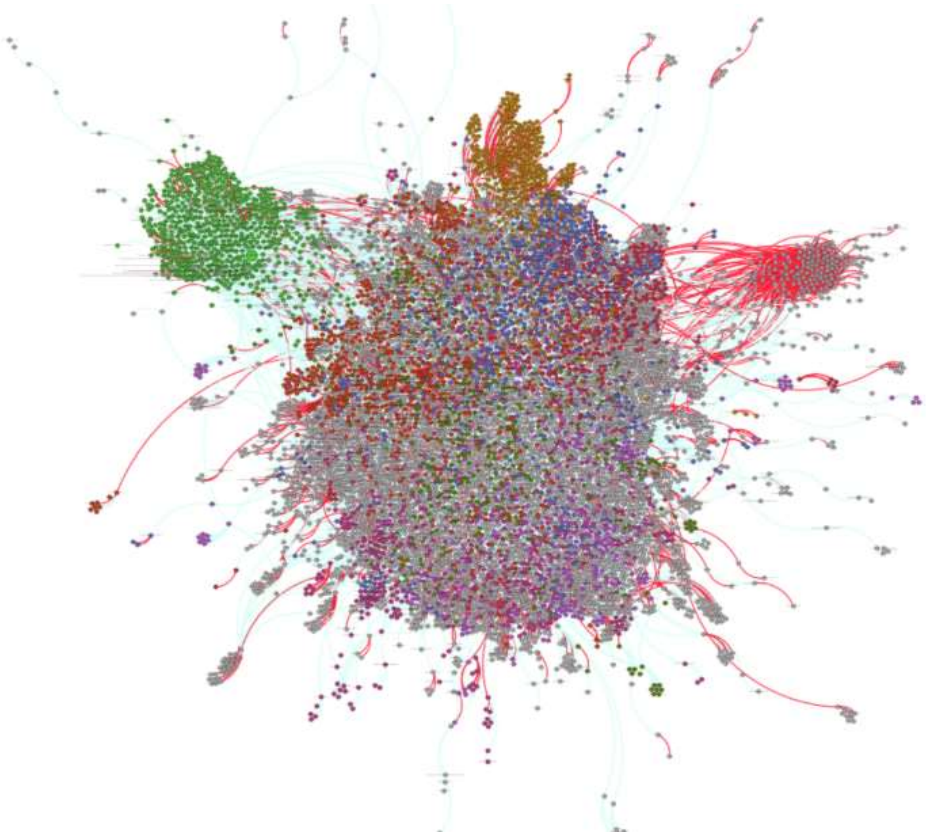


**Fig. 10. Procurement Market in Bulgaria, 2022**



**ANNEX 1. Gathering and assembling data.**

1) The Public Procurement Registry was changed to CAIS in 2020. Both of the registers coexisted for more than three years. Their different structure demanded serious data cleansing. Additionally, some data was missing in various years (such as the number of offers), which demanded additional data scraping. Some rows contained missing or misleading data for price or number of offers. No CPV are present in the open data, which does not allow for automatic sector analysis, and should be done by hand. Additional data, such as dropped-out supplier candidates, could also be added.

2) The Bulstat Register, which contains around 20 percent of the legal entities that carry out procurements (mainly consortia or partnerships under the Obligations and Contracts Act), is open access but lacks open data, necessitating scraping and additional data chaining. No UIC (Unified Identification Code) was available; only the names of the companies were provided, which required additional data cleansing.

3) The Commercial Register consists of large and complex XML files[11]. The data is clean and comprehensive, but no documentation is provided. That demanded sufficient time for back engineering. Once the 3000 unique tags were classified, Python's xml. etree.ElementTree was used to put the information in an SQL database. An interview was conducted with an expert in commercial law to determine which relationships were relevant for the network analysis. The necessary rows, containing information for companies carrying out procurement, were indexed and placed in a CSV table for faster computation.

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