Social Network Analysis of Knowledge and Actor Relations: A Case Study in KLG IT Department

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***Abstract*—IT department is often relied on as business activities enabler. To be able to do that task efficiently while also continuing to innovate, knowledge is necessary. KLG is one of the retail business players in Indonesia; currently their IT department is in effort to capture various types of important knowledge. Unfortunately, it experiences stagnation. What the IT department have now is a file repository, so where to start to implement a more comprehensive solution like Knowledge Management? To better understand the current pattern of communication influenced by its unique culture and structure of the organization, this research uses Social Network Analysis (SNA) one-mode network and bipartite graph. The visualization and analysis of the social network were performed using tools called Cytoscape. From total of 10 IT-side actor nodes and 5 business-side actor nodes, it was found connection value between actors. FA and PM get identical results due to being indistinguishable by other actors. FA/PM got the highest score followed by IT Ops & Support at betweenness (1.0993, 1.0369) and stress centrality (796, 698). At closeness centrality, Ops & Support (0.8750) took the lead, followed by FA/PM (0.7778) and developers (0.7778). In addition to the analysis of the actors' relationships, potential knowledge contributors and actors' interest in different types of knowledge are also identified. Further research will describe how knowledge management strategies are shaped based on these findings.**

Keywords—social network analysis, one-mode network, bipartite network, knowledge management, project management

I. INTRODUCTION

Internet Technology (IT) Department in an organization must be able to harmonize the technology approach used with the business value that it wants to obtain. In doing so, either or both in-depth and cross-disciplinary knowledge is required. The problem is that knowledges is resided in many nodes. Where among them are experience, insight, wisdom and intuition of a person. Making it a challenge to gather and make use of this scattered capital.

This is the case that occurred in the KLG IT department. KLG itself is a corporate from Indonesia whose business is non-IT disciplined, instead, primarily in the distributor and retail industry. Regarding dynamic nature of the organizational knowledge, this study is related to Intellectual Capital (IC) which is the intangible (or less intangible) value of an organization, a combination of human knowledge and skill capital, structural/organizational capital, and social capital that embedded in relationships and interactions between individuals [1], [2]. What the organization have done in relation to this need as pointed out in the KLG IT Department 2021 Work Plan is to create a file repository that more closely resembles a Document Management System (DMS), and that can only accommodate explicit knowledge. The tacit knowledge that moves the organization have potential to be lost because it has never been captured and stored. Fortunately, the challenge can actually turn to be the strength against the competitive industrial world if the IT department able to utilize intellectual capital with the help of knowledge management capabilities [1], [3]. The use of knowledge management to empower this IC, firstly must go through the process of capture.

In fact, designing a suitable model for knowledge capture in an IT department is not easy, given the KM Foundation that must be considered will not only include IT infrastructure and common knowledge, but also the unique culture of the organization, the structure of government and its physical environment [1]. To better understand the current pattern of IT Department communication influenced by this unique culture and structure of KLG as organization, the research question raised in this study is "how the relationship between knowledge and actors in the KLG IT Department". Then to answer the question, this research uses Social Network Analysis (SNA). Specifically, both type of SNA, the one-mode network and bipartite graph to visualizing knowledge flow and need in the IT department development process.

Learning from Wang et al [4] and Xiang et al [5], to be able to perform SNA it is necessary to first identify the nodes involved, both identification of the classification of nodes and their connection can be seen by observing the activities they usually do. The nodes involved can also be of different types and have special relationships such as 'generate' and 'generated by' - not just node 1 connected to node 2, an example of its potential use in research cases such as Rachman and Ratnayake's knowledge flow [6]. The contribution of this research is insight for the organization on which actors need attention and can be empowered more - which are the critical success variables [7], [8] in the flow of knowledge, and which knowledge is considered important and can be contributed by the actors. This insight is expected to be the basis for consideration of knowledge management strategies, especially, knowledge capture model. Several tools that can be used to visualize and run analysis, in the form of GUI or library used in programming, include Gephi,

Cytoscape, NodeXL, Pajek, IGraph and SocNetV [9], [10]. In this research, Cytoscape is used because it is easier to visualize bipartite graphs without additional plugins.

