State-of-the-Art Review

Social Networks and Construction Teams: Literature Review

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Abstract: From the relational contract approaches currently emphasized in construction, researchers have noted that there is enough evidence pointing toward social psychological theories of team formation. Building on a theoretical framework, this paper analyzes social, construction, and team formation literature through a comprehensive literature review. Findings reveal that construction teams form as small worlds out of clusters that emerge either through contractual, professional, task, or trade relationships, which strongly supports the proposed theoretical framework for social networks in construction. This paper contributes to the body of knowledge by bringing together three diverse theories of team formation, social network, and collaborative teams into construction engineering and management research while at the same time identifying gaps and areas for future research. In addition, this study reveals that fragmented construction teams are characterized by clusters, and resources are constrained from one cluster to the other. As such, construction teams lack bridging ties necessary to reduce social distance between members, an area that has received limited attention from researchers. **DOI: 10.1061/(ASCE)CO.1943-7862.0001628.**

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Introduction

Many industries rely on teams of individuals when the end product of a certain engagement depends on the collective individual contributions of every team member. Teams make use of individual knowledge and strengths together with others to potentially achieve higher success than what one can achieve individually.

Specifically in the construction industry, business is conducted based on its different functional areas performed by different parties to plan, design, and construct a project. The defined roles of these project parties in some cases allow them to make decisions without considering their impact on the other members of the team (Love et al. 1999). The effect of the disconnect between decision making and the impact the decision has on others is that parties in the construction industry commonly focus on their roles and their individual or organizational goals without much regard to the overall performance of the project or the other parties that are a part of the project. According to Love and Irani (2003), the interaction between project parties can lead to ineffective communication and coordination issues among team members, which has prompted both industry professionals and researchers to seek innovative ways of improving project and team efficiency and effectiveness in the construction sector.

Project parties can either be individuals or organizational firms that come together to accomplish certain tasks of a project. The basic conventional methods of project management are usually linear models of project governance. According to Keast and Hampson (2007), these conventional linear models have not been able to meet the ever-changing needs of the construction industry. Keast and Hampson (2007) further state that to overcome the inefficiencies of these conventional methods, interorganizational and cross-sectional networks have been introduced and used. These types of networks have the advantage over conventional models in that they foster working relationships by bringing project parties together to improve trust and communication and thus building a more cohesive project team.

The focus on network studies is based on the relationships that exist between the parties in the project, whether it be organizations, individuals, or work units (Brass et al. 2004). Team members are engaged in interconnected relationships within a network, which affects both opportunities and constraints toward performance. The coming together of these team members to form a network encourages cooperation and collaboration. The study of networks is different from other forms of project collaboration because the focus in this paper is on relations rather than individual attributes of team members, and more focused on the pattern of interactions as a team and not as individual units (Brass et al. 2004).

The recent expansion of network research in various fields such as traffic networks, internet and social media networks, and epidemiology has opened the door for researchers to explore problems from a different perspective. According to Lin (2015), the application of social networks can show that human factors and activities are key to team formation and performance. In construction, many perceive the application of social networks as a wider extension of established markets and hierarchical modes of project governance (Williamson 1975). These networks operate on a relational concept and thus require a management strategy and governance considerations. It is on this theoretical underpinning for relational management practice that high-performance teams occur based on their formation (establishing the relationship), and development and management (managing and sustaining the relationship).

Some of the pioneers of social network research in construction (Pryke 2004, 2005; Wambeke et al. 2012) have shown that construction project teams are nodes in a network and must be analyzed

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based on relationships. These authors further suggest including social factors as part of the analysis to evaluate their relationships. In their research, Chinowsky et al. (2010) argued that social networks can be used to assess relationships in a team and hence their performance and cannot be used in place of the traditional project management. Research regarding social networks in construction is in its early stages and thus there are still issues that researchers need to explore. The mechanisms by which construction networks form, the role or influence of each construction team member in a network, and the social factors that influence the interaction of team members are yet to be thoroughly investigated even though they have a great impact on team performance.

Theoretical Framework

A social system has been defined to be a combination of elements such as individual persons that are connected to each other through relations and interactions (Aguilar-Raab et al. 2015). In a construction project, this represents a construction team. Members of the construction team interact and communicate in different ways to maintain their working relationships and to be able to perform their functions. For a construction project to succeed, a construction team bears a collective functional responsibility and an individual's belief in the capability of the team to function as a unit. However, in most cases the interaction between team members is surrounded by individual experiences, behaviors, beliefs, and other factors that exert substantial influence on the quality of team relationships (Gonzalo et al. 2010).

