Network Analysis of PhilGEPS: A Bipartite Analysis of Government Organization and Corporate Awardees

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Abstract

Procurement plays a critical role in the public sector. It is focused on supporting different units of the government to play their unique roles and serve citizens. Having an efficient and transparent procurement system is essential for any government organization to execute its initiatives like healthcare, education, and risk and disaster management.

This study intends to model the complex network of government organizations, corporations, and awarded projects using the historical records available in PhilGEPS. The study focuses on the Information Technology services which supports various types of government organization and have received increased focus in today's age of modernization and digitization. These features were selected to reveal important or dominant corporations that serve the public sector. The study also looks into different time years from two different periods, 2014 and 2019, to analyze the changes of the Philippine procurement landscape.

Using a Bipartite Network Analysis, we were able to see the growth and change of the network from 2014 and 2019. We were also able to reveal specific companies who maintained their importance in the network after 5 years. We were also able to identify important actors in the projected networks of government organizations and corporate awardees. These insights can support decisions of the government in creating policies. Additionally, it can also be used by corporations to get insights on the needs of the government and evaluate their competition.

Based on these findings, we highly recommend the development of an open-source tool that can be added to the functionalities being provided by PhilGEPS. This network analysis tool can be integrated to their monitoring system and help improve transparency and efficiency in the government procurement system.

Keywords: Network Science, Complex Systems, Bipartite Network, Procurement, Government

1 Introduction

In 2019, the Philippine Government Electronic Procurement System (PhilGEPS) recorded a total of 551 Billion Philippine Pesos in awarded contracts. This is equivalent to 15% of the total Philippine National Cash Budget for 2019 (PhilGEPS Open Data).

Procurement is central to the operations of all government organizations. It is used in healthcare like vaccines, drugs, and public hospitals. It is used in educational facilities including desks, chairs, and paper. It also includes core services like Information Technology services that are essential in the operations of many government organizations regardless of the nature of its role and services (About PhilGEPS).

The Philippine procurement system is often characterized by fraud and lack of transparency. Through the implementation of RA 9184, all National Government Agencies (NGAs), Government Owned and Controlled Corporations (GOCCs), Government Financial Institutions (GFIs), State Universities and Colleges (SUCS) including Local Government Units (LGUs) were mandated to use the PhilGEPS. PhilGEPS was created to address this issue and help improve the efficiency and transparency in the procurement function. It has proven to be a viable instrument in the public sector and has been accepted by the World Bank (WB) and the Asian Development Bank (ADB) (About PhilGEPS).

PhilGEPS is the centralized electronic portal that serves as the primary and definitive source of information on government procurement. The platform currently serves as an overall platform for E-Bidding and also hosts historical information on bids and awarded projects (About PhilGEPS).

However, with 1.16 million records in 2019 alone, there is a challenge to easily analyze and reveal patterns in the procurement system. With the goal of increasing transparency in the Philippine procurement system, we explored modeling the complex network of government organizations, corporations, and awarded projects using the historical records available in PhilGEPS. The study focuses on the Information Technology services which supports various types of government organization and have received increased focus in today's age of modernization and digitization. These features were selected to reveal important or dominant corporations that serve the public sector. The study also looks into different time years from two different periods, 2014 and 2019, to analyze the changes of the Philippine procurement landscape coming from two different administrations.

2 Review of Related Literature

In the Netherlands, a bipartite network of corporations and government/state agencies was analyzed in 1978 by Mokken and Stokman. Their study revealed dominant industrial sectors like metals/shipbuilding and chemicals/oil. They also found that state agencies under economic affairs, and education and sciences have the most connections (Mokken and Stokman, 1978).

Network theory was also applied to analysing public-private partnership projects (PPP). Through network analysis, Chowdhury et al. identified the core-peripheral stakeholders, the interdependence of influential intermediary participants, the effect of the structure of the PPP on its outcome. They constructed a bipartite network of the related parties of the PPP agreements and the contracts/agreements. The edge would be constructed by connecting an agreement and a stakeholder of the PPP. Analysis of the projected network of stakeholders reveals that the node or stakeholder with the highest degree is the most influential stakeholder. The most influential stakeholder also had the highest betweenness centrality showing that this stakeholder has greater access to information and can efficiently communicate with others. The study was able to identify the position, power and influence of each stakeholder. The power of a stakeholder is not an individual attribute but it stems from the relationships with other stakeholders in the network (Chowdhury et al., 2011).