After explained the background of the study, the next chapter contains related literature. The methodology explained in the 3rd Chapter, whilst analysis and result presented in the 4th Chapter, then closed with the conclusion.

II. Literature Study

A. Knowledge Management in Organization

Knowledge Management (KM) is a management discipline that seeks to influence the processing of knowledge [11]. The goal of knowledge management is to improve the extent to which knowledge aids in achieving corporate objectives and/or other objectives, for example, increasing the impact of knowledge cost-effectively, such that the benefits of knowledge management exceed the costs of doing so. "The things needed" in activities involved in KM processes is discover new knowledge, capture existing knowledge, share with others, or apply it [1].

B. Knowledge Capture in IT Development Department

Knowledge capture may be defined as the process of retrieving either explicit or tacit knowledge that lies within individuals, artifacts, or organizational entities. It could also be found beyond the organization, such as among consultants, competitors, customers, suppliers, and prior employers of the organization's new employees [1]. The objective of KM Capture is increasing productivity and reducing costs are important things in an organization [12] and develop an effective process to capture tacit or explicit knowledge gained from the project [11], [13]. KM Capture also carried out to anticipate experienced personnel leave and new personnel are introduced, a lack of sufficient knowledge retention introduces inefficiency in project development [14].

IT Development Department in a company is always associated with project management. In a project, there are 4 main domains namely, people, organizational, process, and technical [15]. Each interrelated domain has knowledge in it and KM capture is expected to be a solution so that knowledge can be managed properly.

C. Social Network Analysis (SNA)

SNA represents a relevant guide to comprehend the evaluations of organizational dynamics in both qualitative and quantitative terms [16]. SNA is defined as the mapping and measurement of linkages and flows between information processing units. While it was first primarily used to investigate individual and social group structures and behaviors, it is now utilized in more complicated sectors such as the economy, commerce, health and banking [17].

The more frequently type of SNA used is the 'one-more networks', which nodes are on the same aggregate level as each other: For example, they may be all persons, all organizations, or all countries. On the other hand, there is also the so-called 'bipartite network' or 'bipartite graph' that could have two sets of nodes at different levels of aggregation, and ties indicate membership or participation by members of one set in the other. For example, individuals (a set of nodes) have ties to each organization (another set of nodes) to which they belong [18].

D. Related Works

Research on Social Network Analytics (SNA) itself has been widely conducted; each studies have their respective goals. The following relates to the research topic raised:

Related to the methodology. Wang et al [4] uses SNA to adequately analyze dynamic changes in stakeholders and their relationships. The work breakdown structure (WBS) was used in the first step. WBS used to organize a single project into 4 levels, namely project name, stage, process, and activity. Second step, identify the stakeholders via interview and survey, followed by forming a social network based on information obtained. Discovery of the SNA provide network-level (network size-density-diameter, average degree, clustering coefficient) and node-level (degree-betweenness-closeness centrality) insight. Xiang et al [5] highlighting the issue that, despite improvements in information sharing, not every stakeholder has sufficient understanding or passion for it. They stated that a realistic collaboration-driven mode centered on information sharing can help smart industrial parks flourish sustainably, then use the SNA to recognize cooperation promoters. Survey questionnaires were given to a number of experts in smart industrial parks in order to identify promoters and promoted items in the cooperative process. They were given a five-point scale to use in their replies. In the Technical Integrity Management System (TIMS) development process, Rachman and Ratnayake [6] use SNA as a technique to visualize knowledge and information flow. The questionnaire is used to collect network data and learn about respondents' connections to others, especially when the actors are people. The whole network method necessitates the collection of data on all the relationships in a population of actors within the organization in consideration.

Specifically on the treatment of the role, Issac and Thomas [7] using SNA finds that a holistic information exchange network for the whole set of research academics is built, and the network's and departments' centrality aspects are studied, resulting to a road map that considers who to placate and who to avoid. The publication by Kasztler and Leitner [8] outlines the SNA approach and its ability to discover IC value drivers. The links between various critical success variables and organizational outcomes are thus shown as a graph, and their interactions are studied using specialized SNA indicators in order to determine optimal IC control elements.