The theoretical framework represented in Fig. 1 has been proposed and used in this paper as the point of departure to conduct and guide the investigation of social networks and construction teams through an in-depth literature review. This framework provides the links underlying relationship management in construction teams from a social network perspective. The categories of the potential links are as follows: (1) team formation, (2) social networks, and (3) collaborative team. Specifically, the theoretical framework focuses on team formation models under the social network theory, how team member behavior shapes a construction social network, and how that relates to collaboration. In the following sections, the authors investigate team formation models and focus on the link between social and relational behaviors of team members on collaboration.

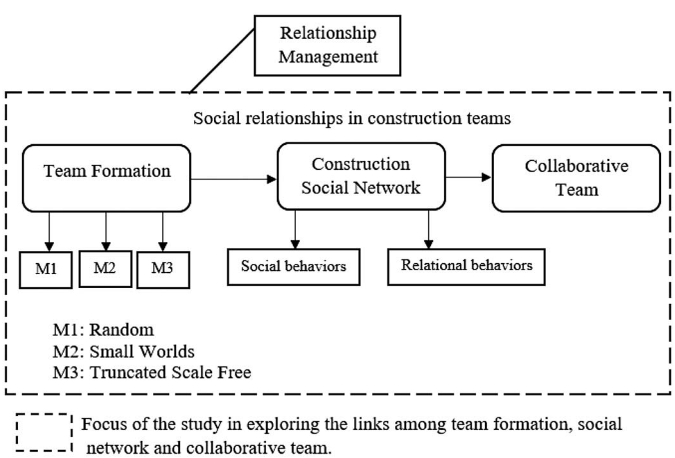

Fig. 1. Conceptual framework for social networks in construction.

Methods

This paper utilizes literature review methodology. Literature review/content analysis is the collection of background information of a research study. The aim of the literature review in this paper is to consolidate and analyze previous studies by other researchers related to the topic and draw parallels to the situation at hand (Chow and Barnsley 2005). Conducting a literature review is a continuous process done throughout the research. The specific objective of the literature review was to investigate construction teams from a social and psychological view by comparing different social network models of construction team formation, development, and management and examine the social behaviors under this view of construction team formation.

To achieve the objective of the paper, a three-step literature review was conducted as shown in Fig. 2. But first, a coding system was developed to help in the validation of the review process and determine whether and how publications in selected publications relate to the current research. In Step I, a comprehensive search was conducted in the ASCE Library as well as other scholarly search engines including Google Scholar and ProQuest to look into previous articles pertaining to team formation, development, and management from a social and psychological view, and this resulted in 317 publications. At this step, a search was also conducted in business research and psychology research journals database including Business Complete and PsycINFO in order to understand the application of the social theory from different fields and draw some parallels. The keywords "social behaviors," "team formation," and "construction teams" were used to conduct the search. The focus of these keywords was either on the title or the abstract. Because the application of social networks in construction is relatively new, the search was not limited to specific types of construction, but rather to the construction industry in general.

Step II included a review of the studies found from the search engines and were thought to be potentially relevant to this study based on the abstract and the key words. An in-depth evaluation of the papers was conducted by looking at the main body of the papers, the conclusion and recommendations for future research. At this stage, articles found to not be relevant to this study together with those that were double counted were omitted. This study resulted in 182 studies that were considered for Step III.

The relevant publications from Step II were then considered for Step III and used to analyze social networks in general as well as construction team formation, development, and management. The studies in Step II were re-evaluated based on the coding criteria established and relevant publications were grouped in different constructs based on the theoretical framework established earlier in the paper. At the end of the process, it was established that 109 studies contained relevant information that could be categorized to one or more of the categories presented in the theoretical framework. Several studies were left out because they were based on overarching theme of managing construction themes with no clear cut categories under which they could be categorized in this study. The output of the analysis was to build on the comprehensive theoretical framework that guided this study.

Findings

The findings presented in this study are first summarized in tables based on the three main links in the proposed social network model. The findings represent top literature findings from the studies analyzed from the search using the methodology presented. Table 1 shows the summary of the studies analyzed based on the journal in

