SOCIAL NETWORK ANALYSIS: A BRIEF INTRODUCTION TO SELECTED ARTICLES AND CHAPTER

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ABSTRACT

This paper aims to review 20 articles and one book chapter, which were published focusing on Social Network Analysis (SNA). This paper provides a brief introduction to SNA, which helps interested researchers in the field to get a quick guide about methods, software, key concepts, and literatures used in SNA. The reviewed articles and book chapter are selected by the course. The review finds that SNA, is multidisciplinary, provides micro-macro bridge, uses weak ties and so on.

KEYWORDS: Social Network, Social Network Analysis, Social Network Data, Review

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SOCIAL NETWORK ANALYSIS: A BRIEF INTRODUCTION

In *The Web of Human Sexual Contacts*, Fredrik Liljeros et al. (2001) explained the sexual behavior of a random sample of 4,781 respondents (although responded 2810 respondents, who were 59% of the total respondents) to explain the mathematical characteristics of a sexual-contact network. The authors analyzed the 1996 Swedish survey of sexual behavior which used questionnaires and personal interviews that were structured. The authors acknowledged that they conducted two independent investigations of non-response error, and found that aged people, especially women were underrepresented in the sample; otherwise, the sample was generalizable in all demographic dimensions. This indicates that the authors were careful to ensure the data quality and representation. The results of the study were persistent with the preferential-attachment systems of scale-free networks. The study also found the scale-free type of the association of an objectively defined, non-professional network, which showed that the 'core group' concept must be inconsistent since there were no well-defined threshold or boundary that disassociates the core group from other individuals (Liljeros et al. 2001). They claimed their results had epidemiological significance, since "epidemics arise and propagate much faster in scale-free networks" (Liljeros et al. 2001). However, we might be cautious to generalize the results of the study for the regions where people have different sexual behavior than Sweden. For example, the tendency of early marriage and high birth rate in Asian countries (e.g., India, Bangladesh etc.) indicates a difference in sexual behavior than that of Sweden.

In *The Diffusion of an Innovation among Physicians*, James Coleman et al. (1957) investigated a question: "what were the social processes which intervened between the initial trials of the drug by a few local innovators and its final use by virtually the whole medical community?" They found that a doctor would be ruled more by what his colleagues said and did in unpredictable situations, whenever and whatever they might occur, than in definitive situations (Coleman et al. 1957). They used two methods. One has considered individuals as unit of analysis, and another has considered networks or relationships among doctors as the unit of analysis. They used survey method,

set physicians of four Midwestern cities as population, took a new drug whose use was defined as spreading, defined broad enactment of the new drug by these physicians as social process. Total respondents covered 85 percent of the doctors of the regions. 'The month during each doctor first used the drug' was set as dependent variable. They applied a different approach where they set social relationships and social structures as the units of statistical analysis, and they showed how a researcher could combine sociometric techniques and survey research. At least, in this regard, this study might be considered as a huge contribution to the research of social network analysis. In the study, they provided details explanation of their methods and analysis, and established their arguments with the empirical data. They discussed both limitations and implications of the study and gave an idea of future research.

In *The Focused Organization of Social Ties*, Scott L. Feld (1981) attempted to contribute to the development of integrated theory to analyze interdependence between networks and other form of social structure. The author acknowledged that the approach was based on Homan's concepts of 'activities, interactions, and sentiments' and on the concept of extra-work foci that arrange social activities and interconnection and disagreed with arguments of Heider's balance theory because this study presented a theory which was sociological, while Heider's balance theory was essentially psychological. The author gave five basic propositions, five transitivity propositions, five bridging propositions, five personal network density propositions, and then attempted to support the theory by 1966-67 Detroit Area Study data presented by Fischer et al. (1977). He gave details explanation of the approaches to data analysis. The author discussed the implications of the theory. For example, Feld (1981) stated that focus theory might be useful to the social organization of ties among entities that do not have the ability or inclination to "think" like individuals, as for instance, social networks have been examined in science, corporations, and international relations. The author also mentioned the limitations of the study, for instance, Feld (1981) wrote, "I have emphasized causes of patterns of networks. It is equally important to understand the consequences of such patterns". The author explains very clearly the definitions, propositions, and assumptions with examples that might be considered as a significant contribution to the study of social network analysis.