III. Methodology

Compiled based on previous related work, the research methodology used for this study is as shown in Fig. 1.

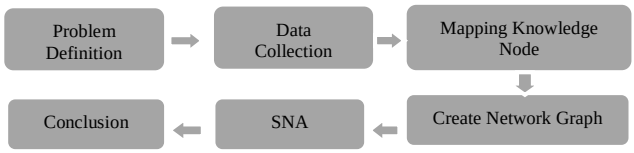

Fig. 1. Research process

1) Problem Definition: The initial stage is to analyze the gap between problems and expectations related to knowledge management in the IT department of KLG. KM starts from knowledge capture. But the question that needs to be answered before making knowledge management model or/and strategy, which is raised to be a research

question, is what knowledge needs to be captured, who plays and has an interest in that knowledge, and how important they are in the network.

2) Data Collection: The main data was obtained through study of KLG's internal documents, interview, for then coupled with questionnaire to IT department employees as they represent nodes that are the subject of this research. Literature review carried out throughout the study to find best practices based on similar research.

3) Mapping Knowledge Node: Data that has been obtained will be mapped using spreadsheet application. The result of this mapping is actors and knowledge nodes.

4) Create Network Graph: Networks will be created based on the nodes and their connection. The tool used for this stage is Cytoscape. Cytoscape is a software platform that allows us to visualize networks, integrate them with any type of attribute data, and perform analysis. Cytoscape applicated for a wide range of issue fields, including bioinformatics, social network analysis, and semantic web.

5) Social Network Analysis: The results of the network graph will be analyzed to understand the current pattern of communication and its potential.

6) Conclusion: The final stage will explain the conclusion from the results of the analysis.

IV. Analysis and Result

As mentioned in the previous section, first, we performed social network analysis to understand the network patterns of knowledge exchange in KLG. This is done by identifying the nodes that play a role in the transaction, for then identifying possible relationships between nodes. Second, using the same node, we perform more specific approach with bipartite network analysis to emphasizing relationships between nodes to the type of knowledge it can contribute.

A. Data Collection

Data collection methodology is done through interview, document studies and questionnaires. The interview was conducted with the project lead of the new repository to clarify the problem statement of current needs, identifying types of knowledge that are important to the company, also node and their relationships according to the interviewee perspective. Internal document used to dig up the truth of the information, especially the types of knowledge and potential node. Finally, questionnaires are distributed to employees who are considered nodes based on their role in the company to confirm their communication patterns at work.

As for the types of considered important knowledge for the organization that have been identified, namely:

1) ***IT Strategy and Planning****:* Short and long term IT Strategic Plan in line with company-wide strategy, which comprise of, at min, IT Vision Mission, IT Architecture, Strategic IT Initiatives and Implementation Roadmap.

2) ***IT Risk, Security and Compliance (RSC)***: Associated with security policies and processes to provide quality assurance and control.

3) ***IT Business Integration and Development Maintenance***: All knowledge related to the process of developing and maintaining IT applications.

4) ***Sharing Knowledge***: All knowledge in the form of discussion activities, presentations, tutors, and others.

5) ***IT Data and Analytics***: Data analysis results and reports used in IT operations, management, and strategies.

6) ***IT Support***: All knowledge related to activities of providing application support and maintenance.

7) ***IT Training***: All knowledge in the form of training programs and continuous learning for all IT teams.

The nodes, the actors—individuals, groups, or things—that make up the network [19], divided into two, the main contributors in defining IT knowledge is internal IT and the contributors from a non-IT point of view are from the business side. Node from internal IT in KLG, consist of:

1) ***Functional Analyst (FA):*** To fulfill user need within the scope of application development, FA connects the users and the technical teams. Analyzing and evaluate processes within a corporation, designing solutions for the problem gaps, up until release oversees the functional realization of the product while continuously updating the documentation.