The group of Yau et al. performed social network analysis (SNA) to explore the network of educational institutions and industrial partners for the grants awarded by the National Sciences and Engineering Research Council of Canada between 2000 to 2010. The group constructed two mode networks for 2000-2005 and 2006-2010, and one mode networks of institutions based on shared partners and one mode networks of partners based on shared institutions. They examined the different centrality measures (authority, hub, total degree, and eigenvector) for the one mode network of institutions. They found the University of British Columbia to be one of the most central research institutions based on the research it shares with the other universities. Similarly, they found that analyzing the one mode network of research subjects that the different centrality measures reflect the dominant research area for a given year. Their social network analysis has shown how funding in research addresses the current needs and how it reflects the need for better oversight of the process. Social network analysis is therefore a useful tool in enforcing good governance (Yau et al., 2012).

Another application of network theory is examining how corruption can distort markets and how it affects the structure of public contracting markets. The study of Fazekas et al., modelled public contracting networks using buyers and suppliers as nodes. They applied their analysis on two similarly corrupt countries the Czech republic and Hungary. They found that a buyer that is flagged as corrupt has 10% fewer suppliers and that the most corrupt buyers alter their networks by 21-38% with government turnovers.

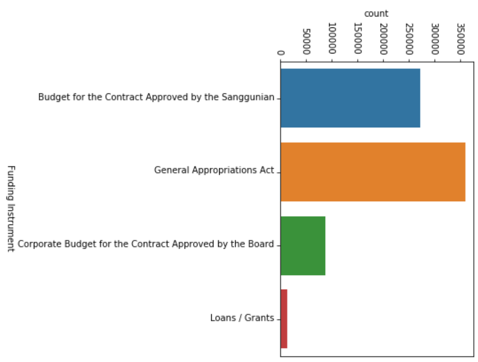
Bipartite networks were also applied in analyzing behavior in design crowdsourcing. One set of nodes for the participants, another set of nodes for design contests. This paper by Chaudhari et al., found that the fraction of total prize allocated to the first prize negatively affects participation. They also modeled contest popularity using the alternating k-star network statistic.

3 Data and Methodology

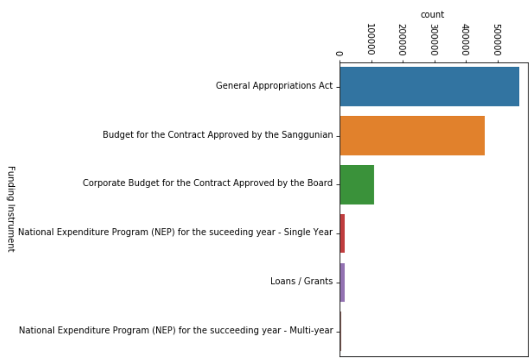
3.1 Data Description

Procurement data was downloaded from the PhilGEPS website (PhilGEPS Open Data). The data was collected for January to December 2014, and January to December 2019. The initial dataframe was filtered to include only Information Technology as the Business Category. A new dataframe was constructed to include only 1) The Organization Name - the name of the government/state agency that needs the project. 2) The Notice Title- the name or a brief description of the project. 3) The Awardee Corporate Title- the name of the company that won the contract., and 4) The Contract Amount.

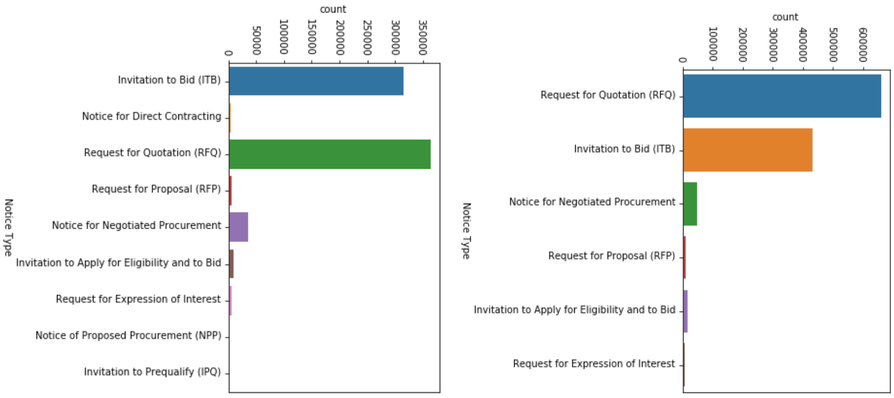
3.2 Exploratory Data Analysis



2014



2019



2014 2019

Figure 1: Count Plots for the Funding Instruments and Notice Types for 2014 and 2019

