Improving Operational Performance: The Role of Network Density

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ABSTRACT

This study explores how the network density of a firm influences operational performance. In this study, network density refers to the extent to which firms are interconnected through multiple business relationships. This study also attempts to synthesize and organize existing definitions of network density in the literature and provide conceptual insights about dense networks. Our results reveal that existing definitions can be classified into three categories: the degree of connectedness, the percentage of possible ties, and the degree of sparseness. We conclude by highlighting this study's theoretical contributions to the field of operations and supply chain management.

INTRODUCTION

Network density has emerged as one of the dominant topics in the literature on social network theory (Cannella Jr & McFadyen, 2016; Lechner *et al*., 2010; Mors, 2010; Phelps, 2010; Soh, 2010; Wong & Boh, 2014). Network density refers to the extent to which firms are interconnected through multiple business relationships (Gao *et al*., 2015; Skilton & Bernardes, 2015;). Social network theory highlights that the actions and performance of a firm can be explained by the structure of their business network where there are many missing ties between disconnected actors (Burt, 1992; Kim & Zhu, 2018; Ma *et al*., 2010). The need to understand the structure of supply networks has led researchers to examine how different levels of network density contribute to organizational performance. The majority of recent studies have focused on examining the outcomes of network density, such as technology adoption (Peng & Mu, 2011), creativity (Gao *et al*., 2015), the formation of a new joint venture (Carnovale & Yeniyurt, 2014), knowledge creation (Hansen *et al*., 2005), innovation (Mors, 2010; Phelps, 2010), and financial performance (Rodan & Galunic, 2004; Rowley *et al*., 2000).

Despite the importance of network density, our review of existing studies reveals three theoretical gaps. First, there is a surprising absence of attention to the role of a dense network in improving operational performance. As pointed out earlier, researchers have mainly tested for the effects of network density on knowledge, innovation, or financial performance. The network literature, however, has suggested that the structural dimension of supply networks does help to enhance not only financial performance, but also operational performance (Kim, 2014). For example, firms, such as Schneider Electric and Toyota, are currently leveraging the benefits of their supply networks to enhance delivery performance, improve product quality, maintain efficiencies in inventory, and mitigate supply chain disruptions (Bellamy et al., 2014; Gokpinar et al., 2013). Second, extant research has provided conflicting results on the effects of a dense network on firm performance. Some researchers, for example, have reported statistically insignificant results on network density (e.g., Bae & Gargiulo, 2004; Roberson & Williamson, 2012; Skilton & Bernardes, 2015; Wong & Boh, 2014). Third, much less attention has been devoted to the conceptual aspects of network density. Substantial opportunities may exist to enhance our understanding of the definitions of network density.

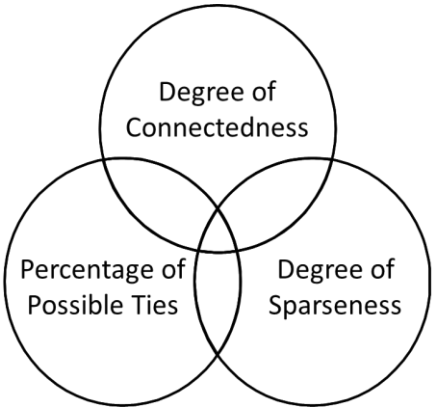
The purpose of this study is to explore the conceptual link between network density and operational performance. We propose a proposition concerning how high levels of network density contribute to operational performance improvement. This study also attempts to analyze the definitions of network density available in the literature of social network theory. Such analysis can help practitioners and academics understand specific dimensions of network density. This paper is structured as follows: In Section 2, we review and classify the definitions of network density. Section 3 presents our proposition on the effects of network density on operational performance. In the final section, we conclude by discussing the theoretical contributions of this study.