In *Structure and Time-Evolution of an Internet Dating Community*, Petter Holme et al. (2004) presented 'statistics for the structure and time-evolution of a network constructed from user activity in an Internet community'. They did visualize and statistically measure their data. Clustering, mixing (degree-degree correlation), average geodesic length, degree, and reciprocity have been studied in the study. Major findings showed that the average degree combines over time, but no discontinuation in the degree distribution; reciprocity was rather low, and reciprocity levels concurred to a steady state quickly; most assortative mixing coefficients had little negative values (i.e., suggesting a pattern of disassortative mixing); the cumulative degree distributions were highly skewed. The geodesic length initially increased as new vertices were linked to the network, but as the network settled the enhancement was limited by the developing average degree; and clustering (i.e., the density of triangles) converges over time to non-zero values (Holme et al. 2004). They used all the user activity on pussokram.com that was logged on 512 days as their data, and they set the smallest time-unit on the log is 1 second. They had given details explanation of the procedure they applied for their analysis. From the social network learning perspective, this study was an iconic work, because this study used social network concepts such as degree distribution, geodesic, clustering and so on in a simple manner. The authors had efficiently chosen the network pussokram.com and used statistical methods which would increase the interest of the less interested network researchers to this field. Moreover, they gave a phenomenological description of large social network, which is a rare attempt. They also discussed the limitations of the study, and the scope of future network studies of the largest scale.

In *Class and Committees in a Norwegian Island Parish*, John Arundel Barnes (1954) examined the way of application of the social class system in a land which prided itself on its confirmation of social equality in an island parish named Bremnes- part of Norway and partly dependent on industry. He defined Bremnes as an intermediate society in terms of networks of primitive and modern society. He used network as a tool for the inquiry of the phenomenon of social class: “as a network of relations between pairs of persons according each other approximately equal status” (Barnes 1954: 45). He discussed a model of a class system which was formed by a cumulative process. For example, “if A was below B and B was below D, A might think that D was too far above him to be treated as an equal and vice-versa” (Barnes 1954: 45). He said that in Bremnes society “there is a network of social ties between pairs of persons arising from considerations of kinship, friendship and acquaintance” (Barnes 1954: 48). He questioned, ‘How does this network work?’ He answered himself by referencing in the similar way a marine-engine factory was coordinated, “while fishing, men are no longer equals, they are organized in chains of command and differentiated according to function” (Barnes 1954: 49). Discussing broad historical perspectives of Denmark, Norway, and Sweden, he made an explanation how the networks of Bremnes were linked to the broader society and the trends of historical events. Thus he concluded that whatever social system a society had in the past, some kind of class society developed with the growth of industrialization; or the developing societies might at least be discussed partly in the defective vocabulary of social class, and the process of industrialization had also begun in Bremnes which might be predominantly susceptible for such groupings for a class system as discussed in the article.

In *Collective Dynamics of ‘Small-World Networks*, Duncan J. Watts and Steven H. Strogatz (1998) introduced ‘small-world networks’. They gave an example of the ‘collaboration graph of film actors’ or the ‘power grid of the western United States’ as ‘small-world networks’. With this exploration, they changed the ordinary idea that the connection topology was predicted to be either completely regular or completely random, rather they argued that many technological, biological, and social networks lied around these two extremes. Due to the nature of small-world networks, they argued, “infectious diseases spread more easily in small-world networks than in regular lattices” (Watts and Strogatz 1998: 440). They did robustness check. They used the idea of path length ($L(p)$) which measures the common separation between two vertices in the graph (a global property) and clustering coefficient ($C(p)$) which examined the cliquishness of a common neighborhood (a local property). They also investigated the functional significance of small-world connectivity for dynamical systems where they tested the transmission of an infectious disease.

In *Information Dynamics Shape the Sexual Networks of Internet-Mediated Prostitution*, Luis E.C. Rocha et al. (2010) examined the noted sexual contracts between 6,624 anonymous escorts as well as 10,106 sex buyers extracted from an online community from its starting and next six years. They discussed about validity of the data, and carefully collected data to ensure the quality of data. For instance, they mentioned “The quantitative conclusions would also tolerate systematic levels of error—if the real-life sex buyers have, say, 1.5 nicknames and report 30% more encounters on average, but that these levels are fairly stable across the sampling time and location, then the qualitative conclusions would not be affected” (Rocha et al. 2010: 5707). They gave detailed explanation of methods as well as theoretical point of views and plotted key findings in a meaningful way. For example, they clearly mentioned, “o gets an accumulated score, we assigned numerical scores as follows: -1 for ‘bad’ encounter, 0 for ‘neutral’ and p1 for ‘good’. Then we considered the average value of these scores GT from the beginning of the dataset to time T. We tested our assumption that this average score is correlated with the sex worker’s ability to acquire new customers in Fig. 1B. For a given time T $1/4$ $T/2$ $1/4$ 1; 116 days, the number of community members posting about a specific sex worker increases by GT (Fig. 1B)” (Rocha et al.