Most of the contracts awarded in 2014 and 2019 were funded by the General Appropriations Act. It would be interesting to note that the number of contracts that were procured by Requesting for Quotation almost doubled from 2014 to 2019 while those that were awarded from Invitation to Bid has increased only by around 30%.

3.3 Building the Network

A two mode graph for Information Technology (IT) projects was constructed for 2014 and 2019. The years were chosen to examine the IT projects awarded during the term of different Philippine Presidents during their 4th year in office. One set of nodes were the Government Organizations and the other set of nodes are the Corporate Awardees. An edge connects a Government Organization with a Corporate Awardee if a project was awarded by the Government Organization to the Corporate Awardee. The undirected edges were weighted with the number of awarded projects by a Government Organization to a Company.

3.4 Network Science Methods

The bipartite network was analyzed using NetworkX. network properties such as the number of nodes, no. of edges, average unweighted degree, average weighted degree, and network diameter were calculated. To analyze a bipartite graph, a projection of the top nodes and bottom nodes are created. The projected graph O is a network of government agencies connected if they have a corporation that was able to secure a contract from each of them. The projected graph A is a network of corporations/contractors that won a contract from the same government agency. Different centrality measures (Degree, Closeness, Betweenness, Eigenvector) were taken from both projections. The top 20 for each centrality measure were then extracted to reveal top Government Organizations, and Corporate Awardees. The networks were then visualized using Gephi.

2014 2019

Figure 2: Bipartite Network of Government Organizations (in blue) and Corporate Awardees (in pink)

4 Discussion of Results

We analyzed the Philippine government procurement as a bipartite network for the years 2014 and 2019. We also analyzed both the projected government organization network and corporate awardee network. We focused our analysis on the changes in the structure of the network and in revealing important actors in the network.

4.1 Bipartite Network

In Table 1, we present the descriptive statistics of the bipartite graphs constructed from 2014 and 2019. These helped us see the structure of the networks and the changes in the properties for both periods. We see that both have 0.0 clustering coefficients because these are bipartite graphs.

Table 1: Bipartite Network Properties

Metric	2014	2019
No. of Nodes	1,424	2,286
No. of Edges	1,769	2,853
Average Unweighted Degree	2.49	2.50
Average Weighted Degree	6.76	5.15
Clustering Coefficient	0.0	0.0
Diameter	17	20
No. of Communities	177	237

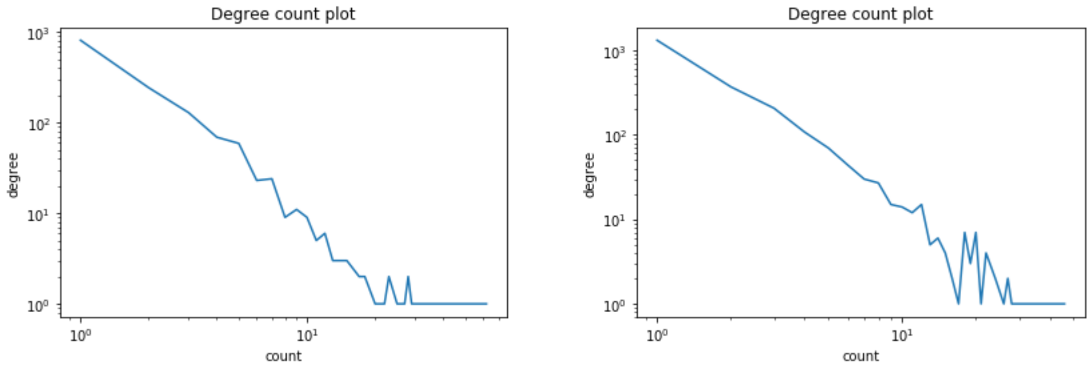


Figure 3: Bipartite Networks Degree Distribution 2014 and 2019

We inspect an increase in the number of nodes which signify the increase in the number of actors in the network composed of different unique Government Organizations and Corporate Awardees. We also inspect an increase in the number of edges which signify the increase in the number of projects from 2014 to 2019. This is intuitive given the context of growth of the Philippine economy and also the increase in the number of government projects like those under the "Build Build Build" umbrella under the 2016-2022 administration.