DEFINITION OF NETWORK DENSITY

To address the effect of network density on operational performance, it is important to synthesize and organize the definitions of network density in the literature. Given that a variety of definitions have been proposed, our review indicates that researchers emphasized differences between network density and network centrality. The difference is that network density is a network-level concept while network centrality is an ego-level aspect (Keith et al., 2017; Mazzola et al., 2015; Peng & Mu, 2011; Tachizawa & Wong, 2015). Specifically, network centrality represents an actor's position relative to an entire social network, which is a structural attribute embedded in a

social structure (Blyler & Coff, 2003; Carter et al., 2007; Fox et al., 2013; Guler & Guillen, 2010; Perry-Smith & Shalley, 2003). By contrast, scholars argue that network density is closely associated with the overall interconnectedness among all actors in a social network (Keith et al., 2017). Dense networks can maximize the returns that a firm can obtain from its relationships with other firms (Bae & Gargiulo, 2004). We also found that the definitions of network density in the literature can be classified into three dimensions: the degree of connectedness, the percentage of possible ties, and the degree of sparseness (see Figure 1).

Figure 1. Dimensions of Network Density.



First, network density has been viewed as the degree of a firm's connectedness with other partners in supply networks. For example, Provan et al. (2007) define the density of a firm's network as the overall level of connectedness among firms. Peng & Mu (2011) argue that network density is the extent of connectivity among members in the network of a project. Sasovova et al. (2010) describe network density as the degree of connectedness between an individual's previous friends and the individual's new friends. Similarly, Carnovale & Yeniyurt (2014) argue that network density is the extent to which the members of a network are connected to one another. Gao et al. (2015) and Cannella Jr and McFadyen (2016) suggest that network density is the extent to which suppliers of a focal firm are interconnected.

Second, network density refers to a percentage of possible ties among members working in a network. For example, Phelps (2010) and Skilton and Bernardes (2015) describe network density as the percentage of all possible ties among firms that had been formed. Mehra et al. (2006) suggest that density is the proportion of ties as a function of the total number of possible ties. Roberson and Williamson (2012) and Shaner and Maznevski (2011) consider ties to be connections or relationships, and define network density is the proportion of current relationships between network members, relative to the total number of relationships. Similarly, Schilling and Phelps (2007) and Soh (2010) describe the density of a firm's network as the ratio of existing ties to the number of possible pairwise combinations of companies. Rosenkopf and Padula (2008) and Rowley et al. (2000) argue that network density is a ratio of the number of a firm's existing ties in a network to the total possible number of ties among its partners. Wong and Boh (2014) take the individual perspective and define network density as the ratio of the number of ties among an individual's contacts to the maximum number of possible ties.

Table 1. Example Definitions of Network Density.

Category	Definition
Degree of Connectedness	• The extent to which the members of a network are connected to one another (Carnovale & Yeniyurt, 2014) • The overall level of connectedness among firms (Provan *et al*., 2007) • The extent to which suppliers of a focal firm are socially interconnected (Gao *et al*., 2015) • The degree of connectedness between an individual's previous friends and the individual's new friends (Sasovova *et al*., 2010) • The extent of connectivity among members in a network of a focal project (Peng & Mu, 2011) • The extent of direct ties among an individual scientist's direct exchange partners at a given time (Cannella Jr & McFadyen, 2016) • The level of cohesion needed to take a coordinated action (Obstfeld, 2005)
Percentage of Possible Ties	• The number of ties among a set of nodes described as a function of the number of pairs of nodes (Borgatti & Li, 2009) • The actual number of alliances divided by the number of all possible ties that can be established within a cluster (Rosenkopf & Padula, 2008) • The ratio of existing ties in a network to the number of possible pairwise combinations of companies (Schilling & Phelps, 2007) • The ratio of the number of links among an individual's contacts to the maximum number of possible ties (Wong & Boh, 2014) • The number of actual ties among a focal firm's partners, divided by the total number of potential ties among partners (Soh, 2010) • The number of a firm's existing ties in a network, divided by the total possible number of ties among its partners (Rowley *et al*., 2000) • The percentage of all possible ties among a firm that have been formed (Phelps, 2010) • The percentage of possible ties between partners of a network that are actually realized (Skilton & Bernardes, 2015) • The number of relations divided by the number of possible asymmetric relations (Hansen *et al*., 2005) • The proportion of actual nominations among the number of possible nominations (Sparrowe *et al*., 2001) • The proportion of ties as a function of the total number of possible ties (Mehra *et al*., 2006) • The proportion of current relationships between network members relative to the total number of relationships that could exist (Roberson & Williamson, 2012) • The proportion of the maximum possible number of connections, not including the links with the ego who is the focal point of a network (Shaner & Maznevski, 2011) • The number of both incoming ties and outgoing ties (Gonzalez *et al*., 2014)
Degree of Sparseness	• The sparseness of a network where possible non-redundancy exits among the contacts (Jonczyk *et al*., 2016) • The absence or presence of ties among alliance partners (Bae & Gargiulo, 2004) • The presence of strong third-party relationships around a relationship (Lechner *et al*., 2010) • The extent of overlapping ties among individuals in a network (McFadyen *et al*., 2009)

