10 Social network analysis

Studying social interactions and relations in the workplace

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10.1 Background

Social networks are defined as a set of nodes (or network members) that are tied by one or more types of relations (Wasserman & Faust, 1994). For those not familiar with network research, a network is a set of actors connected by a set of ties. The actors (often called "nodes") can be persons, teams, organizations, concepts, etc. Ties connect pairs of actors and can be directed (i.e., send a message to someone) or undirected (as in being physically proximate) or valued (i.e., strong vs. weak friendship). A set of ties of a given type (such as friendship ties) constitutes a binary social relation, and each relation defines a different network (e.g., the friendship network is distinct from the advice network). Different kinds of ties are typically assumed to function differently, although empirically they might be correlated. Some typical phenomena such as small-world effect (Pool & Kochen, 1978), the strength of weak ties (Granovetter, 1983), and many others may be observed in social networks.

Social Network Analysis (SNA) is a research methodology that seeks to identify underlying patterns of social relations based on the way actors are connected with each other (Breiger, 2004; Scott & Carrington, 2011). The unit of analysis in SNA is not the individual, but the relationships or interactions that occur between members of the network. Using SNA, the social environment can be mapped as patterns of relationships among interacting members.

When applying a network perspective, SNA can be used to indicate how a certain individual is connected to others, and also indicates the cohesion of a network. There are two key indicators used in SNA: "density" and "centrality." Density provides a measure of the overall "connections" between the participants. The more participants connected to one another (by, for example, their message exchanges), the higher will be the density value of the network. While centrality indicates the extent to which an individual was connected to other actors within a network (Wasserman & Faust, 1994).

In organizational studies, SNA has been widely adopted to study group dynamics, social interaction, and communications in organizations at different levels. Borgatti and Foster (2003) conducted a review of the social network paradigm and summarized four canonical types of study based on network outcomes: structural

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social capital, social access to resources, contagion, and environmental shaping. However, although the volume of social network research in management has increased radically in recent years, SNA is not common in studies about workplace environments and their management. So far, the research that most often applies SNA methods is the ones exploring the spatial proximity effect on building occupants' social interactions (Kabo, 2017, 2018; Zhou & Hua, 2020). The goal of this chapter is to summarize the methodological approaches using SNA methods, taking spatial proximity studies as an example, and propose directions for future research.

10.2 Argument

With the recent trends of new workplace practices such as remote working coworking, an essential question that needs to be more explored is whether and how workplace spatial factors affect human social interactions and networking. However, how workplace environment affects communication and social interactions in organizations is a challenging topic as it requires an understanding of the socialization process, relations, and outcomes that could not usually be studied at the individual level. This type of study goes beyond the approach of user experience studies which are commonly based on individual users' perceptions. In order to understand social dynamics in a certain group, the appropriate method that investigates social interactions and relations ought to be applied. The central argument of this chapter is that SNA can contribute to workplace studies by adding a new perspective and analytical methods to study employees' social behavior in the workplace. SNA in this case offers a new perspective and a set of methods to collect and look into relational data, which is distinct from data or attributions focused mainly on the individual's characteristics.

10.3 Examples of application

By operationalizing spatial factors and other social relations as relational data, a group of studies have explored social interactions and group dynamics in the workplace through SNA. Taking spatial proximity as an example, proximity refers to the spatial distance between occupants and it was found to affect unplanned encounters in the workplace (Hiller et al., 1987; Peponis et al., 2007; Shpuza & Peponis, 2008). A plethora of studies has found spatial proximity affects the formation of social relationships in the workplace and other situations (Allen, 2007; Kabo, 2017; Kleinbaum et al., 2013; Mok & Wellman, 2007; Yuan & Gay, 2006). This chapter showcases examples of how to quantify spatial factors and social factors in relational data and the general process of conducting an SNA study.