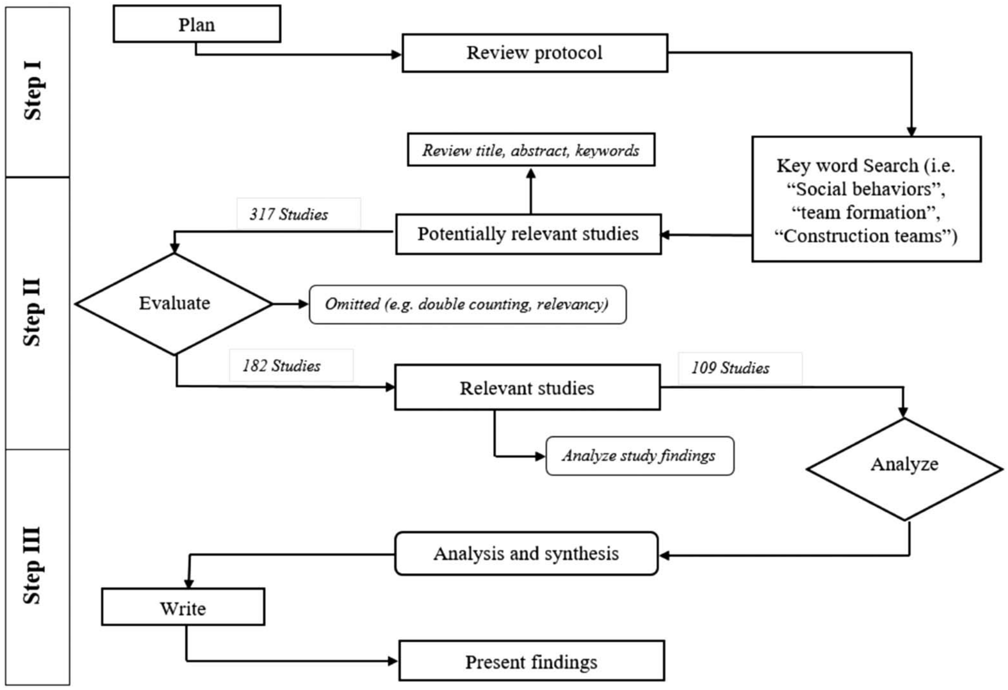

Fig. 2. Literature review approach.

Table 1. Yearly trends in social network research as shown in papers in mainstream publications

Publication source	5-year publication period			
	1998–2002	2003–2007	2008–2012	2013–2017
ASCE *Journal of Management in Engineering*	0	0	2	7
Construction Management and Economics	0	1	9	15
ASCE *Journal of Construction Engineering and Management*	1	0	5	18
Journal of Computing in Civil Engineering	0	0	0	1
Journal of Professional Issues in Engineering Education and Practice	0	0	1	1
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	0	0	0	1
Construction Research Conference Proceedings	0	1	3	10
Books	2	1	1	0
International Journal of Applied Engineering Education	0	0	1	2
International Journal of Architecture, Engineering and Construction	0	0	0	3
Others	2	4	7	10
Total ($n = 109$)	5	7	29	68

Note: "Others" includes nonconstruction journals as follows: *American Sociological Review, Contract Journal; Journal of Behavioral and Social Sciences; Procedia—Social and Behavioral Sciences; Journal of Purchasing and Supply Management; Project Management Institute; International Journal of Project Management; European Journal of Purchasing and Supply Management*; and *Business Ethics: A European Review.*

a 5-year publication period in order to show social network in construction research trends.

Team Formation and Development

In any construction project, a project team is a basic requirement as the team brings together the required human resource required to undertake various design and construction tasks. However, team formation is not just the assembly of human resources, but also to help ensure that the team works together collaboratively and efficiently. Researchers conducted previous studies to investigate construction teams, in which the results reiterate the need for team integration and collaboration (Kumaraswamy et al. 2005; Son and Rojas 2011; Franz et al. 2017; Wen et al. 2017). As is evident from literature, researchers are of the view that effective teams rely on three fundamental dimensions, which include the individuals, the organizations, and the team (Scott and Walker 1995). Nevertheless, team development will depend on the tasks required for a project.

Two broad principles explain the process of team formation in construction. One is the rational view where team members are selected based on factors such as cost, skills, and knowledge. These are driven by instrumental, economic, and other considerations mostly considering the market forces of supply and demand. The argument by this process is that team members need to be selected based on their capabilities of knowledge, skills, and resource accumulations (Aldrich and Kim 2007). The second view is that team members need to be selected based on the social and psychological model, which considers interpersonal skills and how they fit with the other members of the team. Thoits (1984) argued that both social and psychological processes shape human behavior. With that in mind, one can argue that positive social and psychological relations will lead to healthy relationships between team members and thus develop into an effective team.

It is important to note that in construction the two principles of team formation can be used either separately or together to shape project teams. However, it is common that construction teams are procured using the rational view, where team members are selected based on cost, skills, experience, and resources available. Recently, emerging innovative trends, where relationship-based procurement strategies now exist, complement the rational view. For example, partnering and alliancing strategies select team members based on complimentary factors and personal traits that go beyond the rational view requirements (Anvuur and Kumaraswamy 2007).

Team formation and procurement research, and the application of social networks in construction are limited. However, from the relational contract approaches currently emphasized, note that there is enough evidence pointing toward social and psychological theories of team formation. And for this reason, a social network view is a better tool to understand the formation, establishment, and management of a team.

Construction Team: Social Structure Perspective

Network theory has been in use since it was first proposed by Moreno (1934). Moreno's major contribution to social networking was the creation of sociometrics, which is a method in which networks are identified among groups. More authors have since looked at network theory including Von Bertalanffy (1974), who established a general systems theory framework for analyzing networks, which was a move away from the traditional linear theories of cause and effect. Further, Bonacich and Friedkin (1998) defined social influence and the control of actors within a network.