2010: 5707). They measured diameter of giant component, average distance, assortativity, standard error, etc. They found very significant findings in their study. They concluded that internet-mediated prostitution is an experience shaped both offline and online, although the feedback effected from communication between buyers were more marked in internet-mediated prostitution than it might be offline.

In *Meso-Level Networks and The Diffusion of Social Movements: The Case of the Swedish Social Democratic Party*, Peter Hedstrom et al. (2000) analyzed the developmental years of the Social Democratic Party and how it dispersed across Sweden. They introduced the notion of a meso-level network in their study. Imitation or persuasion were the types of mechanisms they considered for their analysis. They explained how their network was a meso-level network. They stated that meso-level network was a low-density network with edges uniting long sociometric and geographical distances, and these edges was developed by a different causal process than the edges of the interpersonal micro level network (Hedstrom et al. 2000: 153). They used a computational model and hypotheses. During 1894 and 1940, they collected data of local social democratic organization in Sweden and the jurisdictional district “harad” was the unit of analysis. They also used demographic data from the population census of 1890, 1900, 1910, and 1920. They used dummy variable showing if the district was a town or not. They applied a discrete-time history approach. They also changed the units from 365 districts to 4566 district-years as a requirement for the model. They applied a simulation model to indicate the potential significance of the meso-level network for the diffusion of the Social Democratic Party, and their explanation implied that the meso-level network had an extensive effect on both the pattern and the speed at which the Social Democratic party distributed through Sweden.

The classic work of Stanley Milgram (1967) on *The Small-World Problem* had brought some important ideas of small-world network. He said that two philosophical perspectives of the small-world problem are important: (1) “the first group thought that any two people in the world, no matter how remote from each other, could be linked in terms of intermediate acquaintances, and that the number of such intermediate links was relatively small, (2) the second group thought that there were unbridgeable gaps between various groups and that therefore, given any two people in the world, they would never link up...” (Milgram 1967: 63). He critically explained Pool-Kochen theory and claimed that “if you could think of the American population as simply 200 million points, each with 500 random connections, the model would work. But the contours of social structure made this a perilous assumption, for society was not built on random connections among persons but tends to be fragmented into social classes and cliques” (Milgram 1967: 63). He was later assigned to prove whether the mathematical approach of Pool and Kochen could be solved by a more direct experimental approach. Thus, after his own study- known as Kansas study, and Nebraska study- he found that on average five intermediaries are essential to satisfy linking any two randomly chosen individuals, regardless of where they live in the United States. Milgram, in collaboration with Charles Korte, applied the small-world method to the study of communications between subgroups in American society-Negro and White. In that study, they wanted to identify the persons who serve as links between Negro and White groups. He said that “if two persons from two different populations could not make contract, then no one within the entire population in which each was embedded could make contact with any person in the other population” (Milgram 1967: 67). The study opened an important research gap for sociological research as he said, “it reveals a potential communication structure whose sociological characteristics have yet to be exposed” (Milgram 1967: 67).

In *Social Sensing for Epidemiological Behavior Change*, Anmol Madan et al. (2010) proposed an application of ubiquitous computing. They applied mobile phone-based co-location and communication sensing to examine distinctive behavior changes in symptomatic individuals, echoed in their total communication, interactions corresponding time of day, diversity and entropy of face-to-face interactions and movement. They finally examined the materialistic information flux and implicit causality between physical symptoms, mental health and behavior. Their experimental location was the place of an undergraduate hall for two months, from February to April 2009. They conducted survey every day for the symptoms of contagious diseases like common influenza and colds. They developed a signal processing approach to elucidate the temporal information flux between behavior changes, physical symptoms, and mental health symptoms, although the authors did not discuss much about the reliability and validity of the approach. They collected social interaction data from mobile phones via SMS logs, data records, WLAN-based location sensing and Bluetooth co-location sensing. In addition, using a daily-self report survey instrument they collected symptom data. They maintained the privacy of the data. They also did a pre-study baseline survey before their original data collection. They attempted to maintain the data quality; thus, they screened a total of 2,994 surveys responses and finally taken 2,283 after following several steps. In order to analyze data, they used the Phase Slope Index (PSI) method. The authors discussed the limitations of their work, and they acknowledged that they did not account for confounding factors. They discussed about the policy implications and future scope of study in the field. Finally, they concluded that information to determine the health status of individuals using information gathered by mobile phones alone can determine the health status, without having definite health measurements about the subject (Madan et al. 2010).