Third, network density refers to the level of relative sparseness of an ego network. For instance, Jonczyk et al. (2016) define network density as the sparseness of a network where possible non-redundancy exits among the contacts. They argue that network density should capture whether contacts of a firm in a network may contain redundant resources. Bae and Gargiulo (2004) claim

that density in a network is defined as the absence or presence of ties among alliance partners. According to Bae and Gargiulo (2004), network density indicates both the absence of structural holes in a collaboration network and of its closure. Along the same line, McFadyen et al. (2009) view network density as the extent of overlapping ties among individuals in a network. Table 1 presents example definitions of network density in the network literature.

NETWORK DENSITY AND OPERATIONAL PERFORMANCE

Network density is likely to influence a firm's operational performance for three reasons. First, dense networks can act as a source of reliable and valid information obtained through multiple reciprocal channels. According to social network theory, firms that are better connected to the network have a competitive advantage over poorly connected firms (Rowley et al., 2000). A dense network generates more paths through which information, knowledge, and ideas can travel within the network (Peng & Mu, 2011). Access to information flow in a network enables firms to exploit their existing technological base and learn best practices, which leads to significant operational efficiencies (Koka & Prescott, 2008). Similarly, as density increases in a network, partners are actively connected to one another and tend to have increased goal alignment (Cannella Jr & McFadyen, 2016). Using multiple communication channels in a dense network, firms can be more accurate in their awareness of other firms' behaviors and performance (Erickson, 1988). Firms that work closely together and share common operations can facilitate the creation and transfer of tacit knowledge on how to make cost reduction improvements (Rodan & Galunic, 2004). Leveraging firm resources, along with the external resources of partner firms, creates synergy effects and promotes the sharing of risk and cost as well as product development, while increasing speed to market (Lin et al., 2009). Along the same line, Kim (2014) suggests that the greater the extent to which a firm utilizes the information of the structural configuration, the greater the likelihood that the firm will perceive network advantages and improve operational performance.

Second, at high levels of network density, it becomes more challenging for firms to absorb and utilize knowledge from more diverse partners (Phelps, 2010). This is because dense networks continually create numerous paths for communicating practical advice and information resources, creating an expectation around attitudes and behaviors for other firms to emulate. (Roberson & Williamson, 2012). The presence of multiple channels among partners can facilitate voluntary agreements on technical standards in industries such as telecommunications (Bae & Gargiulo, 2004). Firms that have high density have a larger common knowledge base than firms with low density, reinforcing commonly held beliefs afforded by extensive and intense past interactions (Hansen et al., 2005). Thus, firms in dense networks may have an opportunity to develop useful routines and practices together. These routines are important to firms because they can reduce operational costs and enhance the quality of a product (Kim, 2014).