Research in exchange theories has shown that the basic elements of the social structure are the social relations among team members in a group where these relations involve the exchange of important information and resources (Aguilar-Raab et al. 2015). Exchange theories describe the social structure as being both a product to create conditions for the emergence of repeat relationships and a constraint as a result of dependence portrayed as networks of social relations (Bernstein 2016).

The concepts of social and relational exchanges found their way into the construction industry through the introduction and understanding of the relational contract theory. Specifically, the work promoted by Mcneil (1980), compared and contrasted relational and social factors. In relational contract theory, primary relations in social networks are referred to as personal relations, which involve all the behaviors of the individual team members, is unlimited in scope and nontransferable, and that the relations are unique (Mcneil 1980). Moreover, this is not limited to just relational contracts, as other classical and neoclassical contracts involve a large number of individuals that require interpersonal relations and interactions between the team members. Team members are motivated to build social interactions in a structured manner without following any legal mechanism subscribed in law to build trust and commitment to achieve a common goal for the good of the construction project (Memon et al. 2015).

Relational contract theory in construction defines the working relationships of team members who work together, mutually guided by socially acceptable guidelines (Kumaraswamy et al. 2005). A construction project brings together many individuals from different backgrounds such as architects, engineers, owner, contractors, and material suppliers who interact to form a social structure otherwise referred in this paper as social networks. Unique to interactions in construction project networks is that they are very dynamic. Chinowsky et al. (2008), while studying social networks, reaffirmed the nature of construction projects as unstable networks because they are temporary, i.e., parties come and go to a project, which reinitiates with every new project. Research has shown that human factors are central to the success of a construction project and therefore understanding the interaction of team members and improving their working relationships can influence the performance and success of a project (Lin 2015). The construction business is becoming more competitive and more demanding in terms of risk and complexity, meaning that there will always be a changing social order in a network of a construction project team (Aldrich and Kim 2007). Therefore, the study and understanding of the social structure of construction teams is timely.

Social Network Analysis

Social network analysis (SNA) has been defined as a tool for analyzing a group of related actors or parties that are either collaborating and/or competing against each other (Aviv et al. 2003). SNA is a very useful tool for analyzing relationships and interactions between parties through social structures. The analysis is a collection of graphs and other mathematical models useful in social sciences, economics, political science, computer science, and others. SNA uses mathematical models to help analyze network attributes related to roles, interactions, linkages, and metrics.

Wasserman and Faust (1994) reiterated the need for information and knowledge exchange for the possibility to use SNA. Information and knowledge exchange will enable the mapping of the network and show the relationship between the members of the network. The combination of social factors and statistical applications make SNA a critical tool in analyzing interactions in networks. According to Li et al. (2013), SNA has two advantages, first being that SNA gives an opportunity to represent the characteristics of members in a network visually, and second SNA gives an opportunity to analyze the interpersonal or interorganizational relationships between members regarding communication, information exchange, and knowledge exchange. The following properties have been explained to characterize a network in general:

- Actor/node/vertex: Represents the social entities within a network, whether it be a discrete individual, corporation, or collective social unit (e.g., people, departments, and agencies).
- Relational tie/edge: Represents the social ties between actors. For example, evaluation of one person by another, transfer of resources, associations, behavioral interactions, or formal relations.
- Dyad: Represents two actors and a tie (edge) between them. Analysis focuses on the dyadic properties (e.g., expected behaviors of reciprocity, and flexibility).
- Triad: Represents a subgroup of three actors (triplets) and the possible ties among them. For example if Actor i likes j, and j likes k, then i also likes k and vice versa.
- Cluster: Represents the groupings of actors in a network.
- Neighborhood: The neighborhood for a vertex or node represents the set of immediately connected nodes.
- Degree: The degree of a vertex or node represents the number of other nodes in the neighborhood.
- Bridging ties: Link between two nodes of which if the link is broken, the nodes are separated into two different components.
- Diameter: Number of ties (edges) on the longest path between any two actors/nodes/vertices in a network.

Different mathematical applications have been incorporated into social network studies to assist in the analysis of the social structure of interpersonal relations. The parameters shown in Table 2, are the SNA measures that have been used to describe and explain patterns exhibited in social networks.