2) ***Project Manager (PM)****:* In charge of planning and controlling within the project scope. Ensure project delivery on time, within budget, and achieving the expected goals.

3) ***IT Operation & Support****:* Monitoring, daily checks, minor repairs/changes, minor application upgrades/patches for specialists, and preventive maintenance. In addition, it provides tier 1 support for physical infrastructure and environments and end-user computing environments for all enterprise functions and Business Unit.

4) ***Developer***: Translate the FA design into an application product. Particularly in KLG, developers are heavily involved in architectural design to provide technical information and suggestions.

5) ***Data Management****:* Ensure data quality and governance. Coordinate with business heads/users regarding the need for data availability and reprocessing.

6) ***Network****:* Develop and maintain the IT network topology document. Establishing, developing, and maintaining computer networks between organizations, including the network equipment.

7) ***Data Center****:* Develop and overseeing the data center architecture, topology and operation. Fix any issue related, also, perform disaster recovery operations and record backups (cooperate with network and/or hardware/system admin team) when required.

8) ***Hardware****:* Installing and upgrading computer components and software, managing virtual servers, and integrating automated processes are all tasks that need to be completed. Provide documentation and technical specifications to IT staff for planning and implementing new or upgrades of IT infrastructure.

9) ***IT Managerial****:* Responsible to formulate, maintaining, and executing short and long-term IT Strategic Plan in line with the company-wide strategy. Ensure effective IT organization, people development, and performance management of IT Teams and adapt to an agile and iterative team environment.

10) ***Risk, Security and Compliance (RSC)***: Manage the department's security and compliance policies and provide guidance on their use.

Node from business side in KLG, consist:

1) ***Business Process Improvement (BPI):*** Have the authority to redesign the process, associated with their responsibility to continuously analyzing business procedures in order to find areas where accuracy, effectiveness, and/or efficiency can be improved.

2) ***Product Owner****:* Responsible to maximize the business outcomes of the product.

3) ***Board of Director:*** Secure success by directing the company's activities collectively while addressing the needs of its shareholders and other important stakeholders.

4) ***Risk Management:*** In charge of planning, organizing, leading, and controlling the organization's activities to minimize the company's revenue risk**.**

5) ***Business User:*** It could be anyone from business side who has direct interest/involvement with certain IT products or services, e.g. salesforce, technicians, etc.

Paths or edges between nodes, first, described through the externalization of the interviewee's insight and then refined through the results of the questionnaire. As seen on Table I the network questions asked to the participants include Node In-Degree (NIN) and Node Out-Degree (NOUT) to shows which nodes communicate with them and in what direction.

TABLE I. NETWORK AND PSYCHOMETRIC QUESTIONS

Network Questions		
Code	Questions	Networks
NIN	Who do you usually refer (e.g., seek/improve solutions, get referrals or confirmations, quote policies) about work?	Work communication network
NOUT	Who usually comes to you or contacts you (e.g., to seek/improve solutions, change requirements, and change business processes) about work?	Work communication network
Psychometric Question		
Code	Question	Scale
PKTN	How much do you need this type of knowledge?	No" to "Need" 5 points
PKTC	From this type of knowledge that you can potentially contribute?	"Unlikely" to "Potential" 5 points

The questionnaire also asked psychometric questions, namely Psychometric Knowledge in Terms of Needs (PKTN) and Psychometric Knowledge in Terms of Contribution (PKTC) to see other node levels of influence to their work, communication frequency, and their potential contribution in particular knowledge type.

Table II shows the demographics of the respondents who filled out the questionnaire. There are two subjects, namely "Node Representative" which is the number of people who represent each node, and "Length of Work" which the number of people based on the length of work at KLG. The questionnaire data collected on 28-31 May 2021 came from 27 respondents out of 174 total employees of the KLG IT department, which means 15.5% data sample.