10.3.1 Spatial proximity as relational data

The spatial distance between any two individuals, as a kind of relational data, is a common measure used to understand how workspace affects employees' encounters and social interactions in recent spatial proximity studies. Kabo (2018)

measured spatial distance in a concept named integration (the average spatial distance of an individual's office space relative to all other spaces) and found that, for individuals, there is a significant correlation between spatial distance and social interaction. Other types of spatial proximity measures, including dyadic physical distance and functional zone overlap, were also significantly and positively correlated with the chance of collaboration among the researchers in a research facility (Kabo et al., 2014, 2015). In an office setting, the spatial distance between any two individuals was found to be negatively and significantly related to potential face-to-face encounters. At the same time, other demographic homophily variables are non-significant (Kabo, 2017). In summary (see Table 10.1), testing the correlation between spatial distance and communication/interaction frequency at a dyadic level shows a new approach to empirically studying the spatial proximity effect on interaction.

Table 10.1 Variables and Data Analysis Methods

References	*Independent Variables*	*Dependent Variables*	*Data Analysis Methods*
Zhou and Hua, (2020)	Perceptual co-presence; Co-presence based on room access history	Friendship and advice network relations	Multiple-Regression Quadratic Assignment Procedure (MQAP) Analysis
Kabo, (2018)	Spatial layout network (integration/distance), interaction network: degree and betweenness centrality	Network collective intelligence; Prestige or status outcome	Heckman sample selection regression models; Multilevel mixed-effect passion model
Kabo, (2017)	Homophily (tenure, gender, education); structure (staff/ manager, group affiliation); proximity (office distance)	Potential encounters (co-presence in different distances)	Quadratic Assignment Procedure (QAP) Analysis
Kabo et al. (2015)	Path overlap; Physical distance between office	Collaboration index (IRB, Research proposal applications)	Zero-inflated negative binomial regression
Wineman et al. (2014)	Space layout (MetChoice; MeanDist); Degree centrality, Betweenness centrality	Innovation involvement; publications	Logistic Regression; Negative Binomial
Wineman et al. (2009)	Department affiliation; Spatial distance (based on depth map)	Co-authorship	Logit Regression
Peponis et al. (2007)	Density of interaction (interact network size & frequency)	Time spent on Productivity (one of the five categories)	Correlation analysis; Space syntax
Rashid et al. (2006)	Space layout variables: Integration, connectivity	Interaction, co-presence, movement	Correlation analysis; Space syntax

In general, spatial distance is an effective proxy for interaction in traditional workspace and arrangement, meaning when people work at an assigned desk and go to the same office every day, spending the entire workday there. However, given new and more flexible ways of working, spatial distance measure shows limitations. Suppose a worker takes a significant amount of time working remotely. In that case, the distance between the assigned office/workstation locations may not accurately reflect the chance for this individual to interact with the neighboring workers. This measure is also challenging for quantifying proximity between workers working in a shared space without assigned desks (e.g., hoteling or hot-desking policies). Because humans have the agency to move, without the help of advanced indoor location positioning systems, measuring the exact distance between occupants remains a challenge.

Instead of measuring the physical distance between the workstations, co-presence is a temporal relational concept that measures how much time any two individuals are in the same space. Hillier et al. (1987) argued that spatial layout in itself generates a field of probabilistic co-presence and encounter. The co-presence pattern has both a describable pattern and a known cause, which the author called the "virtual community" (Hillier et al., 1987). Compared to spatial distance between offices or workstations, co-presence provides another way to represent spatial proximity within a flexible working environment. It is more suitable for studying the chance of social encounters in workplace settings such as hot-desking.

Zhou and Hua (2020) explored whether the use of a shared study space played a role in shaping graduate students' social networks by studying how the co-presence in a shared space was related to the structure of friendship and advice networks. Applying SNA allows the authors to explore the detailed relational data in the whole student group, and conduct a correlational study to understand how space affects social connections in a setting that is not occupied in a fixed schedule. The authors also argued that the increasing data availability in facilities management heralds exciting possibilities for empirically modeling co-presence in small spaces. By calculating "space occupancy time overlap between the occupants," the longitudinal behavioral data obtained from various sensor records could be used to study the proximity effect in the workplace in a new spatial-temporal approach.

