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ANALYZING THE CORRUPTION ON A PROCUREMENT NETWORK USING GRAPH THEORY

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Abstract

The aim of this work was the exploration of the corruption behavior in public procurement procedures for a specific group of health goods with network analysis. By using graph analytics, the presented work intends to support the better understanding of the market function. The whole dynamic network uses contracts value as weight at the relationships. Net analysis contributes to the exploration of possible existence of a cartel or oligopolies at the specific market. The data visualization explains the role that economic operators and hospitals play in the market. In order to award a contract, alternative paths could be analyzed and so the risk of an economic operator leaving the market can be predicted. Furthermore, information concerning possible conflict of interest due to the relationship between the board members of economics operators and the board members of public authorities can be extracted. Using a virtual scenario, the whole methodology is presented in order to identify a conflict between the families' members of the boards of economics operators and the families' members of the boards of the hospitals. A money traffic between the bank account of all the participants' member could be correlated with a contract awarded. Suspicious transactions could be characterized as "red flags" in order to be further explored in the future. The methodology aims to be used more as a "minefield" in order to prevent that type of corruption behaviours rather than as a "trap", in order to capture that kind of behaviours.

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Introduction

The corruption phenomenon is often encountered in public procurement procedures (Maslen 2016). It may seem abstract but it shapes the people lives in many ways (Amin 2018). While usually occurring during the procurement process, instances of post-award corruption also arise (OECD 2010). Corruption sometimes can results rising prices, while sometimes lowering the quality by keeping prices stable (World Bank 2013, Mantzaris 2014). During the execution of the contract, the quantitative modification of the subject of the contract may be concealed without the corresponding modification of the economic object. Sometimes overdue deliveries may be accepted without the appropriate sanctions being imposed.

Public procurement can mean valuable business opportunities, (OECD 2007). The existence of the corruption phenomenon causes distortion of competition. Many healthy businesses, especially small and medium-sized enterprises, are unable to participate in the public procurement market due to the malfunctioning of the market (Ferguson 2018).

Even though transparency and integrity have often been proposed as a solution to poor management problems, excessive or unnecessary transparency should be avoided (OECD 2010). Achieving the objectives is often hampered by the great amount of information and the lack of standardization of procedures and storage of data in databases. Many countries believe and support open contracting. "Technology, when deployed correctly, helps to cut through the complexity of procurement and present large volumes of technical information in an accessible and useful way" (Amin 2018). Network analysis technology is a method with which the numerous relationships between network nodes can be studied and thus, the corruption phenomenon could be eliminated. That way, an effective way of spending of public resources can be accomplished and all the benefits of a free market could be obtained.

1. Corruption on public procurement procedures

The amounts spent for the award of public contracts are significant. The amount spent in Greece by the general government in year 2015 was about 11,10% of the Gross Domestic Product (GDP) with the average for OECD members being 13.12% for the same year (OECD 2017). The OECD estimates that corruption drains off between 20 and 25% of national procurement budgets and the total account for around US\$2 trillion of the annual procurement budget (Ferguson 2018). The phenomenon of fraud does not only affect public contracting authorities, but also companies. Many companies suffer from a financial loss as a result of fraud every year. In 2014, 75% of companies have fallen a victim to fraud (Xiubo 2016).

Transparency International publishes every year Global Corruption Barometer with a Corruption Perceptions Index (CPI). In the year 2018, Greece was ranked at the 67th place. The score of Greece dropped from 48, in 2017, to 45, in 2018. This index ranks 180 countries and territories by their perceived levels of public sector corruption according to experts and businesspeople and uses a scale

of 0 to 100, where 0 is highly corrupt and 100 is very clean. More than two-thirds of countries scored below 50 on this year's CPI, with an average score of just 43 (Transparency 2019). Collusion involves a horizontal relationship between bidders in a public procurement, who conspire to remove the element of competition from the process. Bid rigging is the typical mechanism of collusion in public contracts. Corruption occurs when public officials use public powers for personal gain, for example, by accepting a bribe in exchange for granting a tender (OECD 2010). Corruption in procurement directly affects citizens' access to basic services, such as education, health and infrastructure (Martini 2013). Corruption mostly refers to bribery. Collusion corresponds to cartel agreements between institutions, and conflict of interest is a state when conflicting professional or personal interests of a public official can influence his public duties (Begley et al., 2009). To succeed in effective public procurement, corruption and collusion must be analyzed together (Maslen 2016).