TABLE II. QUESTIONNAIRE DEMOGRAPHICS

Subject	**Parameter**	**Qty**
Node Representative	FA	5
	PM	2
	IT Ops & Support	1
	Developer	10
	Data Management	2
	Network	1
	Data Center	1
	Hardware	3
	IT Managerial	1
	RSC	1
Length of Work	=< 1 year	8
	=< 5 year	13
	=< 10 year	4
	> 10 years	2

B. SNA: Between Actor Nodes

The fifteen nodes identified in previous stage are described in terms of their directed connectivity as seen on Fig. 2 using a visualization and social network analysis tool called Cytoscape. There are total 218 edges, whose details of their relationship as a network can be seen more precisely in Table III. It should be noted that this network focuses on the point of view of the IT department, so that the involvement of the business side is also seen from that point of view.

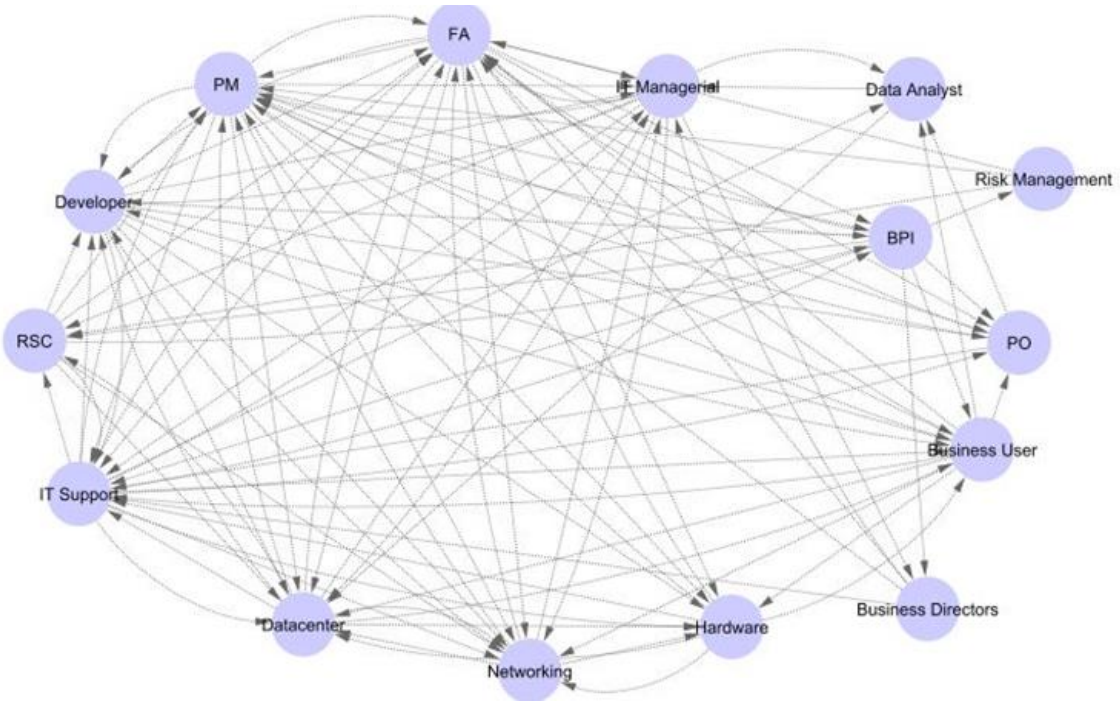

Fig. 2. KLG IT department social network graph

TABLE III. KLG IT DEPARTMENT SOCIAL NETWORK FINDING

Node	In-degree	Out-degree	Edge Count	Average Shortest Path Length	Betweenness Centrality	Closeness Centrality	Clustering Coefficient	Eccentricity	Neighbourhood Connectivity	Partner Of Multi Edged Node Pairs	Stress
FA	13	10	23	1.285714	1.099369	0.777778	0.512821	2	8.923077	10	796
PM	13	10	23	1.285714	1.099369	0.777778	0.512821	2	8.923077	10	796
IT Ops & Support	11	12	23	1.142857	1.036915	0.875	0.525641	2	9	10	696
Developer	8	10	18	1.285714	0.237399	0.777778	0.681818	2	9.909091	7	236
Data Management	4	2	6	2.142857	0.060368	0.466667	0.65	4	9.8	1	64
Network	9	6	15	1.642857	0.066151	0.608696	0.819444	3	10.55556	6	81
Data Center	10	9	19	1.428571	0.363922	0.7	0.666667	3	9.9	9	262
Hardware	7	6	13	1.714286	0.012088	0.583333	0.952381	3	11.28571	6	12
IT Managerial	8	9	17	1.428571	0.625852	0.7	0.583333	3	9.777778	8	478
RSC	5	7	12	1.5	0.245421	0.666667	0.708333	2	10.11111	3	190
BPI	5	8	13	1.428571	0.750827	0.7	0.541667	2	9.444444	4	531
PO	6	4	10	1.857143	0.048077	0.538462	0.714286	3	10.57143	3	48
Business Directors	2	4	6	1.785714	0.01511	0.56	0.9	3	11.4	1	11
Business User	7	9	16	1.5	0.163309	0.666667	0.644444	3	9.7	6	135
Risk Management	1	3	4	1.928571	0	0.518519	0.833333	3	11	0	0

The first thing that can be seen is the identical results obtained for the Functional Analyst (FA) and Project Manager (PM) nodes. This was to be expected, quoted from the interview, the source said “Here, FA are often double as PM, so the other teams it works with may have difficulty distinguishing the two”. Facts on the ground, in some projects FA and PM can be 2 different people, but often the functions are assigned to the same person. In the questionnaire, the representative nodes are more familiar with FA, although those who have experience working with these 2 types of nodes still show that FA and PM have a similar connection.