In *Social Structure and Competition in Interfirm Networks: the Paradox of Embeddedness*, Brian Uzzi (1997) developed a systematic realization of embeddedness and organization networks. He applied ethnographic fieldwork to collect data from 23 entrepreneurial firms. His study focused on the concept of structural embeddedness. He gave a detailed description of his methodology. He followed grounded theory for data collection and analysis. He conducted in-depth interviews which were open-ended, conducted for two to six hours, performed over a five-month period. Two pilot interviews were also taken. Interfirm relationship was considered as unit of analysis. In addition, he focused on gaining construct validity and took initiative to minimize response bias. He found that embeddedness was a rationale of exchange that promoted economics of time, integrative agreements, Pareto progress in allocative capability, and complex adaptation. He proposed a framework that explained how these properties varied with the coordination of social ties, the formation of the organization network, and an organization's structural situation in the network (Uzzi 1997). Moreover, he argued that fixed ties primarily developed out of mediator referral networks and earlier personal relations. In these cases, one actor with a fixed tie to two disconnected actors acts as their "go-between". He added, "the level of embeddedness in a network increased with the density of embedded ties". On the basis of the study observation, he made propositions, although he left the testing and refinement tasks for future research. He discussed the implication of the findings. For example, he stated that "embeddedness was a unique logic of exchange that results from the distinct social structure of organization networks and the micro-behavioral decision-making processes they promoted". The study visualized the networks and used the properties of social networks for the analysis. For example, he argued that "atomistic relations occupied a confined area of economic life and that the critical transactions on which firms depended most were embedded in networks of social relationships that produced positive and unique outcomes that were difficult to imitate via other means". This study also discussed the limitations of the study, for example, the author said that he did only focus on the "concept of structural embeddedness", and "neglected other types of embeddedness that affected organizations, including cognitive, institutional

and so on”.

Barry Wellman (1988), in a chapter titled *Structural Analysis: from Method and Metaphor to Theory and Substance*, described the progress, differentiating characteristics, and inquiring principles of structural analysis. He argued that structural (or network) analysis has developed as a “distinctive form of social inquiry having five paradigmatic characteristics that gave its underlying intellectual unity”. He discussed two research trends: (1) “the (mostly British) anthropological development of the social network concept, and (2) the (mostly American) increase in quantitative analysis and substantive scope”. The first tradition at first saw the network as just a concept, then they started to promote basic quantitative measures of properties such as density to discuss the form of social networks, after that with progress, they gradually expanded it as an approach. The second tradition focused on the questions of network form. He added to the description of this tradition that examiner of “both whole and egocentric networks had been concerned with the effects of network properties on the integration of large scale social systems, in particular, they studied: (a) the conditions under which triads of ties concatenated to form larger networks” (Davis and Leinhardt, 1972; Davis, 1979; Holland and Leinhardt, 1977); (b) “the addition of new members to networks through ramifying ties” (Rapoport, 1979); (c) “the likelihood of network ties between members of large-scale social systems” (Milgram, 1967); (d) “the impact of interpersonal network characteristics on the integration of large-scale social systems” (Granovetter, 1973, 1982) (Wellman 1988). He described the distinguishing characteristics of structural analysis, for example, he stated that the world was composed of networks, not groups. He explained six analytic principles of structural analysis. For instance, he said ties were “usually asymmetrically reciprocal, differing in content and intensity” (Wellman, 1988). Overall, this chapter consists of a critical discussion of different important perspectives of structural (network) analysis.