Corrupt behavior in public procurement leads to inefficient spending of public funds and has an impact on the economy of a country (Lindskog et al., 2010). So from these point of view, the conflict of interest, the bribery and the bid rigging are all together correlated with the ineffective competition and this way to inefficient spending of public funds. That's why corrupt behavior was selected in order to better describe the corruption phenomenon.

1.1 Conflict of interest

Generally, as conflict of interest is defined "a situation in which a public officer has a private or other interest which is such as to influence, or appear to influence, the impartial and objective performance of his or her official duties" (Reed 2008). Conflict of interest can occur at many stages of the procurement cycle. These stages could be the creation of needs for the goods or services, the financing approval in order to overcome the need, the specifications, the evaluation of bids, the contract award and the contract execution. However, the evaluation and award of bids is often assessed as one of the most vulnerable phases, due to the high level of technical expertise required (Martini 2013). The conflict of interest is usually regulated by the national legal framework and it is detected through the complaints.

1.2 Bribery

Bribery it is a tangible problem that is keenly occurring at public procurement procedures. Bribing is difficult to be proved because it is obscured with care (Büchner 2008). Usually bribery is investigated following a complaint. Of 427 bribery cases surveyed by the OECD, 57% concerned the award of a public contract (OECD 2014). The legal framework governing public procurement procedures cannot effectively prevent bribery. Bribery comes in its both forms, active for those who offer money or promise payment and are made by those who benefit to win a contract, and passive, that is, the public servants involved who accept the payment or the promise of payment respectively. As in the case of a conflict of interest, bribery may occur at different stages of a commission. From the wording of the need to the execution of the contract. Frequency and intensity of bribery varies depending on the

stage and position of the public officer. As a global rule, bribery is proportional to the size of the contract and to the risk assessment of the targeted sector (OECD 2007). The size of a contract is not uniquely defined by its value but may be related to the market share associated with that contract. For example, the assignment from one central market of a single contract for the supply of a specific type of healthcare equipment to all the hospitals in the country for a period of three years would have led the company to have a dominant position on the market.

1.3 Bid rigging

The most important factor that facilitates corruption is the small number of participants (OECD 2010). Developing strong competition helps to award the best value for a money contract. According to the OECD definition, “Bid rigging happens when groups of firms conspire to raise prices or lower the quality of goods, works or services offered in public tenders”. Bid rigging always aims to eliminating competition resulting in high prices. Thus, the government pays more or loses in quality. Mapping and understanding the operation of the market can help to avoid collusion arrangements or bid-rigging conspiracies between competitors. Markets in which products are standardized and do not frequently change their specifications, or place unjustified barriers to entry to new companies, help to develop this phenomenon (Maslen 2016).

Transparency is of critical importance in order to prevent corruption. However, transparency could have as a result offering so much information to economic operators that makes the procurement procedure predictable, which can further assist collusion (OECD 2010).

2. The Greek platforms and the open procurement data

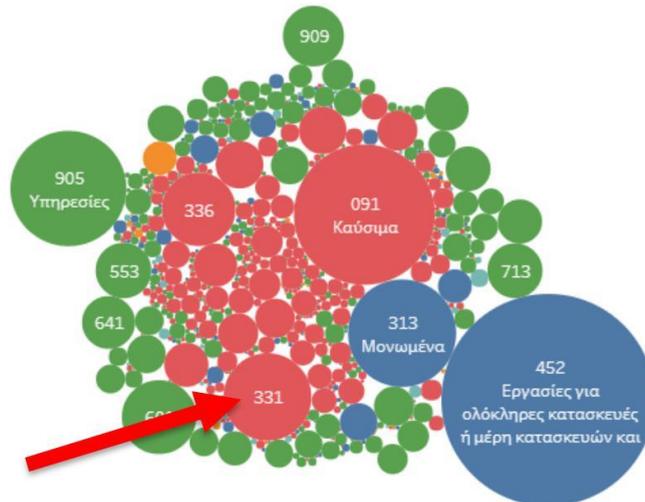
The big crisis that broke out in 2008 has hit the Greek economy significantly. The proper management of public wealth and the elimination of corruption are now imperative. All these years, a major effort has been made so as to revise the framework of procedures. Transparency of procedures was recognized as a good practice. In 2010 the state passed a law by which all public bodies were obliged to publish all their decisions electronically on a specific portal (<https://diavgeia.gov.gr/>), including those relating to the award of public contracts.