The importance of a node in a network may be determined by its in and out degree centrality [20]. In-degree measures number of other nodes that have received support from the node, in reverse, out-degree measures the number of other nodes the node has endorsed [21]. FA and PM are the most prestigious nodes characterized by the largest in-degree value (13), followed in sequence by IT Ops & Support (11), Data Center (10), Network (9), Developer and Managerial (8), Hardware (7) RSC (5) and Data Management (4). Regarding the opposite direction, IT Ops & Support are the most gregarious in work node characterized by the largest out-degree value (12), followed in sequence by FA, PM and developer (10), Data Center and Managerial (9), RSC (7), Network and Hardware (6) and Data Management (2).

Although popularity is significant, it is not the only factor to consider. Betweenness centrality is a metric that represents a different kind of significance: the extent to which a given vertex is located on the shortest pathways connecting other vertices [21]. Another way to think about centrality is the importance of nodes in linking other nodes. In other words, the absence of nodes with high betweenness centrality would break apart the network. From the findings, it can be seen that for the case of the KLG IT department, the nodes with the largest betweenness are aligned with nodes with relatively many degrees namely FA, PM and IT Ops & Support. Even so, Hardware with a rather decent degree, not as little as Data Management, turns out to have the smallest betweenness. This means that other nodes do not have a high communication dependency [20] on Hardware node.

Then to measure of reach, is the speed with which information can reach other nodes from a given starting node use closeness centrality. IT Ops & Support followed by FA, PM and developer being the fastest, Managerial and Data Center, RSC and Network, only then only then by Hardware and Data Management. Why Data Management is the last one in this matter can also be seen through its average shortest path length value. Its average shortest path length value is 2, bigger than other nodes. Another way to measure reach or distance, arguably as a much simpler notion than closeness [22], is eccentricity. The eccentricity result also finds Data Management as the farthest.

It's also useful to consider how a network develops over time, concept called triadic closure saying “If two people in a social network have a colleague in common, there's a good chance they'll become acquaintances at some time in the future” [23]. This pattern is actually seen in the detailed results of the questionnaire where representatives who work longer generally communicate with a greater variety of nodes. Using triadic closure simple measure, clustering coefficient define probability of two randomly selected friends of the node are friends with each other. The results of this measurement can also be seen in Table 3.