As seen in Figure 3, we see that both networks' degree distribution observes a power law and suggests that both are scale-free graphs. Our analysis also shows that the average degree between the two eras remain unmoved at approximately 2.50 degrees. This unweighted degree signifies the number of unique corporate awardee that are connected to a government organization. It is interesting to see that this property remains unchanged.

However, we do not observe the similar trend when looking at the average weighted degree. The average weighted degree decreased from 6.76 to 5.15. Given that the number of unique corporate awardee remained constant, this means that on average government organization to corporation interactions are less repeated. However, we can only speculate the meaning of this observation. This may suggest that there is less preference to a current supplier or there is a high level of competition between firms. It can also suggest a more efficient system that requires less repeat orders.

With the increase in the number of nodes and the edges, we also see an increase in the diameter or the longest shortest path in the network. This shows the expanding network of government procurement. We also observed an increase in the number of communities in the network which shows that the growth of the network is not just limited to the growth of the existing communities but also the emergence of new communities following the growth of the network.

We used Degree Centrality to reveal the most important actors in the network and compared the changes in position. We saw that 5 out of 10 of the actors remain in the top 10 most important nodes.

The most notable actor is Masangkay Computer Center which maintained its position as the most important node with the highest degree centrality. This shows a sustained dominance of one company in serving many government organizations. This shows a possible preferential awarding of the public sector to Masangkay Computer Center. This preference may come from the company's excellent service, competitive pricing, or unique services. It can show the entrepreneurial success of the company that can be used as a role model by other entrepreneurs or it can also be a sign of anomalous behavior. These possible insights are purely speculative currently. What is certain is their importance in the procurement network in supporting many government organizations.

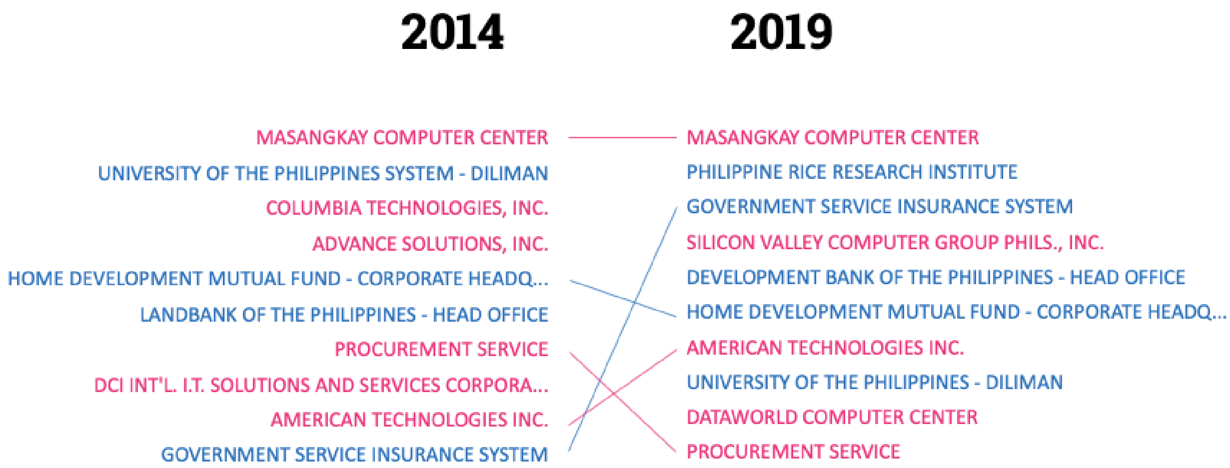


Figure 4: Top 10 Degree Centrality for Bipartite Network

Another notable insight is the Philippine Rice Research Institute which ranked 2nd in 2019 from not being in the Top 10 in 2014. This high rank in importance shows the increase in activity of the government organization that can be explained by an increase in strategic focus of the government, an increase in budget, or a change in leadership.