10.3.2 Social characteristics as relational data

Known as "birds of a feather always flocked together," homophily is the principle that contact between similar people occurs at a higher rate than among dissimilar people (McPherson et al., 2001). Social homophily as a network variable describes whether any two persons in a network share the same social characteristics such as race, gender, age, culture, group affiliation, etc. Homophily studies have dealt widely with various kinds of social relations such as marriage, friendship, advice networks, managers' instrumental networks in organizations, business relationships, job referrals, and so on (Kilduff & Tsai, 2003, p. 52).

In these studies, social homophily network is commonly constructed as a matrix with numbers of "1" or "0" to represent whether any two actors shared the same characteristics such as gender, ethnicity, or have attended the same event, etc. The goal is to use a matrix to show the similarity between any two actors regarding a specific characteristic. For data analysis, previous studies have used Quadratic Assignment Procedure (QAP) and Multiple-Regression Quadratic Assignment Procedure (MQAP) analysis to explore the correlation between matrices to understand factors (such as proximity, social homophily, etc.,) that affect network formation. In a research institution, Kegen (2013) found that there is no significant gender homophily effect but rather proximity effect on research cooperation, research support, and social acquaintance. It helps to differentiate the proximity from social homophily effect on interactions and communication patterns. In a study about the homophily of network ties in distributed teams, Yuan and Gay (2006) found that both homophily in group assignments and in location had significant impacts on the development of network ties. SNA allows a researcher to study social characteristics in a form of matrices that can be constructed through individuals' similarities or differences in social characteristics.

10.3.3 Summary of process

10.3.3.1 Identify network variables

Each research design for SNA starts with defining what kind of data and for what purpose will be gathered. The first step is to understand the main goal of the research as well as specify the independent variable or dependent variables that describe relations between actors. Besides the general research design process, researchers and practitioners need to understand relational data are unique, and not every research needs relational data. Research questions related to experiential factors such as work environment satisfaction, commonly based on an individual's experience, could be studied without including relational data. However, topics related to the number of friends, who collaborates with whom (e.g., co-authorship), and communication patterns can benefit significantly by understanding the specific network of friendship, advice, communication, etc. Besides, it is also important to understand that network ties sometimes have direction (e.g., who sends messages to whom) and value (e.g., the strength of friendship tie). While designing the survey questions, it is also important to include questions regarding the actors' and ties' specific characteristics besides questions about relations.

10.3.3.2 Selecting a proper sample

Selecting a proper sample is especially important when the data is collected using surveys, questionnaires, or observations. So far, most SNA studies in workplace research use a purposive sampling strategy and try to obtain every actor's response to construct a whole network. The researcher needs to understand that collecting

data from every actor is important, and losing data from important ones might significantly affect the study's final results. In such a situation, researchers need to make sure to have access to collect information from every actor in the network, and be aware of the limited capacity and time when it comes to collecting data. The sampling procedure and targeted sample size should be defined before the data collection will be performed.

10.3.3.3 Data collection

SNA research has identified three types of data also called units of analysis, which should be and are investigated: relations, ties (Garton et al., 1997), and actors. Many methods of obtaining network data such as questionnaires, interviews, observations, and artifacts exist (Garton et al., 1997). Wasserman and Faust's (1994) book provides comprehensive guidance regarding data collection tools and methods for SNA.

10.3.3.4 Data preparation

Network data analysis puts emphasis not on the individuals themselves but on the relationships among people. In contrast to data about individual characteristics, network data normally consists of a rectangular array of measurements. Collected data has to be represented in a way that facilitates the application of SNA methods. A widespread representation is graph or matrix, which can be done manually by extracting information from surveys, interviews, and observations or automatically using data-mining techniques for data cleaning. The goal of data preparation is to represent the collected data in the form of a network.

10.3.3.5 Applying appropriate analytical methods

Taking spatial proximity studies as an example, three types of data analysis have been explored in previous studies according to different research questions by calculating (1) the number of actors ties, (2) the correlation between network matrices, and (3) network graphs. For studies exploring how spatial factors affect individuals' social connectivity in a network, the number of ties (in networks such as friendship, advice, etc.) has been used to describe how individuals are connected to others (Tagliaro et al., 2022). Correlation analysis and regression analysis could be conducted to explore how spatial factors affect an individual's social connectivity. In some other studies, network variable is simplified as "1" or "0" to represent whether there is a relationship or not, such as co-authorship (Wineman et al., 2009, 2014). The logit regression is a common analytic method in this case.