From March 2013 the operation of the Central Electronic Registry of Public Contract (KHMDHS at: <http://www.eprocurement.gov.gr/kimds2/unprotected/searchRequests.htm>) was established, in order to strengthen public procurement procedures. The incorporation of the 2014/23/EU, 2014/24/EU and 2014/25/EU Directives set the rules to remove barrier to competition. However, it is considered that the appropriate means for monitoring anti-corruption measures were not defined. In most cases, the preliminary proof is made by a simple written statement, and only in case of a complaint or a sample check, a further inspection is carried out.

3. The main idea

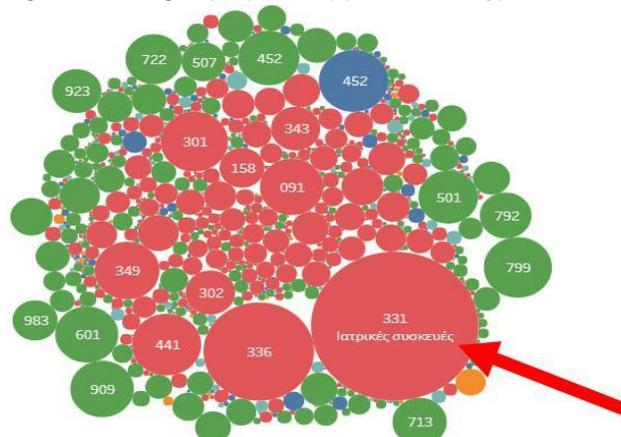
Certain sectors frequently subject to public procurement, including medical goods and services, may be particularly prone to anticompetitive or corrupt practices (OECD 2010). Public procurement procedures in the health sector have been checked by the audit bodies for various reasons several times. Hospital administrations have often been accused of mismanagement. The large budgets and the inelastic need to supply goods related to the provision of health services to patients create the appropriate market environment for the development of corruption. Because the traditional way to analyze all those operations are so complex and costly, particularly for very large data sets, this crucial form of analysis is often overlooked. Graph databases are designed to query intricate connected networks and they can be used to identify fraud rings in a fairly straightforward fashion (Sadowksi 2017). Figure 1 shows the total cost of the competition procedures per cpv category for Greece, for the year 2018. The goods are displayed with red color, the services with green color, the works with blue color and technical services with yellow color. The number "331" shows the category for healthcare equipment. Figure 2 shows the number of competition procedures per cpv category for the same year.

Figure 1: CPV groups (Total Cost) per contract type



Source 1: <https://ppp.eaadhsy.gr>

Figure 2: CPV groups (amount) per contract type



Source 2: <https://ppp.eaadhsy.gr>

The main idea came from the need to interconnect and process the data of the competition processes. Whether or not there is a conflict of interest is something that is poorly monitored since it is covered with a simple statement from the contracting authority and the economic operators on their part. At the same time, the functioning of the market, the recurring assignments to the same economic operator, the possible relationships that partnerships can have, are scarcely monitored.

Finally, the phenomenon of bribery is something that is only found after a complaint. The unusual movement of the procurement agencies or the bank accounts of the family members could be considered to be linked to the award of a contract, under the appropriate legal framework. Graph databases offer new methods of uncovering fraud rings and other sophisticated scams with a high-level of accuracy, and are capable of stopping advanced fraud scenarios in real time (Sadowksi 2017).

4. Methodology

Firstly, the available data provided by open access public platforms was considered appropriate to be used. Specifically, it was considered appropriate to utilize contracts of year 2018 in two categories of goods. The use of time elements was chosen to create a dynamic reporting system.