Third, dense networks can serve as a source of trust in supplier-customer relationships. The network literature stresses that dense networks promote trust and reciprocity among networked firms, increasing cooperation among partners, but mitigating absorptive capacity problems (Coleman 1988; Phelps, 2010). High density leads to easy monitoring and maintenance of reputations, which creates trust and promotes intense social interaction (Jensen, 2008; Peng & Mu, 2011). Density in a network and repeated ties with several partners give rise to a shared environment in which cooperative norms and trust govern exchange relationships (Soh, 2010). In other words, network density enables firms to have close ties with other firms, which can generate deterrence-based trust, including an ability to detect deviant behaviors in an efficient manner (Gao et al., 2015; Sosa, 2014). Such network density not only helps the transfer of fine-grained information, but also promotes trust, a form of social capital that enhances the diffusion of complex information and the development of norms for acceptable behavior (Coleman, 1988; Yang et al.,

2011). Firms in a densely connected network can trust one another to honor obligations, creating a better environment for their exchanges while lowering the risk of opportunistic behavior (Uzzi, 1996). Trust facilitates consensus between partners and is necessary for gaining full cooperation and for transferring resources and knowledge (Peng et al., 2010). On the other hand, a lack of trust causes potential partners to doubt a firm's ability and operational performance (Fleming & Waguespack, 2007).

Moreover, high density networks mean structural homophily, where members in the network are very similar and have access to diverse partners and diverse resources (Carnovale & Yeniyurt, 2014). Dense networks, in which triads are closed and unconnected partners are absent, encourage firms to accumulate social capital because such a network structure generates trust, reciprocity norms, and a shared identity, which increases knowledge sharing and cooperation (Coleman, 1988; Phelps, 2010). When the density of a network increases, there is a likelihood that networks will change by dropping old members or adding new members (Cannella Jr & McFadyen, 2016). It can be argued that dense networks are advantageous for developing cooperation and trust through collective monitoring and sanctioning (Rowley et al., 2000). Roberson and Williamson (2012) argue that network density increases the strength of procedural justice climates in self-managing teams.

Lower levels of interconnectedness among network partners can lead to lower levels of trust and a higher threat of opportunistic behavior (Bellamy et al., 2014). Lack of trust hinders knowledge transfer among partners and limits a firm's ability to accumulate new knowledge, thus slowing down the process of conceptualization and evaluation of new actions (Andrevski et al., 2016). Firms embedded in a low-density network where partners are sparsely connected to one another can hardly rely on the network's control mechanism (Kim, 2017).

This reliance on trusted partners is particularly salient when the need to protect information or knowledge is paramount because it reinforces ties among the firms' immediate, pre-existing relations (Hernandez et al., 2015). Soda et al. (2004) found that firms with a high level of closure over time often build more trust-worthy behaviors and routines and enhance firm performance. Such trust, engendered by dense networks, allows for greater relation-specific investments in business relationships, speeding up the processes of customization and leading to performance improvement (Batjargal et al., 2013; Zaheer & Bell, 2005). Network density leads to lower levels of competition driven product market entry, because firms in a densely connected networks act in similar ways and try to lower the cost of competing (Skilton & Bernardes, 2015). Firms can utilize external resources in networks for the purpose of accessing knowledge and cutting operating costs (Rowley et al., 2000). Therefore, we suggest the following:

Proposition: The network density of a firm positively influences its operational performance.

CONCLUSION

This study makes three contributions to the literature of operations and supply chain management. First, this study helps to clarify the conceptual dimensions of network density. As far as we know, there has been no study that has reviewed existing definitions of network density in the literature. We synthesize a broad range of conceptual aspects of dense networks and classify 25 definitions into three categories: the degree of connectedness, the percentage of possible ties, and the degree of sparseness. Second, this study advances extant research in the social network literature by exploring the effects of a dense network on operational performance. We enrich our understanding of the network structure and its impacts on performance. Lastly, this study offers

a proposition to explain how and why network density has a relationship with operational benefits. Future work could build upon our arguments and predictions to examine how successful firms leverage their advantages in supply networks.

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