In *Economic Action and Social Structure: The Problem of Embeddedness*, Mark Granovetter (1985) raised a classic question of social theory: how institutions and behavior are influenced by social relations? Thus, he examined “the extent to which economic action was embedded in structures of social relations in modern industrial society”. Considering the key debates of under-and over socialized accounts as well as account of economic action, he travelled back and forth across the literature and debates to find his answer. In the economic literature, he found “fundamental answers to the problem” and claimed that “one is linked to an under socialized, and the other to an over socialized, conception of human action” (Granovetter 1985). The author showed an insight of network analysis for solving problems that had been hunted by social scientists from long past. However, the author did not discuss much about his methods of inquiry. In addition, he could show enough empirical findings in support of his argument, although he referred many previous literatures to prove his arguments. For example, he argued that “social relations were mainly responsible for the production of trust in economic life” (Granovetter 1985), but he did not provide enough empirical findings or network data in support of his argument. If he could provide some visual examples of social structure (or network), it would be more interesting. Finally, through this article, he generated an argument that most behavior (he concentrated on economic behavior) was “closely embedded in networks of interpersonal relations and that such an argument avoided the extremes of under-and over socialized views of human action” (Granovetter 1985).

In *Emergence of Scaling in Random Networks*, Albert-Laszlo Barabasi and Reka Albert (1999) have attempted to prove their argument “the development of large networks is governed by robust self-organizing phenomena that go beyond the particulars of the individual systems”. In other words, they showed the vertex connectivity “follow a scale-free power-law distribution”. They provided real world examples and visualized data in support of their argument. As an example of

social network, they stated the “collaboration graph of movie actors where each actor was represented by a vertex, two actors were being connected if they were cast together in the same movie”. They also showed the use of power-law scaling with this example. They also gave the examples of “WWW, electric power grid of the Western United States, and citation patterns of the scientific publications” in their description. With the examples of these networks, they argued that “many large random networks share the common feature that the distribution of their local connectivity was free of scale, following a power law for large k with an exponent γ between 2.1 and 4, which is unexpected within the framework of the existing network models”. They argued that “the power-law tail, unlike Erdos-Renyi (ER) model and Watts and Strogatz (WS) that claimed vertices with large connectivity were practically absent, characterizing $P(k)$ for the networks studied indicated that highly connected (large k) vertices had a large chance of occurring and dominating the connectivity” (Barabasi and Albert 1999). Moreover, they argued that, unlike the assumption of ER model and WS model, the “number of vertices N increased throughout the lifetime of the network”. In addition, they showed that most real networks exhibited preferential connectivity. They also proved by an example that the “absence of preferential attachment eliminates the scale-free feature of the distribution, and both ingredients- growth and preferential attachment- were needed for the development of the stationary power-law”. Since the “growth and preferential attachment were mechanisms common to a number of complex systems including social networks” (Barabasi and Albert 1999), this study might be considered as an important contribution to the field of social network analysis.

In *How People Interact in Evolving Online Affiliation Networks*, Lazaros K Gallos et al. (2012) investigated the “formation and evolution of networks by monitoring the addition of all new links”, and they also explained “quantitatively the tendencies used to create ties in these evolving online affiliation networks”. They found “significant differences in behavioral traits in the social tendencies among individuals according to their degree of activity, gender, age, popularity, and other attributes”. They also found that “women reciprocated connections three times as much as men and that this difference increased with age, and men tended to connect with the most popular people more often than women do, across all ages” (Gallos et al. 2012). This study visualized the data and did statistical analysis. Using a longitudinal analysis and selecting pussokram.com and qx.se as the cases they conducted the study. They recorded the activity for 512 consecutive days, and at the end of the data collection, the community had 28,876 members. This study was also important since it observed “Nordic region’s largest and most active web community of homosexual, bisexual, and transgender people”. A detailed and clear description of the methods of the study had been provided. The authors discussed the limitations of the study. Implication of the study and the scope of future studies in the field had been clearly mentioned. The authors suggested to be cautious to generalize the “results to establish generic trends based on gender, age etc. as it would require an extensive study of a large number of social networking sites under different settings”. From the social network learning perspective, this study might be considered as model research work in the field.

