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Dong-Young Kim

University of North Florida, d.kim@unf.edu

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CLOSENESS CENTRALITY: A SOCIAL NETWORK PERSPECTIVE

Dong-Young Kim, University of North Florida

Although the topic of a firm's network centrality has received significant attention in the literature, little is known about the theoretical concepts behind closeness centrality. This study reviews the definitions of closeness centrality that have been proposed by researchers. This research also provides a proposition about how a firm's closeness centrality influences its supplier firm's performance in a supply chain context. Our findings show that extant research has viewed closeness centrality as one of the following dimensions: the distance to other firms, the number of links to other firms, and the level of embeddedness. We found that closeness centrality has been conceptualized as a firm's ability to efficiently gain access to information and to achieve competitive advantage.

Keywords: Centrality; Closeness; Social network; Supplier; Performance

INTRODUCTION

Scholars in the field of management and supply chain management have been increasingly interested in the role of closeness centrality in improving firm performance and competitive edge. Closeness centrality is understood as a firm's critical ability to achieve success in a changing and competitive environment. In this study, closeness centrality refers to a firm's shortest distance to all other firms within supply networks (Borgatti and Li, 2009; Carter et al., 2007; Paruchuri and Adate, 2017; Soh, 2010; Wang et al., 2014). Prior research has found that the shortest distance is equal to the short-path lengths to other actors in a network, in a way that influences a firm's knowledge flows and productivity (Paruchuri and Adate, 2017). A firm's position in a network indicates the firm's structural proximity to all other firms and the potential to control the flow of information and resources (Stam and Elfring, 2008). Firms that have closeness centrality can achieve better standardization efforts and thus can attempt to increase their innovation performance (Soh, 2010). Indeed, many focal firms are dependent on external resources controlled by their suppliers and are struggling to enhance their closeness centrality in supply chain networks (Lin et al., 2009).

Despite the importance of closeness centrality, our review of the literature on social networks shows that researchers have explored the impacts of centrality from an isolated perspective. Extant research on centrality has limited its attention to an integrated view of how closeness centrality has been conceptualized and why a focal firm's closeness centrality influences its supplier performance. It is therefore important to review and organize the existing definitions on closeness centrality published in refereed journals. To address these research gaps, this study answers the following research questions: What does closeness centrality mean? How does closeness centrality affect supplier performance? The main purpose of this research is to review the definitions of closeness centrality proposed by researchers. We focus on exploring closeness centrality as a main topic because closeness centrality accounts for a focal firm's ability to achieve a greater speed of access to market. The other purpose of this research is to provide a proposition about how a focal firm's closeness centrality influences its supplier firm's performance. Closeness centrality has been discussed in social networks studies with the aim of

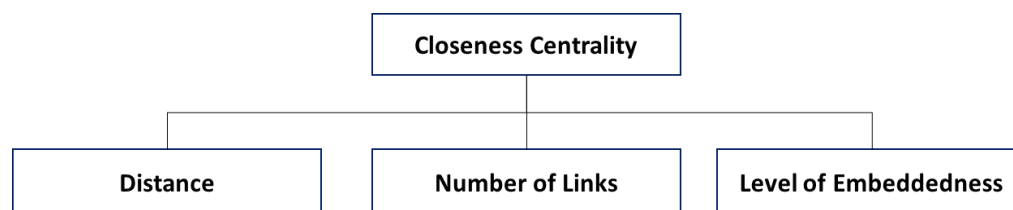
identifying a firm's network position and understanding its influence on performance (Soh and Roberts, 2005). A firm with higher closeness centrality can reduce the time required to pursue new creative ideas and develop innovative products and services (Perry-Smith and Shalley, 2003). In terms of the methodology used in this study, we focused on reviewing articles published in leading journals, such as Academy of Management Journal, IEEE Transactions on Engineering Management, International Journal of Operations & Production Management, Journal of Business Logistics, Journal of Operations Management, Journal of Supply Chain Management, and Strategic Management Journal. We searched for articles whose abstract and keywords include centrality, central, and closeness. We also restricted our sample to articles using the network software UCINET to compute network centrality.

The remainder of the paper is organized as follows: Section 2 discusses the definitions of closeness centrality proposed by researchers. The definitions will be classified into three specific dimensions. In Section 3, we outline methods to measure closeness centrality. Section 4 presents the proposition of the role of a focal firm's closeness centrality in improving supplier performance. The final section discusses the contribution of this research.

WHAT IS CLOSENESS CENTRALITY?

Although researchers have proposed different definitions of closeness centrality, our review shows that the definitions of closeness centrality can be categorized into three dimensions: the distance to other firms, the number of links, and the level of embeddedness. Figure 1 shows the dimensions of closeness centrality.

Figure 1. Dimensions of closeness centrality.