Finally, the stress centrality measures the amount of communication that passes an element in an all-to-all scenario. The highest score is on FA and PM, then IT Ops & Support and IT Managerial followed by Data Center, Developer, RSC, Network, Data Management and the smallest is Hardware. High stress number does not always suggest that the node is vital for sustaining the connection between nodes whose pathways pass through it. It is possible for two nodes to be connected by alternative shortest pathways that do not pass through the node. When contrasted to the graph's average stress value, which is produced by averaging the stress values of all nodes in the graph, high and low values are more relevant [24].

C. SNA: Bipartite Graph

Bipartite network links occur only between nodes of different kinds, not between nodes of the same kind (e.g. people related to other people) [25], [26] as in prior SNA. In fact, many complex networks are made of real-world data structured in a bipartite manner [27]. Especially in this case, it is used to describe the relationship between the people/actor node and the knowledge type node in relation to the possibility of being a producer and the need as a consumer. The graph is divided into two, based on the direction.

Fig. 3 shows potential contributors, concentrated on actor node out-degree. The number of knowledge types that the actor/contributor node can contribute can be seen in Table IV. Fig. 4 shows who the knowledge recipients are specific by the type. Unexpectedly, turns out that the results show that all nodes think they need all of these knowledge types.

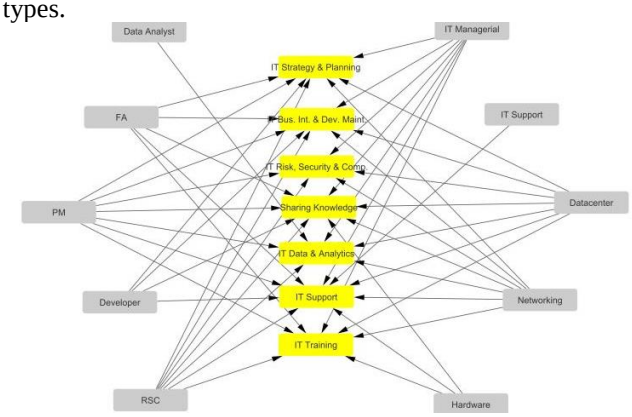

Fig. 3. Knowledge-contributor relationship graph

TABLE IV. KNOWLEDGE-CONTRIBUTOR RELATIONSHIP FINDING

Node	Out-degree
FA	5
PM	7
IT Ops & Support	1
Developer	4
Data Management	1
Network	7
Data Center	7
Hardware	3
IT Managerial	7
RSC	7

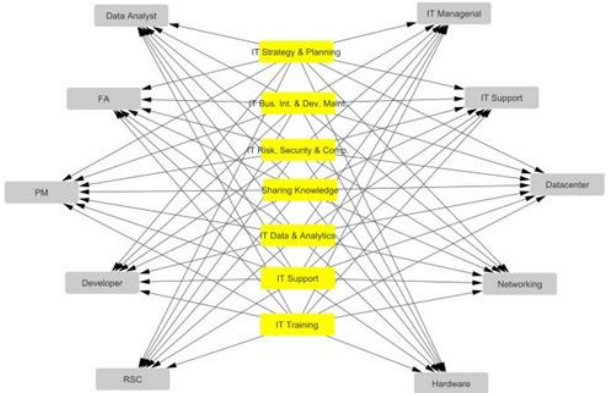

Fig 4. Knowledge-recipient relationship graph

V. CONCLUSION

The specific findings can be summarized. First, from the KLG IT department social network, FA, PM and IT Ops & Support are the most important nodes in linking to other nodes. Their absence in the network can break the communication link. In contrast, the least significant are the Hardware node, their absence does not break the chain of communication. Second, IT Ops & Support followed by FA, PM and developer node who have high closeness centrality are likely to be close to the majority of people. This indicates the individual will have a strong chance of hearing from most of their friends' friends. They will be an useful source of secondhand knowledge because it is freely accessible to them. Third, the good news are most of the nodes have high potential in generating and sharing various types of knowledge and have a great curiosity about those knowledge. Seeing this, it is predicted that the challenge for organizations is to curate the captured knowledge along with providing qualified media so the sharing and acquisition needs can be accommodated.

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