Table 2. Social network analysis measures

Parameter	Interpretation and calculation
Topology	The pattern in which project team members are connected in a network presented visually to interpret its emergence and meaning.
Network density	A measure of how well a network is connected, to indicate a number of interactions. Calculated by the ratio of the number of edges/relational ties in the network over the total number of possible edges/relational ties between all pairs of nodes.
Clustering coefficient	A real number between 0 and 1 to define whether there is clustering or not. Calculated by the number of closed triplets (e.g., three actors) in the node's neighborhood over the total number of triplets in the neighborhood.
Average path length	Any sequence of nonrepeating nodes that connects the two nodes. Calculated by the average of the path that connects two nodes with the shortest number of edges/relational ties.
Component	Represents the network connectivity degree, which is calculated by a subset of nodes interconnected by edges/relational ties.
Degree centrality	Used to measure a node's influence or popularity as a distribution of relationships. Calculated by the number of links into or out of a node.
Closeness centrality	A measure of the speed with which information can reach other nodes from a given starting node. Calculated by measuring the average of all shortest paths from a node to all other nodes in the network.
Geodesic distance	A measure that can indicate either the distance between two general nodes with the greatest separation in a network or the distance between two specific nodes in question. For example, a project network with a large geodesic distance between a structural engineer and concrete subcontractor means that many parties will transfer a request for information between the two parties before an answer is originated and returned.

Table 3. Analysis of social network models in construction

Social network models in construction	Number of times cited in the literature	Number of studies appeared
Random networks	15	4
Small worlds networks	26	7
Truncated scale-free networks	21	6

Social Network Models in Construction

Based on the theoretical underpinning of SNA that interactions of many team members create networks, the properties and structure of networks in other subjects have been studied. For example, SNA has been used in a computational network such as the worldwide web (WWW), as well as internet structure networks, collaboration networks, and neural networks (Sen et al. 2003). Table 3 shows the analysis of social network models in construction as presented in the reviewed studies in the mainstream publications.

In construction-specific research, the three main models of network structure studied include regular, small-world, and random networks as shown in Fig. 3. The figure illustrates the connections between the different members in the models.

Random Networks

Imagine a world in which individuals are free to interact with one another as they wish. Random networks exhibit a scenario that does not limit the members of the network by any factor like resources, skills, or knowledge. Members can access one another within the network and that there is no clustering. It is for this reason that the average path length between members is quite short because the ties are not direct.

Consider a case of a potential homeowner who wants to build a home. The homeowner directly contacts construction individuals or organizations that they know well to perform the construction work rather than going through the traditional procurement bidding process using the rational view explained in this paper. It is anticipated that the team thus formed by the homeowner will face few difficulties in forming a team or recruiting additional new members to the project. However, it will prove to be difficult in a random network to determine who among the many are accessible and will add value to the team.

Small World Networks

The early theorists of small world networks, such as Travers and Milgram (1967), argued that individuals, whether having good or bad relationships, can form relationships with other socially and geographically distant individuals. According to Watts (1999), the small world networks model differs from the model of the random network in two ways. First, rather than networks forming randomly across populations, small world networks are formed based on social-cultural constraints, and as such, relationships develop when people have something in common. For example, relationships develop at workplaces, as neighbors, or through friendships based on a commonality. Therefore, people with similar characteristics are grouped together while people of dissimilar characteristics are kept away from the network. Hence, small world networks exhibit high

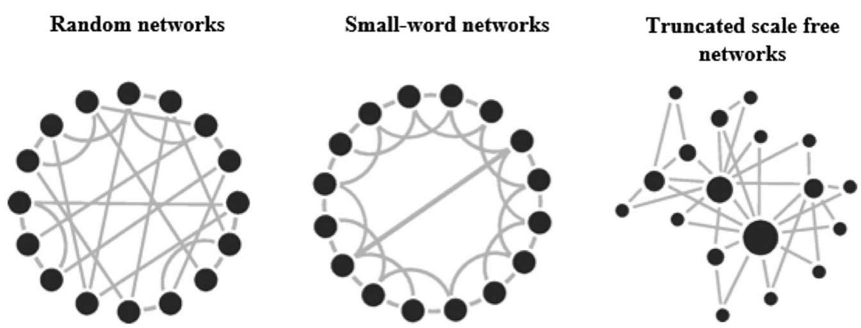

Fig. 3. Network structure from regular to random network. (Reprinted from Anderson et al. 2014, © ASCE.)

density within the groups or clusters while raising the average path length in social networks.

Second, because small world networks represent a fragmented cluster-to-cluster network, bridging ties (e.g., links between two nodes that are otherwise broken, the nodes are separated into two components) are necessary. Bridging ties will help clusters to form global networks (e.g., highly interconnected relationships), which need long distance ties to form small world networks. Additionally, more bridging ties are needed to reduce the average path between any two individuals (Watts 1999). Then, to decrease fragmentation, the average path length between individuals in a network needs to be reduced as much as possible. In social networks, clustering coefficients and average path length can be used to demonstrate the level of fragmentation/integration. Clustering coefficients range from zero to one, in which high values represent a high level of integration. According to Fleming and Marx (2006), a benefit of small world networks allows individuals in the network to develop more skills and knowledge, engage with new technology, and encourage innovation.