Using degree centrality, we were able to show the important actors in the network. This can be used by the government to see anomalies by comparing the insights of the network to what they are expecting from the approved budgets and strategic initiatives of the government. This analysis can be improved by looking at a more granular annual comparison to track the movements in rankings more closely.

4.2 Corporate Awardee Projected Network

In Table 2, we present the descriptive statistics of the projected network of corporate awardees from 2014 and 2019. These projections have corporate awardees as nodes and similarities in government organization served as edges. These helped us see the structure of the networks and the changes in the properties for both periods. The analysis of the projected network is different because the edges do not signify an awarded project from one node to another. The edge in the projected graph is created when two corporations receive projects from the same government organization.

Table 2: Projected Corporate Awardees Network Properties

Metric	2014	2019
No. of Nodes	777	1,416
No. of Edges	4,705	7,771
Average Degree	12.11	10.98
Clustering Coefficient	0.60	0.59
Diameter	8	10
No. of Communities	161	219

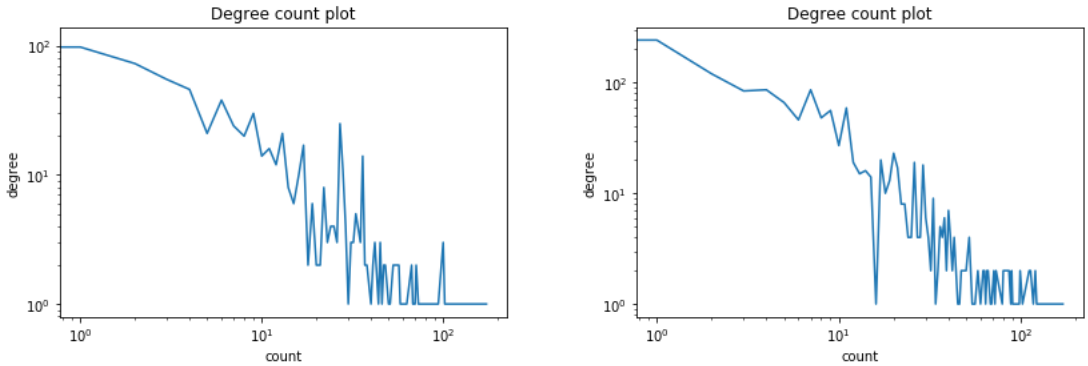


Fig 5: Corporate Awardee Projected Network Degree Distribution 2014 and 2019

Following the increase in the size of the bipartite network, we also see an 80% increase in the number of nodes which signify the increase in the number of actors in the network which shows that there are now more corporations serving the public sector. We also see a 65% increase in the number of edges which signify the increase in the number of shared relationships with government agencies. It is interesting to note the lower increase in edges compared to the increase in nodes. Overall, we saw that the projected network also grew when looking at the diameter.

As seen in Figure 3, we see that both networks' degree distributions are close to a power law distribution. Both of the degree distributions are noisy and have drops in value in between. Our analysis also shows that the average degree between the two eras decreased from 12.11 to 10.98. This signifies that on average a corporation in 2019 has less shared connections than in 2014.

The clustering coefficient decreased from 0.60 to 0.59. This means that the corporations are now less clustered but by a small margin only. The value of the clustering coefficient is above 0.5 which shows that the network is highly clustered. We also observed that more communities have emerged going into 2019.

We used Degree Centrality to reveal the most important actors in the network and compared the changes in position. We saw that 5 out of 10 of the actors remain in the top 10 most important nodes. The importance in this network reveals corporations who serve a lot of government organizations that are also served by other corporations.