Of all the medical materials used by public hospitals, the categories of materials with cpv 33111730-7 (materials of angioplasty) and cpv 33111710-1 (materials of angiography) were selected. Contract data were retrieved from the platform of KHMDHS. In addition, the data of the members of the public hospitals' boards and the administrations of economic operators were drawn from the website DIAVGEIA (<https://diavgeia.gov.gr>), the website of tou National Printing Office (www.et.gr), the website of the General Commercial Registry (GEMH) (<https://www.businessregistry.gr/publicity/index>) and the open database at <https://opencorporates.com>. Data such as people's relatives and bank accounts, are not open. That's why a virtual scenario including the board members of the companies and the hospitals, and all their relatives was created.

For the processing of data, graph analytics was chosen. Analytics is the ability to discover meaningful patterns and interesting insights into data using mathematical properties of data. Graph analysis as a theory has its basis in a brand of mathematics called graph theory. Graph analysis uses graph theory in order to explore data which are stored as nodes and relationships. It's important to highlight that plots or pies are charts and not graphs. Computer scientists developed graph algorithms which have been used by many platforms effectively.

Accordingly, all data were stored in CSV files. In total, 37 files were created including information concerning the nodes and relationships. Data were imported in neo4j 3.5.1, an open source graph database management system. Using Cypher a lot of queries were written in order to analyze the database. Because of the limitations in the visualization of the data provided by neo4j browser 3.2.17, database was connected with Gephi 0.92 for better data visualization. Finally, taking into account that this Gephi version supports multilevel analysis, the network topology was examined and other statistical measurements were extracted.

4.1 Database creation

Following the data mining process, separate records were created with information concerning the names of economic operators and hospitals who signed a contract for materials with cpv 33111730-7 (angioplasty materials) and cpv 33111710-1 (materials of angiography) in 2018. 1224 contracts were replicated by corresponding links between 23 public hospitals and 24 companies. The 1224 relationships had various properties, such as the contract value, the start date and the end date of the contract. The contract value was used as weight of the relationships. Separate records were created with the members of the board of directors of these companies and public hospitals. Then files were created with the relatives of the members of the boards. The relations of affinity that were created were up to the fourth degree of kinship and included: spouses, children, parents, parents of the spouses, siblings, siblings in law, grooms or brides, uncles or aunts, uncles or aunts of the spouses, cousins, cousins of the spouses, spouses of the cousins. In the end, files with the bank accounts of all of them were created. All the files were loaded into the graph database and the relationships were assigned as shown in Table 1 below:

Table 1: Statistics of the neo4j database

labels(n)	NumofNodes	AvgNumOfProp PerNode	AvgNumOfRelat ionships	MinNumOfRelat ionships	MaxNumOfRelat ionships
[Hospital]	23	4.0	63,91	25	105
[PersonCompany]	194	8.0	10,30	8	15
[Company]	33	4.0	45,55	7	135
[PersonHosp]	202	8.0	10,75	7	14
[ChildboardComp]	163	6.0	4,39	2	6
[SpouseboardComp]	145	5.0	11,64	9	15
[ParboardComp]	388	7.0	5,93	4	9
[SpouseboardHosp]	156	5.0	9,53	7	12
[SiblingboardHosp]	150	7.0	5,68	4	7
[parboardhosp]	404	7.0	5,04	3	7
[ChildboardHosp]	214	6.0	4,60	2	6
[SiblingboardComp]	138	7.0	5,86	4	7
[SiblinginlawboardHosp]	121	8.0	4,92	4	5
[UncleOrAuntspouseboardHosp]	408	8.0	6,19	4	7
[SiblinginlawboardComp]	104	5.0	5,79	5	6
[CousinsboardComp]	1067	9.0	4,92	4	6
[UncleOrAuntboardHosp]	438	8.0	7,12	4	8
[ParspouseboardComp]	290	7.0	6,76	5	8
[UncleOrAuntboardComp]	599	8.0	2,78	1	4
[ParspouseboardHosp]	312	8.0	5,21	3	6
[UncleOrAuntspouseboardComp]	406	8.0	6,92	5	8
[GroomOrBrideboardHosp]	113	8.0	4,73	4	5
[CousinsboardHosp]	1005	9.0	4,77	4	5
[GroomOrBrideboardComp]	81	8.0	4,80	4	5
[SpouseCousin spouseboardHosp]	398	10.0	4,79	4	5