For research that explores correlations between networks/matrices, such as how spatial proximity network is correlated with friendship network, methods like QAP and MQAP are commonly used (examples shown in Table 10.2 and Table 10.3) and they offer an opportunity to compare proximity effect with other social homophily effects such as gender and ethnicity (Kabo, 2017; Zhou & Hua, 2020). QAP

Table 10.2 Example of QAP analysis that calculates the correlation between different matrices by using quadratic assignment procedures to develop standard errors to test for the significance of association (Zhou & Hua, 2020)

	QAP correlation between networks									
	F(s)	*F(w)*	*Advice*	*Co (sur)*	*Card (s)*	*Social*	*Class*	*S-gen*	*S-nat*	*S-coh*
Friendship (strong)	1.00									
Friendship (weak)	−0.16**	1.00								
Advice	0.52**	0.17**	1.00							
Copresence (survey)	0.32**	0.20**	0.47**	1.00						
Card access (same-day)	0.23**	0.18*	0.47**	0.59**	1.00					
Social media	0.64**	0.17**	0.62**	0.40**	0.38**	1.00				
Class collaboration	0.40**	0.12*	0.37**	0.28**	0.15*	0.46**	1.00			
Same-gender	−0.04	−0.13*	–	−0.06	−0.02	0.02	–	1.00		
Same-nationality	0.13*	0.13**	0.25**	0.13**	0.22**	0.22**	0.06	−0.03	1.00	
Same-cohort	0.39**	0.03	0.23**	0.13**	−0.03	0.27**	0.15**	0.03	–	1.00

Note: ** $p < .01$; * $p < .05$.

Table 10.3 Example of MQAP analysis that shows when multiple matrices were entered into the regression to see each matrix's effect while controlling others. For example, the Model 2 (M2) for predicting Friendship (strong) relations suggests that the standardized regression coefficient for the impact of social media on strong friendship was 0.46 (p<0.01), which was significantly higher than Copresence (survey) 0.07 (p>0.05) (Zhou & Hua, 2020)

MQAP regression results												
	Friendship (strong)				*Friendship (weak)*				*Advice*			
	M1	*M2*	*M3*	*M4*	*M1*	*M2*	*M3*	*M4*	*M1*	*M2*	*M3*	*M4*
Intercept	0.10**	−0.02**	−0.02**	−0.08**	0.21**	0.19**	0.19**	0.17**	0.14**	0.03**	0.03**	−0.02**
Copresence (survey)	0.30**	0.07	0.06	0.05	0.19**	0.15*	0.15*	0.15*	0.51**	0.29**	0.28**	0.27**
Social media		0.48**	0.43**	0.39**		0.08*	0.07	0.06		0.46**	0.43**	0.39**
Class collaboration			0.13**	0.12**			0.03	0.04			0.09	0.10
Same-nationality				0.01				0.06*				0.09**
Same-cohort				0.15**				−0.01				0.05
R-square	0.10	0.41	0.42	0.47	0.04	0.05	0.05	0.06	0.22	0.44	0.45	0.46
Observations	702	702	702	702	702	702	702	702	702	702	702	702

Note: ** $p < .01$; * $p < .05$.

regression has a unique data structure in which each matrix of relations represents a variable, and analogous cells across the set of all matrices constitute a case (Krackhardt, 1987). In both QAP and MQAP analysis, the unit of analysis is a dyad, a pair of individuals who may or may not have some sort of relation connecting them to one another. Once a dataset is assembled and an OLS regression is carried out, the resulting coefficients indicate the direction of effect of independent variables upon the dependent variable.

The network graph visualization shows undirected and directed graph structures and is another common way for network visualization. This type of visualization illuminates relationships between actors and entities, and it can be generated through software such as Gephi, UCINET, and coding software such as igraph and RStudio. Zhou et al. (2021a) used a network graph to describe the groups' spatial adjacency preference in a network format during an organization's space planning (shown in Figure 10.1). They argue that such a network graph is good at showing the patterns of the group's location in a network and its relationships with the others. This information can be helpful to inform spatial choices regarding interior space layout and people's distribution within the building.