First, from the perspective of the distance to other firms, researchers argue that closeness centrality is the shortest path to all other partners. This dimension is related to speed in accessing the information available in direct and indirect relationships with supply partners. Interestingly, some researchers highlight the shortest distance as a key aspect of closeness centrality (Carter et al., 2007; Hansen, 2002; Soh, 2010). Distance-based centrality represents the average length of the minimum path (Easton and Rosenzweig, 2015) or the average distance from connections with others (Wang et al., 2014). For example, Carter et al. (2007) describe closeness centrality as the sum of the shortest distance between a firm and every other firm in the network. Soh (2010) defines closeness centrality as a firm's shortest distance to all other firms within the network. Along the same line, Hansen (2002) argues that closeness centrality refers to the shortest path length between a department and another department in a network.

By contrast, others emphasize that the sum of reciprocal geodesic distances is a critical aspect of closeness centrality (Paruchuri and Awate, 2017; Perry-Smith and Shalley, 2003;

Perry-Smith, 2006; Wang et al., 2014). For instance, Borgatti and Li (2009) define closeness centrality as the sum of distances to or from all other nodes. Paruchuri and Awate (2017) describe closeness centrality as the sum of reciprocal geodesic distances to every firm in a network. Wang et al. (2014) suggest that closeness centrality refers to a firm's average distance of connections to other firms in a network. Similarly, Perry-Smith and Shalley (2003) conceptualize closeness centrality as the average distance between a firm and all other firms in the network.

Second, researchers claim that closeness centrality should be considered as the number of links among firms in supply chains (Fox et al., 2013; Gulati et al., 1999; Stam and Elfring, 2008). From this perspective, a central firm is only connected to a few intermediate partners in order to efficiently gain information about opportunities and threats (Soh and Roberts, 2005). A firm that reaches a limited number of partners can translate informational benefits into power in a timely manner (Hanneman and Riddle, 2005). This means that a central firm increases its importance by quickly accessing network information and sharing the information with other partners (Perry-Smith and Shalley, 2003).

For instance, Stam and Elfring (2008) suggest that closeness centrality is the number of links that it takes for a company to reach every other company. Similarly, Gulati et al. (1999) argue that closeness centrality is the number of companies that a focal firm must go through to reach other companies in the network. Fox et al. (2013) describe closeness centrality as the inverse of the average number of partnership links from each company to all other companies in its network. In sum, these definitions underline that the number of links that a firm has is important when the firm tries to have access to information and resources available in supply networks.

Finally, researchers view closeness centrality as the level of embeddedness. Scholars point out the information aspect of network embeddedness by providing empirical evidence on how information volume, richness, and diversity provided by different network positions, can improve a firm's performance (Mazzola et al., 2015). Hallen et al. (2014) argue that a firm's network centrality is the degree of embeddedness. Such embeddedness can positively influence emotion-based trust and embedded distributors' motivation to act opportunistically (Dong et al., 2015; Jonczyk et al., 2016). Embeddedness is positively associated with the success of a partnership among companies because embeddedness promotes cohesion between partners during the collaboration period (Polidoro et al., 2011). A firm with a central position in a network has a tendency for over embeddedness in their existing network, which may result in the risks of learning myopia (Levinthal and March 1993; Lin et al., 2007).

In this category, researchers emphasize that the level of embeddedness is one of the most crucial aspects of closeness centrality. For example, Jonczyk et al. (2016) define closeness centrality as the extent to which each firm is embedded in supply networks. Similarly, Lechner et al. (2010) describe closeness centrality as a firm's indirect and direct contacts. Soh and Roberts (2005) argue that closeness centrality expresses where a company is relative to other companies, including both indirect and direct partners, on the shortest path.

In this study, closeness centrality refers to the extent to which a firm is directly or indirectly embedded in supply networks (Jonczyk et al., 2016; Lechner et al., 2010). Our review of the definitions shows that researchers have described closeness centrality as one of the three dimensions: the distance to other firms, the number of links, and the level of embeddedness. We found that the choice of a dimension is based on the authors' focus on what dimension should be explored. Thus, it is difficult to argue that there is any advantage or disadvantage of each of the conceptualizations. Table 1 shows example definitions of closeness centrality.

Table 1.
Example definitions of closeness centrality.

Category	Definition
Distance	<ul style="list-style-type: none"> • The sum of the shortest distance between a firm and every other firm in the network (Carter <i>et al.</i>, 2007) • The sum of distances to or from all other nodes, where distance is defined graph-theoretically in terms of the number of links in the shortest path between two nodes (Borgatti and Li, 2009) • The firm's shortest distance to all other firms within the network (Soh, 2010) • The sum of reciprocal geodesic distances to every firm in the network (Paruchuri and Awate, 2017) • The average distance of connections from a firm to other firms in a network (Wang <i>et al.</i>, 2014) • The distance between a firm and all other firms in the network, which is computed as the average distance between an actor and other members of the network (Perry-Smith and Shalley, 2003) • Respondent's average distance to other members of a network (Perry-Smith, 2006) • The shortest path length between a department and another department in a network (Hansen, 2002) • The degree of closeness of each node to a core of densely connected nodes in the network (Cattani and Ferriani, 2008)
Number of links	<ul style="list-style-type: none"> • The number of links that it takes for a company to reach every other company (Stam and Elfring, 2008) • The number of companies that a focal firm must go through to reach other companies in the network (Gulati <i>et al.</i>, 1999) • The inverse of the average number of partnership links from each company to all other companies in its network (Fox <i>et al.</i>, 2013)

Level of embeddedness	<ul style="list-style-type: none"> • The extent to which each firm is embedded in a network (Jonczyk <i>et al.</i>, 2016) • A firm's indirect and direct contacts (Lechner <i>et al.</i>, 2010) • The extent to which a company is connected to other companies, including both indirect and direct partners, on the shortest path (Soh and Roberts, 2005)
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HOW CAN WE MEASURE CLOSENESS CENTRALITY?