Truncated Scale-Free Networks

According to Albert et al. (1999), truncated scale-free networks normally emerge in a growing network where new team members will connect with more connected or networked members. These types of networks are very dynamic. The two main distinguishing characteristics of truncated scale-free networks are as follows:

- Larger clustering coefficients as compared to random networks, meaning that team members add a link one at a time and these links will attach to a team member with many other team member links; and
- Their diameter (representing the amount of information carried through a certain link) increases with the increase in the number of vertices (Amaral et al. 2000).

All truncated scale-free networks are considered to exhibit small world network properties while small world networks do not necessarily exhibit truncated scale-free networks (Aldrich and Kim 2007).

In construction projects, a good example of a truncated scale-free network would be the act of teaming up with firms that demonstrate a good reputation or possess many valuable resources. Members in a truncated scale-free network prefer to associate with other firms with a good record of either quality work, experience, or firms with resources to complete certain tasks.

Applying Social Networks to Construction Team Formation, Development, and Management

Construction teams commonly form as small world networks out of clusters that emerge either through the result of either contractual, professional, task, or trade relationships. Typically, construction teams are fragmented and lack bridging ties necessary to reduce social distance between members. As early stated, construction teams are commonly selected using the rational process model where team members are selected based on cost, skills, experience, and resource base, while some construction teams can be selected using relationship-based procurement strategies that can be adopted to complement the rational model. Unknown connections, or strangers to construction teams, is common as these connections help to bring together potential members who never worked together before and do not know each other.

When a construction team finds themselves in clusters, the effect is that they may not have direct links to resources or information. It shows the impact of the embeddedness of individual team members and the constraints they face in breaking the clusters to reach resources and information directly. To understand how small world networks of construction teams can transform to high performance teams, the authors investigate the following questions in the subsequent sections:

- How do individual positions in small world networks different from truncated scale-free networks?
- How does the position of an individual member affect interpersonal relationships with other team members?
- How do construction teams break clusters?
- What is the role of social factors in team formation?

Individual Positions in Truncated Scale-Free Networks

In their analysis of team formation and management using different social network models, Aldrich and Kim (2007), used entrepreneurial teams to explain that centrally located team members occupy positions of influence and this gives them an advantage over those team members who are not centrally located. Aldrich and Kim (2007), further argued that due to their strategic positions in the network, centrally located team members can identify opportunities and also mobilize other team members to act collectively, quickly, and efficiently. But because construction teams are formed as small world networks, changing to truncated scale-free networks occurs through either forming coalitions or forming bridging ties with others based on social factors (Aldrich and Kim 2007).

Team members in small worlds and truncated scale-free networks can improve their efficiency by involving others, which is largely dependent on the location of the team members in the network. Densely clustered and less connected team members are less efficient and do not represent high performing teams. In order to gain a more strategic location in the network, team members in a cluster need to break from constraints either through use of technology-based collaborative tools or by freely seeking social relationships around structural holes (e.g., breaking the gap between two team members who have either complimentary resources or information). The arrangement of truncated scale-free networks makes it easier to break cluster constraints when compared to random and small world networks. Therefore, the consensus is that construction teams will perform well if they possess truncated scale-free network characteristics.

Position of Team Members and Interpersonal Relationships

In network theory, high density networks can be unfavorable to a team member as these types of networks force team member into some conformity, which can limit a team member's independence and innovation (Borgatti 1997; Putnam 2000). Glanville (2004) argued that the potential assistance available to high-density team members from others in the network are redundant because the information and resources are likely to be widely shared. Another effect of high density networks is they can give information that is not required, which is referred to as an echo to a team member, and unnecessary information can have a negative effect on the members in a social network.

Breaking Clusters in Construction Networks and the Role of Social Factors

To achieve high performance in teams, construction projects teams need to be viewed and managed from a social collaborative perspective (Chinowsky et al. 2010). Construction teams, once established, need to link up with other individuals in search of resources and information to perform the work. Finding valuable information or resources will depend on the location of the team members. Locations of team members will enable them to recognize opportunities that will link them to useful information. Because construction teams are often in the form of highly fragmented clusters, valuable information lies along the paths that go beyond the clusters. In other words, the communication ties between different

Table 4. Analysis of the characteristics of successful teams

Characteristics of successful teams	Industry: Nonconstruction	Industry: Construction	Number of times cited in the literature	Number of studies appeared
Shared leadership roles	x	—	21	7
Individual and mutual accountability	x	x	16	3
Team purpose	x	—	11	2
Collective work products/Shared goals	x	x	9	1
Problem solving	x	x	45	10
Performance measures	x	—	12	4
Trust and commitment	x	x	77	19
Dispute resolution	x	x	83	22
Group culture	x	—	3	1
Effective/open communication	x	x	57	14
Shared accountability	x	x	22	3
Pride	—	x	7	2
Values	—	x	6	3
Reliance	—	x	17	5
Experience	—	x	47	8
Knowledge exchange	x	x	18	11
Information exchange	—	x	23	7
Independence	—	x	2	1

Note: "x" indicates that the characteristics of successful teams that are either published in nonconstruction or construction literature.

clusters contain valuable information. Therefore, construction team members who are seeking valuable information outside their clusters will need an indirect link to these other individuals outside of the cluster.