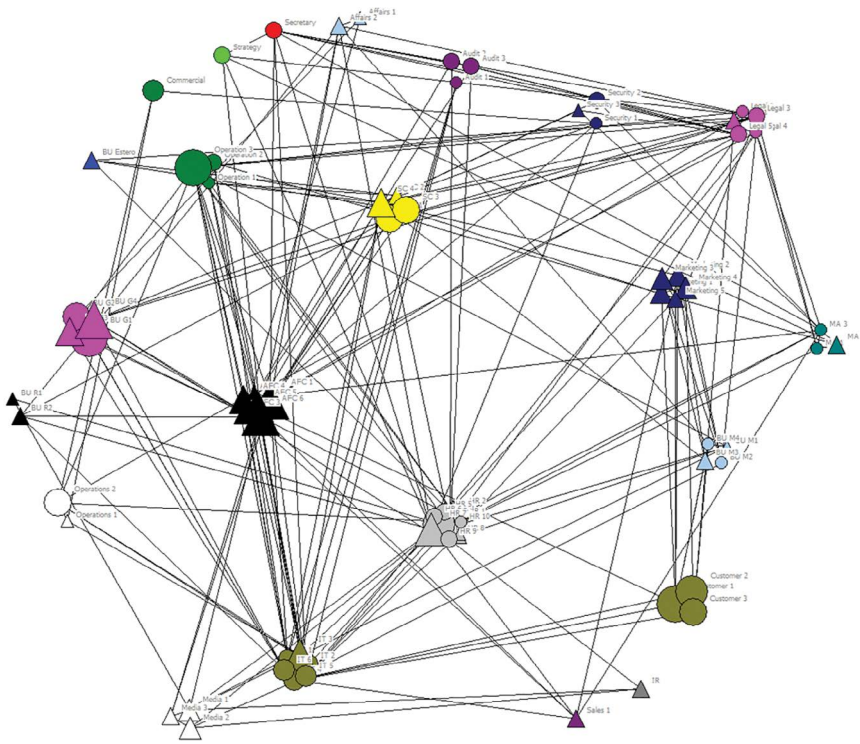

Figure 10.1 Network diagram of workgroup's spatial adjacency preference (Zhou et al., 2021a)

10.4 Implication

10.4.1 A SNA approach to study how space affects communication in workplace

The network approach to studying proximity effects provides opportunities to combine spatial and social network analyses. A five-step approach to conduct a workplace study based on SNA method is proposed by the author (shown in Figure 10.2). As discussed in Section 3.1, both spatial distance and co-presence relationships at a dyadic level can help researchers explore communication patterns in the workplace more detailedly.

For dependent variables, depending on the research questions, network variables such as degree centrality and closeness centrality could be used to describe an individual or group's connection to others in the communication/interaction network. Other data sources such as the building occupancy and email exchange records which reflect an organization's communication patterns become feasible to obtain nowadays. They suggest a promising new category of user behavior information to better understand how space aligns with the actual workflow and collective behavior.

For independent variables, co-presence has been explored as a new type of variable for quantifying proximity in a flexible or shared work environment. With the development in sensor technologies, more sensor-based tools are now available for measuring building occupants' presence and movement in an indoor environment.