[CousinSpouseBoardComp]	415	8.0	5,58	4	6
[BankAccountHosp]	16398	4.0	1,01	1	2
[SpouseCousinSpouseBoardComp]	284	10.0	4,88	4	5
[CousinSpouseBoardHosp]	576	10.0	5,42	3	6
[BankAccountComp]	16128	4.0	1,04	1	3

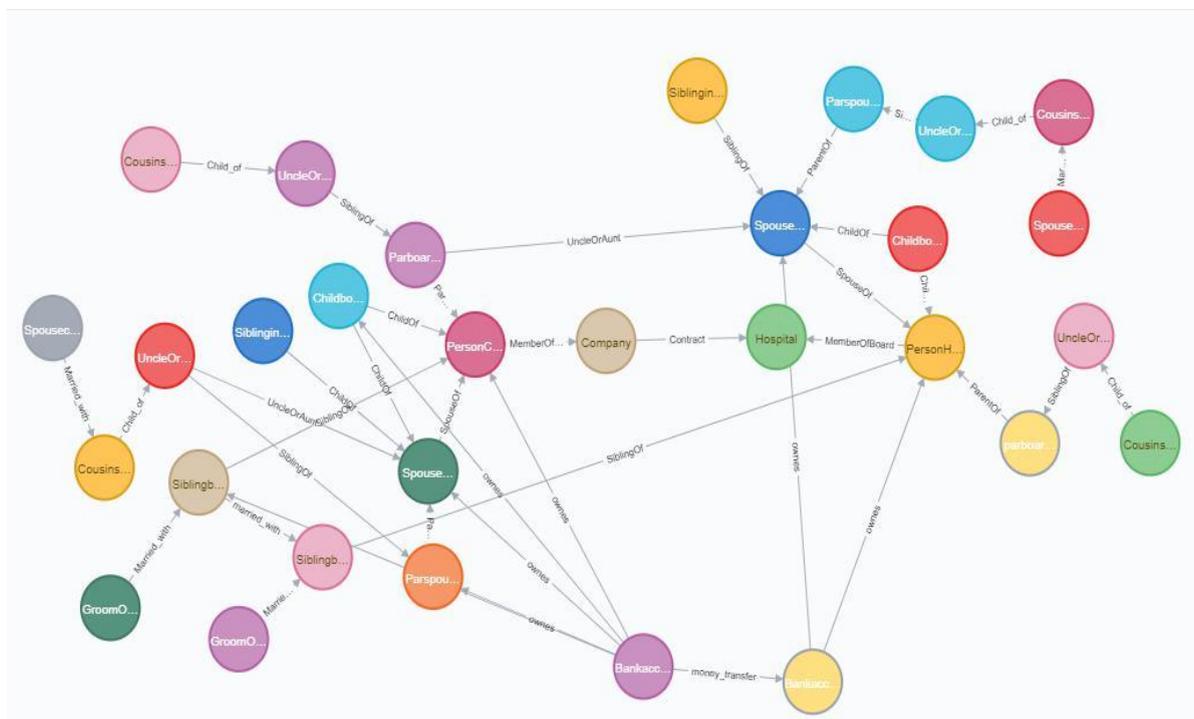
The database created had a total size of 49,16MB while the other characteristics are shown in Figure 3 below. In Figure 4 the relations between the nodes are shown in accordance with the label. Using Neo4j graph algorithms, it's easy to understand the model and predict complicated dynamics. The flow of resources or information, the network failures spread, and the influences on and resiliency of groups could be studied in short time (Holder 2018).