In *Social Structural Determinants of Similarity among Associates*, Scott L. Feld (1982) demonstrated “how the social structuring of activity leads people to develop relationships with others who are similar to themselves”. He conducted sample survey and a study of friendships in one large factory to support his arguments. He presented a “theory of focused choice” which had emphasized the “precedence of foci as social structures”. According to focused choice view, “individuals had little choice in becoming associated with certain foci (e.g., their families), and whatever the basis of their initial association with a focus, it might be difficult, costly, and time-consuming to disassociate from the focus and/or become associated with others” (Feld 1982). This paper used the Fischer Northern California Data (Fischer 1982) and the James Woolens Factory Data (James 1951). Although this paper discussed about the scope of future research in the field, it

did not discuss about its limitations. This paper found that there was age homophily. Another important finding of this study was that “social structure alone” could not analyze homophily, since “variations in the homogeneity of focused sets could have large effects on variations in homophily”. Finally, this paper recommended that the oversight of structural factors had caused the inaccuracy of the extent to which people “prefer” to accomplice with similar others (Feld 1982).

In *Structural Holes and Good Ideas*, Ronald S. Burt (2004) argued that “opinion and behavior were more homogeneous within than between groups, so people connected across groups who were more familiar with alternative ways of thinking and behaving, which gave them more options to select and synthesize”. He assumed that “people who stand near the holes in a social structure were at higher risk of having good ideas”. He showed how interesting ideas were related to structural holes. He stated that ideas came “over a variety of paths from a variety of sources” (e.g., Von Hippel 1988), but idea generation at some point involved someone moving knowledge from this group to that or combining bits of knowledge across groups (Burt 2004). This study used the personnel records of managers as a background data. He collected network data by the standard survey method (using web-based questionnaire) of name generators and interpreters. He used “background and performance data on all 673 managers” in the study. The survey provided “5,010 observations of 4,139 relationships distinguishing five levels of connection between two people”. The study used network constraint to measure brokerage where size, density, and hierarchy were the analytic tools. He visualized the network data and explained details in support of his argument. The author mentioned the implication of the findings. He concluded that according to the hypothesis good ideas emerged in the organization. He also found that a “brokerage advantage in idea production, and company systems were working correctly to reward brokers who produced good ideas”.

In *Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance*, Roger Guimera et al. (2005) proposed “a model for the self-assembly of creative teams”. The model proposed that the “emergence of a large connected community of practitioners could be explained as a phase transition”. The study found that “team assembly mechanisms determined both the structure of the collaboration network and team performance for teams derived from both artistic and scientific fields” (Guimera et al. 2005). They used data from both artistic and scientific fields. They visualized their networks and statistically analyzed the data in support of their arguments. They provided detailed explanation of the study procedure and analysis. Although they mentioned (briefly) the limitations of the study, they did not clearly discuss about the implication of the findings in future research.

In *The Strength of Weak Ties*, Mark S. Granovetter (1973) focused on the cohesive power of weak ties. This focus on weak ties opened the door of “discussion of relations between groups and to analysis of segments of social structure” which was not readily defined from the point of view of primary groups, wrote Granovetter (1973) in the article. He argued that “the analysis of processes in interpersonal networks provided the most effective micro-macro bridge”. He claimed that weak ties were important because “weak ties were more likely to link members of different small groups than were strong ones, which tended to be concentrated within particular groups”. On the basis of qualitative analysis, he had chosen a “limited aspect of small-scale interaction” which he called the “strength of interpersonal ties” and showed “how the use of network could relate this aspect to such varied macro phenomena as diffusion, social mobility” and so on. He identified an important SNA analytic problem. For instance, he said that there was no agreement “whether ego’s network should be treated as composed only of those to whom he was tied directly, or should include the contacts of his contacts, and/or others”. One major implication of the paper was that the “personal experience of individuals was closely bound up with larger-scale aspects of social structure”.

In *Threshold Models of Collective Behavior*, Mark Granovetter's (1978) purpose of analyzing threshold models is to create mathematical procedures for examining the cohesion features of any distribution's equilibrium following various possible perturbations. By 'social structure' he meant the "influence any given person had on one's behavior might depend upon the relationship", and by 'threshold' he meant the "number or proportion of others who must make one decision before a given actor does so". This study found that "groups with similar average preferences might generate very different results". His analysis was important because he showed a way of "linking micro to macro levels of sociological theory". Moreover, the strength of the Threshold Model was that this model might be "useful in small-group settings and those with large number of actors". He said that these models could be "applied to processes not usually called "collective behavior," such as voting, residential segregation, diffusion of innovations, educational attainment, strikes, migration, and markets- as well as the more typical process of crowd behavior and social movements" (Granovetter 1978). Although the author had discussed the implications of the findings, he did not clearly mention the limitations of the study.