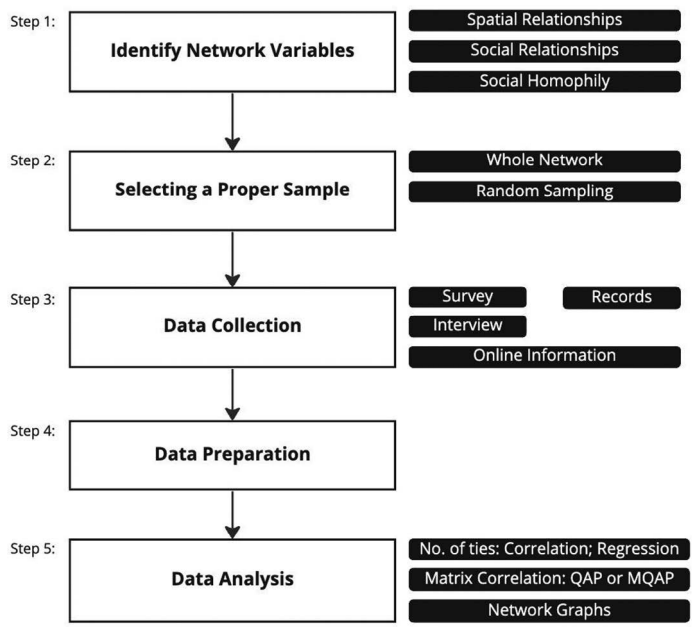

Figure 10.2 Summary of conducting a SNA study

Multiple review articles have been published recently regarding different categories of occupancy detection technology used in previous studies and discuss their pros and cons (Azimi & O'Brien, 2022; Zhou et al., 2021a).

10.4.2 A SNA approach to study spatial adjacency preferences for space planning

During office space planning, there is a common strategy to construct a spatial adjacency diagram, or a "bubble" diagram, which indicates the desired circulation connections between spaces to achieve optimal work efficiency or other goals, such as facilitating communication and collaborations (Cherry & Petronis, 2007). This diagram synthesizes the required or preferred spatial proximity information obtained from the end users and provides recommendations for the spatial layout design. Questionnaires and interview instruments were developed to collect spatial adjacency preferences in previous case studies of large organizations' office planning (Preiser, 1993).

SNA software such as UCINET and Gephi are appropriate tools for processing and visualizing data indicating communication patterns and spatial preferences during space planning for large organizations. Identifying the central groups in a collaboration and communication network can help detect the workgroups that are suitable for being located at the center of a floor plan or close to core areas, which would increase the accessibility for the other groups (Zhou et al., 2021b). Network graphs also show exciting possibilities for space planners based on a deeper understanding of the organization's communication pattern. They are good at showing the patterns of the group's relationships with the others; they might be helpful in informing interior space layout and people's distribution within the building.

10.5 Conclusions

SNA allows researchers to conceptualize concepts such as spatial proximity, social interaction, and social homophily as relations that could be studied through networks. It provides the opportunity to explore the confounding relationships between workspace and the other social characteristics variables and allows the exploration of new relational measures such as co-presence in time. The SNA approach to study spatial proximity effect in the workplace contributes to answering the question raised by Gans (2002, p. 133) regarding space and human behavior: "do both natural and social space have casual power, creating social effects, and if so when, how, and why?"

Future studies can explore applying SNA methods to further study how space affects employees' communication and interaction patterns in workplace. Several limitations and challenges are identified when applying SNA:

1 *Network changes as time passes by*.
It has to be acknowledged that social network is not static and any social network analysis at a specific time only shows evidence describing the social relations to

the particular moment. To study how the spatial proximity effect affects social interaction through SNA, future studies need to consider the evolving character of social networks. Multiple rounds of network data collection, especially before and after the change in spatial factors, will be beneficial for studies showing evidence of social network changes.

2 *Considering virtual communication.*
With the broad adoption of remote working, social interactions in the workplace have become growingly dynamic. Studying workplace spatial factors in such a flexible context is a timely topic and requires more diverse methods to explore workplace design and space planning. Studies have suggested that interactions in physical space and virtual communication channels are not exclusive but interrelated (Zhou & Hua, 2020). It would be interesting to explore the role of spatial factors' role in social interactions and how they interact with other online communication channels.

10.6 Further readings

There are some excellent handbooks written by Wasserman and Faust (1994) and Domínguez and Hollstein (2014) introducing various SNA methods and describing all the steps involved in data collection and statistical analysis:

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications.* Cambridge University Press.

Domínguez, S., & Hollstein, B. (Eds.). (2014). *Mixed methods social networks research: Design and applications*. Cambridge University Press.

In addition to these handbooks, Nohria et al. (1992) and Kilduff and Tsai's (2003) books introduced networks research in organizational studies which covers information about both theories and methods:

Nohria, N., Eccles, R. G., & Press, H. B. (Eds.). (1992). *Networks and organizations: Structure, form, and action*. Harvard Business School Press.

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