Figure 3: Database characteristics

Store Sizes	
Count Store	21.22 KiB
Label Store	16.02 KiB
Index Store	5.92 MiB
Schema Store	16.01 KiB
Array Store	8.01 KiB
Logical Log	35.58 MiB
Node Store	655.86 KiB
Property Store	5.43 MiB
Relationship Store	1.46 MiB
String Store	64.01 KiB
Total Store Size	49.16 MiB

ID Allocation	
Node ID	43790
Property ID	138445
Relationship ID	44314
Relationship Type ID	13

Figure 4: Schema of database



4.2 Database connection

Neo4j delivers simple data visualizations to analysts (Bhatt 2017). In order to produce a better visualization of the graph a connection with Gephi was considered as necessary. Gephi is an open-source software for network visualization and analysis. In order to connect neo4j with Gephi, a plugin called APOC should be firstly installed in the graph database. The APOC library consists of many (about 450) procedures and functions to help with many different tasks in areas like data integration, graph algorithms or data conversion. Following, at the platform of the Gephi the plugin "Graph Streaming" was installed. Then, the "Master Server" at Gephi should be started. After that using the algorithm of "CALL apoc.gephi" the total graph database or a part of these data, could be transferred to Gephi.

5. Main Results

The capture of data has highlighted the difficulty to identify and analyze the behavior of corruption. In order to study the contracts of 23 hospitals for only two categories of materials, cpv 33111730-7 (angioplasty materials) and cpv 33111710-1 (materials of angiography), for the year 2018, a network of 43722 nodes and 44196 relationships had to be analyzed. Using graph analytics, this network can extract information about the role of economics operators in the procurement network.

Furthermore, the analysis provides us with data which can be transformed to information about conflict of interest, in the way that a contract can be checked with the existence of a relationship between the members of the boards of the companies and the members of the boards of the hospitals. The analysis was not limited to this. Specifically, the analysis may nominate persons who declare that they have no relationship, but mention the same telephone or the same address (Gustavo 2017). Finally, the interconnection of individuals with their bank accounts showed important findings. The results confirmed that when there is a bank transaction, by any person who may indirectly or directly be linked to the award of a public contract, the network may show it.

5.1 Market Analysis

23 hospitals and 33 companies were included in the network. The total number of contracts was 1224. The "Company 5" covers 10.39% of public contracts and is associated with 127 contracts with 23 hospitals. The "Company 14" covers 9,74% of public contracts and is associated with 119 contracts with hospitals, while the "Company 2" covers 8.76% of public contracts and is associated with 107 contracts with hospitals. With regard to the values of contracts, the largest amount (€949.207 corresponding to the 12,63% of the total amount) was received by the "Company 5". The "Company 14" received €871.186 (11.60% of the total amount) and the "Company 2" received the amount of €794.306 (10,57% of the total amount).

Concerning the hospitals, the "Hospital 8" awarded the largest volume of contracts (105), the "Hospital 7" awarded 95 contracts and the "Hospital 10" awarded 93 contracts. With regard to the values of the contracts, the largest amount (€572.8177 corresponding to 7,62% of the total amount) was instructed by the "Hospital 8". The "Hospital 10" awarded €542816 (7.22% of the total amount) and the "Hospital 9" awarded the amount of €514.994 (6,85% of the total amount). Figure 5 shows a visualization of the

companies, with their size being proportional to the number of contracts. In Figure 6 a visualization of the data depending on the volume of contracts by the public hospitals is illustrated, while in Figure 7 the visualization of data for the "Hospital 8" that has the largest volume of cargo handling is shown.