In *The Spread of Obesity in a Large Social Network over 32 Years*, Nicholas A. Christakis and James H. Fowler (2007) conducted a quantitative study to investigate "whether obesity might also spread from person to person", which perhaps "contributing to the epidemic, and if so, how the spread might happen". Using a longitudinal statistical model, they "evaluated a densely interconnected social network of 12,067 people approached repeatedly from 1971 to 2003 as part of the Framingham Heart Study". The study defined "obesity as body-mass index". The authors had graphed the network using Pajek software and used longitudinal logistic-regression models as a tool of basic statistical analysis. This feature indicates that this study is an important work for the learners of social network analysis who want to use both Pajek software and statistical analysis for their own study because this study described the procedures and visualized the networks very efficiently. After the study, the authors found that a respondent's "chances of becoming obese increased by 57% if he/she had a friend who became obese in a given interval. Among pairs of adult siblings, if one sibling became obese, the chance that the other would become obese increased by 40%". In a similar pattern, the probability of becoming obese for spouse increased by 37% if another spouse became obese. However, these effects were not found "among neighbors in the immediate geographic location". Those who among same sex had comparatively greater influence on each other than those of who are among opposite sex. To mention the implications of the study, the authors stated that the "necessity of approaching obesity was not only that it was a clinical problem but also it was a public health problem".

DISCUSSION AND CONCLUSIONS

The reviewed articles and book chapter widely covered from theoretical and methodological research issues (e.g., Milgram 1967; Watts and Strogatz 1998) to empirical analysis (e.g., Liljeros et al. 2001; Holme et al. 2004) to micro-macro linkage in sociological theory (e.g., Granovetter 1978). The time of publication of the articles is also very widespread, spanning from 1957 to 2011. The articles and chapter covered diversified academic fields such as sociology, physics, mathematics, public health, political science, economics, social psychology, communication studies, etc. Sample survey, ethnographic fieldwork, and archival data were common sources of data for SNA study in the literature. Degree distribution, average distance, assortativity, clustering, power-law, preferential attachment, clique, weak ties, strong ties, structural holes, ego, alter, etc. were the common SNA concepts that were used in the studies/literatures. It is found that use of Pajek software and statistical analysis (e.g., logistic regression model) were common and popular approach for SNA data analysis and presentation. Web based social ties had been efficiently analyzed (e.g., Holme et al. 2004) using the SNA methods. Although, collecting data on sensitive issues like sexual behavior were challenging, SNA study methods and

tools might be an effective solution to this problem. However, SNA study had also been dealing with some analytic problems. For instance, Granovetter (1973) said that there was no agreement “whether ego’s network should be treated as composed only of those to whom he was tied directly, or should include the contacts of his contacts, and/or others”. ‘Most welcome’ part of all the studies were the results. From the perspective of sociological research, the most important results were the demonstration of scientific examination of social ties using SNA study methods, because understanding the patterns of social relationships (or social ties) has been a basic goal of sociologists. In addition, Granovetter (1973) argued that “the analysis of processes in interpersonal networks provided the most effective micro-macro bridge”. He claimed that weak ties were important because “weak ties were more likely to link members of different small groups than were strong ones, which tended to be concentrated within particular groups” (Granovetter 1973). Furthermore, SNA study found significant findings on the diffusion of social movements study (e.g., Hedstrom et al. 2000), the examination of internet community (e.g., Holme et al. 2003), the problem of embeddedness (e.g., Granovetter 1985), social interaction in online affiliation networks (e.g., Gallos et al. 2011) and so on. From theoretical and methodological perspectives, major findings of the SNA study include new ideas of small-world network (Milgram 1967), growth of scaling in random networks (e.g., Barabási et al. 1999), structural holes and good ideas (e.g., Burt 2004), the strength of weak ties (e.g., Granovetter 1973) and so on.

Especially new researcher in SNA field could get a quick and easy guide of literatures that might be important in their SNA study. Moreover, this paper provides key discussion regarding methods, concepts, strength and weakness of the reviewed articles and book chapter to the reader that could also be effective for them to grasp the key ideas of the literatures in SNA field.