Researchers have defined closeness centrality in different ways. However, closeness centrality has been measured as the sum of the length of the shortest paths between a firm and all other firms in a supply chain network (Fox *et al.*, 2013; Paruchuri and Awate, 2017). While there are a variety of software programs that can be used to measure closeness centrality, our review of the literature on social network indicates that Ucinet 6 software is one of the most popular softwares for producing matrices and calculating closeness centrality (Carter *et al.*, 2007; Cattani and Ferriani, 2008; Fox *et al.*, 2013; Gulati, R., 1999; Lin *et al.*, 2009; Paruchuri and Awate, 2017; Soh, 2010; Stam and Elfring, 2008; Wang *et al.*, 2014). The higher the closeness centrality, the closer a firm is to all other firms. More specifically, the closeness centrality for firm i in year t can be measured as follows:

$$\text{Closeness}_{it} = \sum_{j=1}^N \frac{1}{d_{jit}}$$

where d_{jit} is the shortest path between firm i and j in year t , and N is the total number of firms in the network.

CLOSENESS CENTRALITY AND SUPPLIER PERFORMANCE

Working with a central firm that is closely connected to other firms is an important factor in understanding variations in supplier performance. This is because the closeness with other firms represents the shortest path lengths linking firms and promotes an increase in the efficiency of information processing and decision making, which is critical to commercializing new products (Pappas and Wooldridge, 2007; Easton and Rosenzweig, 2015). It can be argued that a supplier firm's ability to learn rapidly and combine existing resources depends on whether the firm is highly embedded in an interorganizational network (McDermott *et al.*, 2009). A supply network where every node is connected to all other nodes is complex and involves high coordination costs (Kim *et al.*, 2011). In the network, a centrally located firm tends to be connected to fewer intermediate partners and shares information using the shortest paths (Fox *et al.*, 2013). Such closeness centrality enables a highly central firm to work closely with other firms and to therefore have efficient access to information about the market and its competitors (Soh and Roberts, 2005). One of the results of closeness is that information rapidly diffuses to fewer connections, which means that any loss or distortion of information is avoided (Easton and Rosenzweig, 2015). This implies that closeness centrality impacts how quickly information travels within the network and how efficiently a firm handles information (Prell, 2012).

The centrality of the shortest distance among firms also indicates an ability to independently solve a problem and increases the potential for growth. Centrality is a source of informal power and increases access to various resources (Ahuja et al., 2003). A high level of centralization clearly differentiates core and peripheral participants, which influences the level of understanding of strategic issues and the range of engagements in problem-solving processes (Kiss and Barr, 2017). A firm with closeness centrality is an independent actor in a network and reaches other firms without relying on many intermediaries (Prell, 2012). Centrality enables a firm to perceive power and identify growth opportunities, which provides the confidence and discretion needed for problem solving (Perry-Smith and Shalley, 2003). When a firm occupies a position of high closeness centrality, it can have a powerful influence on resource allocation decisions because it is exposed to sources of information and has a sense of ownership over resources (Lin et al., 2009; Hanneman and Riddle, 2005). Empirical research has reported that distance-based centrality helps in signaling the status of a firm (Stam and Elfring, 2008).

Centrality also improves its ability to manage new ideas and novel information (Pappas and Wooldridge, 2007), and access information that passes over fewer connections (Easton and Rosenzweig, 2015). Accordingly, we suggest that when a supplier collaborates with a focal firm with high closeness centrality, the supplier may learn from the experience of the firm how to promptly access unique information and how to link the information with performance improvement.

Proposition: The network centrality of a focal firm which closely connects to other firms positively influences the performance of its supplier.

DISCUSSION

This study makes three contributions to the literature. First, this study reviews the definitions of closeness centrality proposed by researchers. Our findings indicate that extant research has viewed closeness centrality in one of the following ways: the distance to other firms, the number of links, and the level of embeddedness. Second, this study discusses the significance of closeness centrality by providing a proposition about the relationship between a focal firm's closeness centrality and its supplier's performance. We suggest that future researchers examine conditions and contingencies under which the association between closeness centrality and supplier performance remains positive. Finally, this study applies the insights of closeness centrality to the supply chain context. Extant research has paid little attention to the supply chain context and has instead mainly discussed the effects of a firm's degree centrality and structural holes on organizational performance. This study therefore advances our understanding of the concepts of closeness centrality and its performance implications in supply chains.

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