Figure 5: Visualization of the companies, using out-degree value

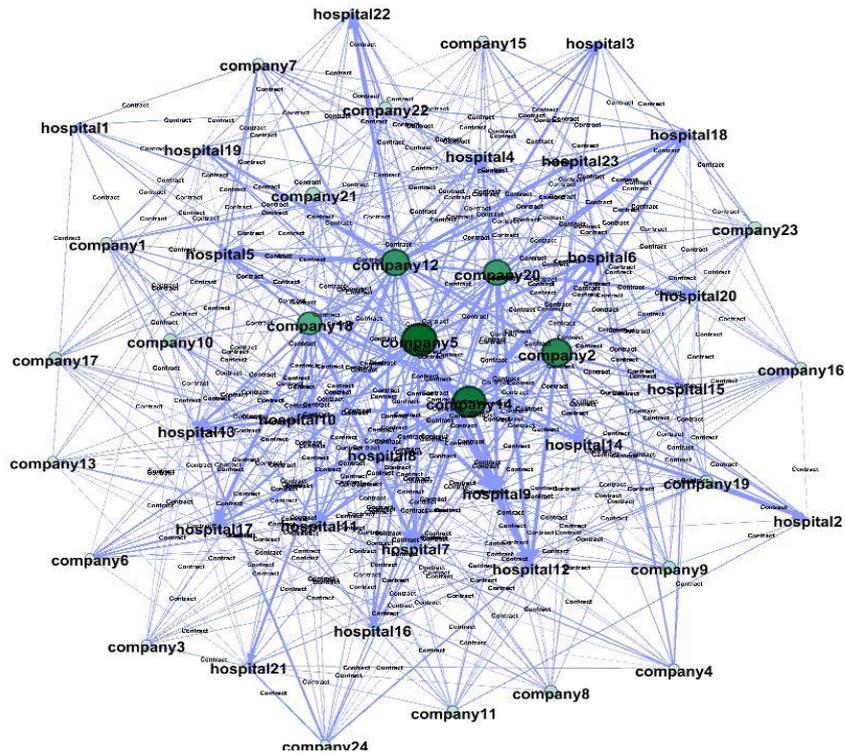


Figure 6: Visualization of the hospitals, using in-degree value

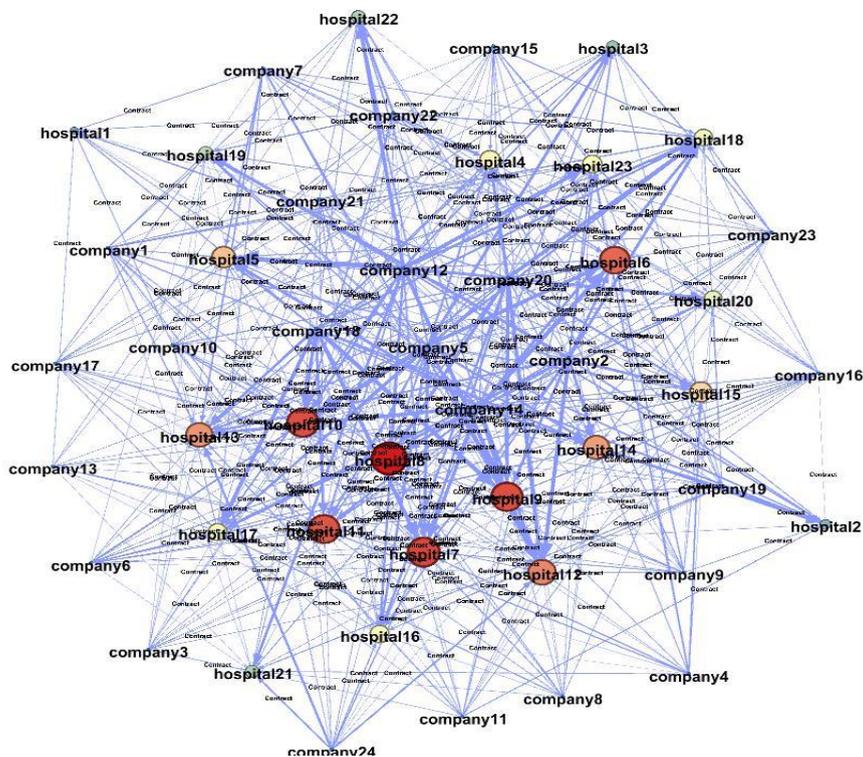
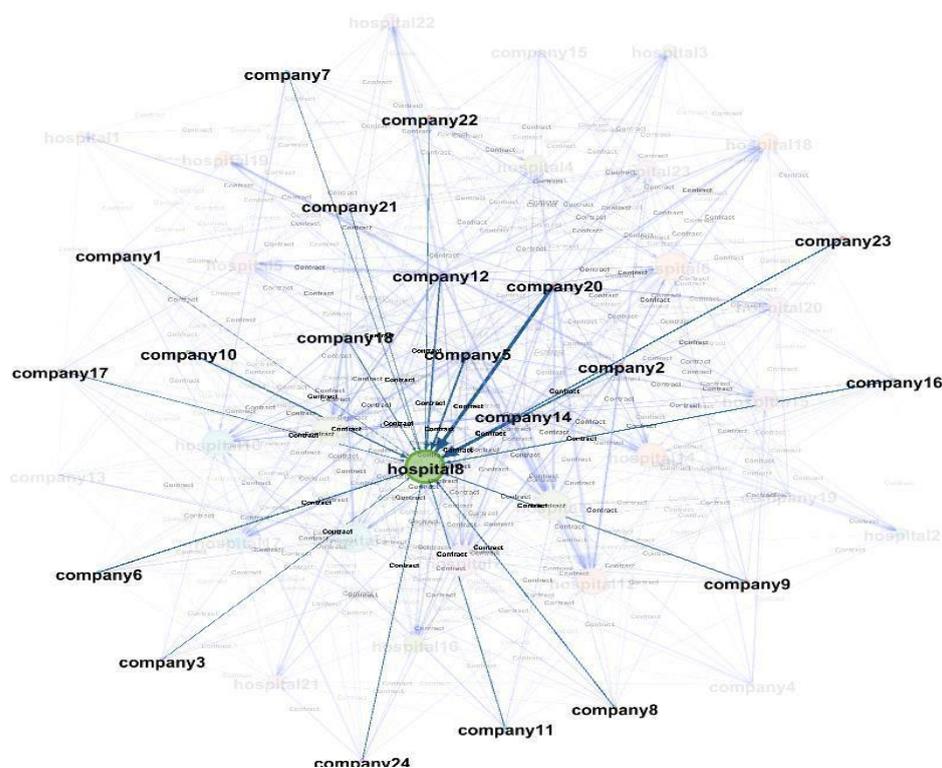