Social Factors

A network structure does not predict attitudes or behaviors directly (Burt 1992), but instead it predicts the similarities between attitudes and behaviors. In any project, good social relations between the project team members can lead to very effective teams. Team members who support each other and share information can then freely work collaboratively as well as solve any arising issues together. Social relationships, such as project partnering or project alliances, bring together a number of organizations and individuals to work on a project and the structural pattern of the project team will either facilitate or limit their behaviors under such factors as communication, knowledge sharing, and information exchange (Mickan and Rodger 2000). Some researchers both in construction and in nonconstruction industries have looked at the social characteristics of successful teams. Table 4 presents the findings of the characteristics of successful teams as presented in the studies reviewed.

Construction Social Network Model

The study of social networks in construction is in its infancy. As such, a search of the literature in academic databases and construction journals provides only one construction social network model. The model by Chinowsky et al. (2008), as shown in Fig. 4, was developed based on the hypothesis that projects need to be managed as social collaborations to achieve high performance, where social collaboration emphasizes developing teams with high trust and shared values. This model has two components of dynamics and mechanics. However, it is very difficult to separate the concepts of these two components from each other. For example, a communication to pass information can constitute an exchange of knowledge. The dynamics part of the model are the motivators of fostering relationships among team members while the mechanics part serves as the need for an effective relationship. The purpose of the model is to assess the strengths and weaknesses of relationships in teams as social connections, while the focus of the model is the interrelationships between the team members.

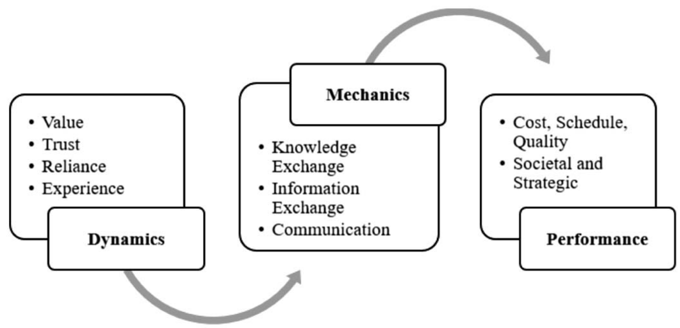

Fig. 4. Construction social model. (Adapted from Chinowsky et al. 2008, © ASCE.)

In another study investigating social network models in construction, Pryke (2004) analyzed construction teams as coalitions to evaluate the difference between the traditional forms of project procurement and the more relational forms of procurement. The difference between the studies of Chinowsky et al. (2008) and Pryke (2004) is that the former looks at interrelationships of individuals in a team while the latter looks at organizations as team members. Pryke (2004), who looked at the social ties between organizations, concluded that by only analyzing social ties at the interpersonnal level the opportunity to understand the impact of performance incentives and contractual relationships on interorganizational relationships is lost (Ruan et al. 2011). Further, Chinowsky et al. (2008) recognized that contractual relationships could affect construction social networks and explained that the instability of construction networks, and that the expectation for construction teams to transition from formation to collaboration rapidly, will affect the social network as well as the performance of the project team.

Discussion

The central figures in a construction project are the human resources, and the success of the project will depend on the coordination of these human resources involved in delivering the project. The different construction project team members involved will constitute top level management down to the lowest laborer at the jobsite. The interaction between these different actors from different backgrounds forms the network. The social behaviors of these actors play a key role on how they interact and thus the quality of relationships within the network. Construction networks are dynamic in that some actors may come late into the project while others leave at different times depending on the completion of assigned responsibilities and activities. Also, the different social factors that exist between the project actors may also keep changing throughout the project.

The construction social network model proposed by Chinowsky et al. (2008), presents the social factors that represent the relational dimension as well as communication representing the structural dimension. In other words, the model achieved in bringing together the individual attributes or characteristics of team members with what drives the individual members' behaviors toward others in the network. The goal of the model is to establish high levels of trust and knowledge exchange through social collaboration and integration. The underlying concept of the construction social network model is that by achieving high levels of trust and focusing on shared goals within a project network, the model will also lead to the increase of information and knowledge exchange, which can translate to high performance in projects. The model further moves away from the traditional measures of project success (i.e., time, cost, quality, productivity, and safety) to emerging issues such as societal and strategic concerns (Chinowsky et al. 2008).