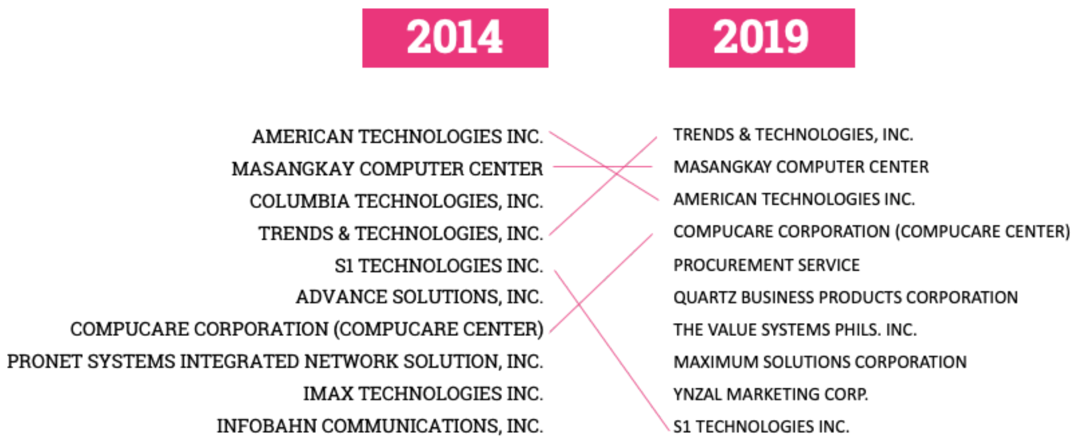


Figure 6: Top 10 Degree Centrality for Corporate Awardee Projected Network

Further analysis must be done to see if these corporations have the same or different product offerings. For our analysis, we assume that they have similar offerings since we have limited our analysis on Information Technology specifically. We see in the rankings that similar to the bipartite networks analysis, we still see Masangkay Computer Center as an important actor. This tells us that the government organizations awarding projects to Masangkay Computer Center also award projects to others. It tells us that government organizations do not prefer to have Masangkay Computer Center as their sole supplier for any Information Technology requirements because its connection is shared with a lot of other corporations. This can be interpreted as the robustness of the network since we can say that government organizations are exposed to multiple corporations when it comes to Information Technology. This can also tell us the level of either or a combination of collaboration and competition amongst Information Technology goods and service providers.

4.3 Government Organization Projected Network

In Table 3, we present the descriptive statistics of the projected network of government organizations from 2014 and 2019. These projections have government organizations as nodes and similarities in corporations awarded as edges. These helped us see the structure of the networks and the changes in the properties for both periods. The analysis of the projected network of government organizations is similar to the corporate awardees where edges do not signify an awarded project from one node to another. The edge in the projected graph is created when two government organizations award projects to the same corporation.

Table 3: Projected Government Organizations Network Properties

Metric	2014	2019
No. of Nodes	647	1,017
No. of Edges	5,994	7,988
Average Degree	18.53	15.71
Clustering Coefficient	0.54	0.56
Diameter	8	9
No. of Communities	159	213

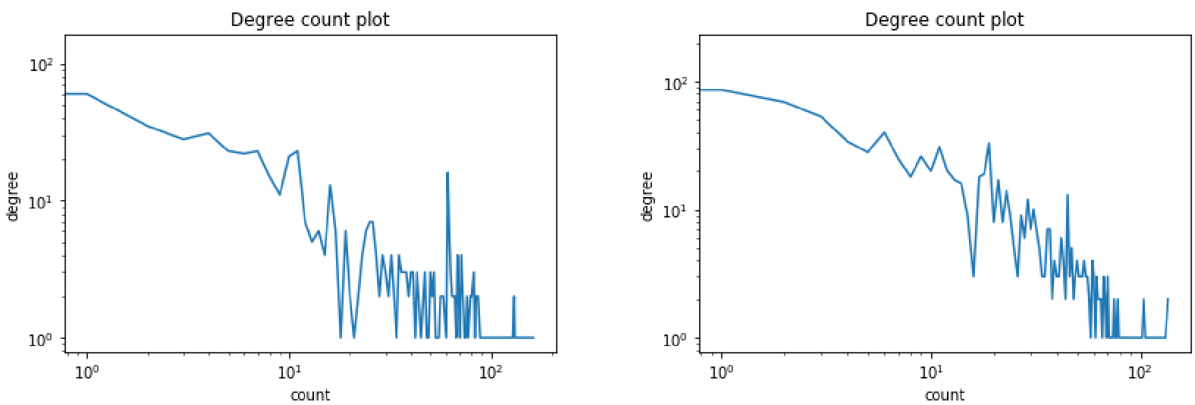


Fig 5: Government Organization Projected Network Degree Distribution 2014 and 2019

Following the increase in the size of the bipartite network, we also see an 57% increase in the number of nodes which signify the increase in the number of actors in the network which shows that there are now more government organizations in the PhilGEPS system and awarding projects to corporations. We also see a 33% increase in the number of edges which signify the increase in the number of shared relationships with corporations. It is interesting to note the lower increase in edges compared to the increase in nodes. Overall, we saw that the projected network also grew when looking at the diameter.