Figure 7: Visualization of the "Hospital 8", using in-degree value



5.2 Red flags about the board

At first glance, there is no evidence of corruption in all contracts awarded. At the first level of analysis a link between the members of the boards of companies and the members of the boards of the hospitals is not shown. Looking a little better at the data, it's easy to understand that in 5 cases, corruption behavior may be identified. In particular, as emerged in the graph analysis of the network, there is a conflict of interest between the "Hospital 17" and the "Company 18" in a contract worth €25.409. Specifically, the cousin of a member of the board of the company is married with the sibling in law of a member of the board of the Hospital.

In a contract of €25392 between the "Company 14" and "Hospital 9" there is a conflict of interest, since the sibling of a board member of the company is married with the sibling of a board member of the hospital.

In the contract of €31.896 between the "Hospital 10" and the "Company 5", a conflict of interest was found as well, since the parent of a board member of the company is the uncle of the spouse of the member of the hospital board.

Finally, two more contracts should be explored, since relatives of members of the boards of companies and hospitals, were found to have a common address and telephone (OECD 2009). In details, the contract between the "Company 12" and the "Hospital 9", a groom of a member of the board of the company appeared to have stated the same telephone number and same address with the cousin of a member of the board of the hospital.

In the contract between the "Company 20" and the "Hospital 7" the groom of the member of the board of the company appeared to have stated the same telephone and same address as the sister of a member of the board of the hospital.

5.3 Money traffic

Out of the total of 32526 bank accounts of the graph database, it appeared that 3 banking transactions may be linked to bribery, and therefore they should be further investigated. In particular, in a value contract of €32,565 between the "Hospital 5" and the "Company 12", there was a €1,000 banking transaction from an account belonging to a sibling in law of a member of the board of the company to an account belonging to a cousin of a member of the board of the Hospital. One more €700 transaction from an account belonging to a sibling in law of a member of the board of the company, to an account belonging to a parent of the spouse of a member of the board of the Hospital was observed. Finally, a transaction of 500 € from an account belonging to an uncle or an aunt of a member of the company's board to an account belonging to a groom or to a bride of a board member of the Hospital was identified. At this point, it is emphasized that this methodology aims to prevent such transactions rather than identify them.

6. Conclusion

The analysis of data in public contracts using graph analytics may lead us to identify the phenomenon of corruption. The processing of data which include all bids submitted in each competition would lead us to make better conclusions with regard to the function of the market and the development of the phenomenon of bid rigging. Furthermore, other people should be added to the analysis, beyond the board members of the companies and hospitals. Such persons are all those who affect the process, such as the members of various boards for competitions. Finally, the relationships between the members of the boards of the companies can give us important clues to the functioning of the market and the existence of a cartel.

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