However, the model fails to define how different networks achieve certain levels. Although the quality and efficiency of communication is critical for construction projects, Chinowsky et al. (2008) only mention communication and information exchange in their model, but fail to explicitly define the transition between communication, information, and knowledge. Reflecting on this, a need exists for a better framework to show how relationships are formed and maintained from the project execution through project close out. At the different stages of team member interaction, the status of the relationships can be measured using both the relational and structural dimensions. A clear analysis of the interaction between social factors and relational exchanges within the team members will help to assess the quality of project relationships easily.

Based on the assertion that successful collaborative relationships rely on relational forms of exchange characterized by high levels of trust, the Chinowsky et al. (2008) model seems to be an extension of relational trust proposed by the Rousseau trust model (Rousseau et al. 1998), where the relationship depends on the information that is passed from one team member to another regarding the trust level that exists between the two. Relational trust is derived from the repeated interactions between team members over time (Rousseau et al. 1998). This trust will depend on the previous experiences with the other team member, as well as on benevolence and integrity. Relationships will greatly depend on the *what* of the exchange. Given this, the Chinowsky et al. (2008) model does not present characteristics of team members but rather presents the levels of relational trust that drives exchanges in the network.

Cognizant of the fact that different parties with different backgrounds are solicited to form a construction team and hence a project network and together with the previous literature, a five-step process of relational management tasks in construction networks have been identified (Keast and Hampson 2007; Kickert et al. 1997). These are as follows: (1) *agglomeration*—identifying and selecting team construction team members; (2) *networking*—creating relationships between construction team members; (3) *mobilizing*—bringing construction team members to agree and devote their resources and necessary skills to achieve project goals by aligning individual goals to that of the project; (4) *integrating*—adjusting and promoting social factors through members achieving strategic positions and recruiting new members or removing nonproductive members from the network; and (5) *sustaining*—establishing an innovative culture to deal with issues and conflicts together with proper communication processes.

Conclusion

This paper aimed to explore the mechanisms by which construction networks form, the role or influence of each construction team member in a network and the social factors that influence the interaction of team members. In this regard, the authors explored three social network formation models to understand network formation and application in construction team formation, and highlighted the differences between random, small worlds, and truncated scale-free networks. By comparing the three, the authors identified how each of the social networks emerge in other fields in real life and how that applies to construction project specific teams. Construction project teams emerge as small world networks through the clusters formed as a result of either contractual, professional, task, or trade relationships. However, to understand the interaction between team members, social networks account for the social ties that do not have any formal authority recognized by traditional project contracts.

Considering both the Chinowsky et al. (2008) model and the Rousseau trust model (Rousseau et al. 1998), this paper builds on a theoretical framework that bridges the missing link that exist between them and the arguments they represent. The proposed theoretical framework presents the entire relationship management within a social network model by providing the links between team formation, social networks, and a collaborative team. The theoretical framework provides for the different models of team formation, drivers of a social network that are represented by social factors based on the hypothesis that these two are antecedents of a collaborative project team.

To improve performance in construction networks, project team members need to break clusters by forming links to other team members in another cluster. Forming links will enable team members to access information and resources necessary to improve their performance. Very dense or very sparse networks are not good for efficiency and thus not characteristic of high performing teams. For increased performance, team members need to gain strategic locations by breaking constraints that keep them in a particular cluster either through use of technology-based tools or by freely seeking social relationships with team members who have either complimentary resources or information. To this end the authors hypothesize that truncated scale-free networks are less vulnerable to failure as compared to either random or small world networks, and recommend that construction researchers explore this hypothesis.

Regardless of the industry, social characteristics of high performing teams have been described in the literature. These social characteristics include shared goals, independence, open communication, trust, shared commitment to working together, shared accountability, shared values, and experience. What is common from the previous researchers who have looked at these characteristics is that they have investigated actionable proactive and reactive principles. Further analysis of the construction social model together with the relational trust model reveals that the construction social network model presents the different levels of relationships that exist between construction team members. Relational trust identifies social factors affecting relationships as previous experience, benevolence, and integrity.

In conclusion, this paper contributes to the body of knowledge by bringing together three diverse theories of team formation, social network, and collaborative team into construction engineering and management research while at the same time identifying gaps and areas for future research. In addition, this study reveals that fragmented construction teams are characterized by clusters and resources are constrained from one cluster to the other. As such, construction teams lack bridging ties necessary to reduce social distance between members an area that has received limited attention from researchers.

SNA in construction is a concept in its early stages and it combines social interaction with collaboration between construction project team members. In that regard, this paper recommends the use of SNA to measure the level of collaboration in construction teams using the social factors identified using real data. Also, an in depth analysis can be conducted to determine the relationship between social factors and relational behaviors of construction team members in a construction project.

Data Availability Statement

No data were generated or analyzed during the study. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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