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REFERENCES

1. Barabási, A.L., & Réka A. (1999). *Emergence of Scaling in Random Networks*. *Science* 286, 509-512.
2. Barnes, J. A. (1954). *Class and committees in a Norwegian Island Parish*. *Human Relations* 7, 39-85.
3. Burt, R.S. (2004). *Structural Holes and Good Ideas*. *American Journal of Sociology* 110(2), 349–99. Available at: <https://www.jstor.org/stable/10.1086/421787>.
4. Christakis, N.A., Fowler, & J.H. (2007). *The Spread of Obesity in a Large Social Network over 32 Years*. *The New England Journal of Medicine* 357(4), 370-379.
5. Coleman, J., Katz, E., Menzel, H. (1957). *The Diffusion of an Innovation among Physicians*. *Sociometry* 20(4), 253-270.

Available at: <https://www.jstor.org/stable/2785979>.

6. Feld, S.L. (1981). *The Focused Organization of Social Ties*. *American Journal of Sociology* 86(5), 1015-1035. Available at: <https://www.jstor.org/stable/2778746>.
7. Feld, S.L. (1982). *Social Structural Determinants of Similarity among Associates*. *American Sociological Review* 47(6), 797-801. Available at: <https://www.jstor.org/stable/2095216>.
8. Fischer, C.S., Jackson, R. M., Stueve, C. A., Gerson, K., & Jones, L. M. (1977). *Networks and Places: Social Relations in the Urban Setting*. Free Press, New York.
9. Fischer, C.S. (1982). *To Dwell among Friends: Personal Networks in Town and City*. University of Chicago Press, Chicago.
10. Gallos, L.K., Rybski, D., Liljeros, F., Havlin, S., & Makse, H.A. (2012). *How People Interact in Evolving Online Affiliation Networks*. *Physical Review X* 2, 031014-1-14. DOI: 10.1103/PhysRevX.2.031014.
11. Granovetter, M.S. (1973). *The Strength of Weak Ties*. *American Journal of Sociology* 78(6), 1360-1380.
12. Granovetter, M. (1978). *The Threshold Models of Collective Behavior*. *American Journal of Sociology* 83(6), 1420-1443. Available at: <https://www.jstor.org/stable/2778111>.
13. Granovetter, M. (1985). *Economic Action and Social Structure: The Problem of Embeddedness*. *American Journal of Sociology* 91(3), 481-510. Available at: <https://www.jstor.org/stable/2780199>.
14. Guimera, R., Uzzi, B., Spiro, J., Amaral, L.A.N. (2005). *Team assembly mechanisms determine collaboration network structure and team performance*. *Science* 308(5722), 697-702. DOI: 10.1126/science.1106340.
15. Hedström, P., Sandell R., Stern C. (2000). *Mesolevel networks and the diffusion of social movements: the case of the Swedish social democratic party*. *American Journal of Sociology* 106(1), 145-172. Available at: <https://www.jstor.org/stable/10.1086/303109>.
16. Holme, P., Edling, C.R., Liljeros, F. (2004). *Structure and time-evolution of an Internet dating community*. *Social Networks* 26(2), 155-174.
17. James, J. (1951). *Clique organization in a small industrial plant*. *Research Studies* 19, 125-30.
18. Liljeros, F., Edling, C.R., Amaral, L.A.N., & Stanley, H.E. (2001). *The web of human sexual contacts*. *Nature* 411(6840): 907-908.
19. Madan, A., Cebrián, M., Lazer, D., & Pentland, A. (2010). *Social sensing for epidemiological behavior change*. Paper presented at the UbiComp'10 - Proceedings of the 2010 ACM Conference on Ubiquitous Computing 291-300. DOI: 10.1145/1864349.1864394.
20. Milgram S. (1967). *Small-World Problem*. *Psychology Today* 1(1), 61-67.

21. Rocha L, Liljeros, F., & Holme, P. (2010). Information dynamics shape the sexual networks of Internet-mediated prostitution. *PNAS* 107, 5706-5711.
22. Uzzi, B. (1997). Social structure and competition in interfirm networks: the paradox of embeddedness. *Administrative Science Quarterly* 42 (1), 35-67. Available at: <https://www.jstor.org/stable/2393808>.
23. Watts, D., & S. Strogatz. (1998). Collective dynamics of 'small-world networks'". *Nature* 393, 440-442.
24. Wellman, B. (1988). Structural Analysis: From Method and Metaphor to Theory and Substance. In: Wellman, B., Berkowitz, S.D. (Eds.), *Social Structures: A Network Approach*. Cambridge University Press, Cambridge, pp. 19-61.