As seen in Figure 5, we see that both networks' degree distributions are close to a power law distribution. Both of the degree distributions are noisy and have rises and drops in value in between. Our analysis also shows that the average degree between the two eras decreased significantly from 18.53 to 15.71. This signifies that on average a corporation in 2019 has less shared connections than in 2014. We see that government organizations now have less similarities with each other.

The clustering coefficient increased from 0.54 to 0.56. This means that the corporations are now more clustered but by a small margin only. The value of the clustering coefficient is above 0.5 which shows that the network is highly clustered. We also observed that more communities have emerged going into 2019.

We used Degree Centrality to reveal the most important actors in the network and compared the changes in position. We saw that 3 out of 10 of the actors remain in the top 10 most important nodes. This is less than what we found in the bipartite network and corporate awardee projection network. The importance in this network reveals corporations who serve a lot of government organizations that are also served by other corporations.

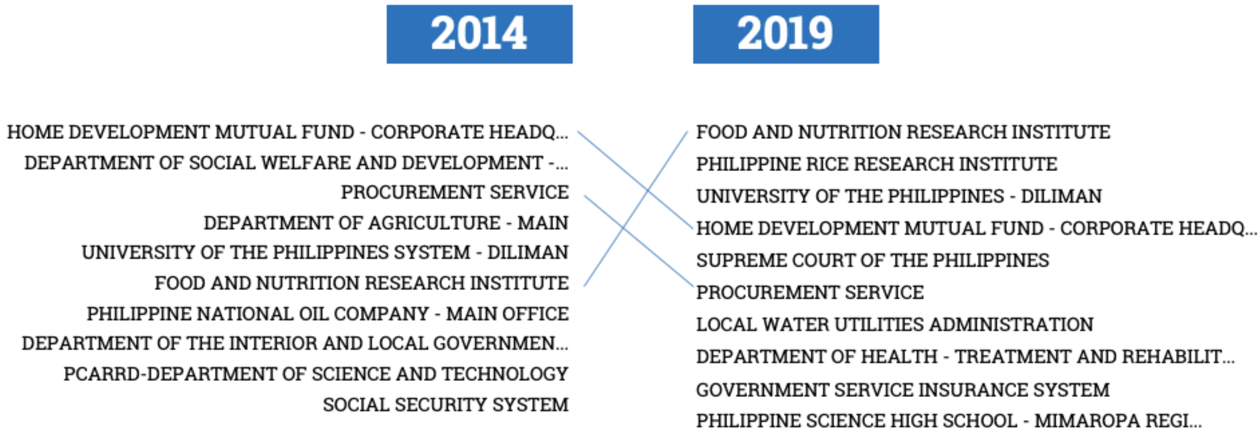


Figure 7: Top 10 Degree Centrality for Government Organizations Projected Network

Further analysis must be done to see if these government organizations are awarding projects that have the same or different goods or services. For our analysis, we assume that they have similar offerings since we have limited our analysis on Information Technology specifically. This insight can help the government offices benchmark themselves against other winning bids for both budget planning and project awarding. This can also be used as leverage for procurement planning and aid collaboration between government organizations to get better bids and agreements and increase the procurement system efficiency.

5 Conclusions

This paper analyzed the network of Government Organizations and Corporate Awardees for IT projects in 2014 and 2019. The analysis reveals that the network has changed and grew comparing 2014 and 2019. Using degree centrality in the bipartite network, we have identified key actors among corporations and government agencies. The degree centrality for the projected networks for corporate awardees were also compared in 2014 and 2019. It reveals that the top corporations that serve shared government organizations were almost the same in 2014 and 2019. These are the dominant companies serving the IT needs of the government.

This work can provide an initial model of the network of government procurement and understand the nature of past projects. It could help the Commission on Audit to scrutinize the awarded contracts in each government agency or for each business category. This paper also identified dominant companies that secure contracts with the government, it could help in promoting good governance by ensuring fair practices in Government Bids and Awards. The study can also guide businesses who want to enter partnerships with the government as it would reveal areas of least competition, underserved government agencies, and dominant companies. Lastly, the study can be utilized by the government in making more informed policies that ultimately improve how it spends its budget.

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