THE USE OF SOCIAL NETWORK ANALYSIS IN LOGISTICS RESEARCH

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INTRODUCTION

Behavioral research in the fields of logistics and supply chain management has been characterized by an over-reliance on the use of the survey methodology, and to a lesser extent case studies (Carter and Ellram 2003; Mentzer and Kahn 1995; Wacker 1998). Yet as recently noted by Parente and Gattiker (2004), practitioners are becoming evermore reluctant to complete questionnaires due to increased workloads, company policies, and the proliferation of survey requests. In addition, survey research works best in areas that can be defined by closed-ended questions, which is not practical in all circumstances. Likewise, case studies have been criticized due to potential difficulties concerning precision of measurement and a lack of quantitative rigor (Kerlinger 1986). For all of these reasons, additional behavioral research methods are needed to triangulate existing findings (McGrath 1982), tackle areas that are not satisfactorily addressed by survey and case study research, and to lessen the burden placed on members of professional organizations such as the Council of Supply Chain Management Professionals (CSCMP) with large-scale, mass mailed survey requests.

One such research method is social network analysis (SNA), which can be applied both within and between organizations in a supply chain. The purpose of this paper is to introduce SNA to the fields of logistics and supply chain management, provide an in-depth example of the use of SNA, and to outline potential future applications of SNA within both an organizational and interorganizational context. The authors provide an example of an application of SNA within an organization that developed and implemented an inbound logistics reporting system that evolved in response to warehousing safety and environmental concerns. This is a substantive topic which has increasingly

been emphasized within the logistics literature focused on socially responsible logistics (Carter and Jennings 2002; Murphy and Poist 2002) and more specifically within logistics and supply chain literature that has examined safety (e.g., Brown 1996; Crum and Morrow 2002; Mejza et al. 2003) and environmental concerns (e.g., Goldsby and Stank 2000; Murphy, Poist, and Braunschweig 1996; Zhu and Sarkis 2004).

Handfield (2002, p. 11) notes that another trend is "an increasing awareness of cross-functional and cross-enterprise decision-making when approaching management problems" in supply chain management research. Although there have been rich research streams examining cross-functional working relationships in certain substantive areas, such as the role of marketing and manufacturing in new product development (e.g., Griffin and Hauser 1996; Houston et al. 2001; McDermott 1999), and a recent call for research that examines cross-functional decision-making (Handfield 2002), there has been scant attention paid toward collecting and analyzing cross-functional data regarding logistics and supply chain initiatives (Pagell and Krause 2004; Zacharia and Mentzer 2004). One useful approach for examining cross-functional interactions in logistics and supply chain initiatives might be to conceptualize the structure of these initiatives from the perspective of relational, social networks (Brass 1984; Fombrun 1986; Lincoln and Miller 1979; Ronchetto, Hutt, and Reingen 1989; Walker 1985). However, the logistics management literature has been basically devoid of research employing SNA (Phillips and Phillips 1998).

From a managerial perspective, SNA is a powerful tool that allows managers to map informal networks of communication and workflow. As organizations increasingly compete based on their ability to manage knowledge (Garvin 1993; Hult et al. 2000; Hult, Ketchen, and Nichols 2003), information is found and work is performed through information networks within firms. Unfortunately, senior executives tend to view these informal networks as unobservable and unmanageable (Cross and Prusak 2002). Yet managers can map, oversee, and influence social networks (Krackhardt and Hanson 2000) through the use of SNA. Organizations increasingly use knowledge of social networks to identify opportunities for internal collaboration (McGregor 2006).

The remainder of the paper is organized as follows. We introduce the SNA methodology in the next section, and discuss its potential applications to logistics and supply chain management research. We then provide an in-depth example of the application of SNA, by introducing a framework and related hypotheses suggesting that individuals can derive influence based on both formal structural variables (such as rank and tenure) as well as informal relationships developed among organizational actors. In the following section, we describe the methodology and report the results from a social network analysis of the 30-member, cross-functional environmental and safety initiative described above. In the final two sections of the paper we consider the managerial and theoretical implications of our findings, discuss the study's limitations and provide suggestions for the future application of SNA by logistics and supply chain management researchers.

SOCIAL NETWORK ANALYSIS (SNA)

Social network analysis (SNA) has been defined as a mapping and investigation of the relations among a group of actors. The relations can represent, for example, friendship, liking, communication, workflow, or the exchange of goods among actors representing individuals, organizations, or even nations (Scott 2000). Social network analysis thus expresses the linkages among actors. This section of the paper highlights the application of SNA to existing organizational research and to extant interorganizational research, with the goal of reviewing and further defining SNA.

Social network analysis is a powerful methodology for describing and analyzing the interrelationships of units or nodes within a network. The nodes of the networks can be individuals, a group of individuals such as a department within an organization, or organizations within a larger network such as a supply chain. Given the flexibility in defining these nodes, SNA can be effectively used to study both organizational and interorganizational phenomena. At the organizational level, the network describes the relationships among individuals or groups within the firm, while at the interorganizational level, SNA has examined the interrelationships of organizations within horizontal and vertical networks. For more complete reviews of this research we refer the reader to Borgatti and Foster (2003), Gulati (1998), and Gulati, Nohria, and Zaheer (2000).

Organizational Research

Network research within organizations has examined the transactional networks, which have focused on the exchange of affect (e.g., friendship, liking), information, or tangibles (workflow) (Tichy, Tushman, and Fombrun 1979). The potential contribution of the SNA methodology is its focus on relationships among actors as the unit of analysis. Unlike the traditional multivariate analyses performed in logistics and supply chain management research, which focus on an actor (usually the individual, and sometimes the organization) as the unit of analysis, SNA focuses on the patterning of relationships among actors in a network. As noted by Fombrun (1982, p. 281):

> In usual survey research and statistical analysis, an interview is regarded as *independent* of others ... whereas in network analysis an individual interview is seen as *part* of some larger structure in which the respondent finds himself. Thus, the individual is not tested independently. He is seen as *embedded* in a context that both constrains and liberates.

The analysis of such interrelationships among individuals within a social network can potentially result in highly revealing findings that would not be achieved with conventional survey and case study methodologies traditionally in the field of logistics and supply chain management. One such benefit of the SNA methodology in organizational research is the discovery of the "hidden" informal organization that can exist within a more formal organizational structure. These informal networks, which consist of the relationships that employees establish with each other, often cut across formal functional boundaries and reporting procedures, and help accomplish difficult initiatives and meet challenging deadlines (Krackhardt and Hanson 2000). The SNA methodology is particularly valuable here, because while:

> managers often pride themselves on understanding how these networks operate ... What's startling is how often they are wrong. Although they may be able to diagram accurately the social links of the five or six people closest to them, their assumptions about employees outside their immediate circle are usually off the mark (Krackhardt and Hanson 2000, p. 104).

Other SNA issues examined within organizational research include the formation and use of connections within a network, a concept that has been labeled 'social capital' (e.g., Walker, Wasserman, and Wellman 1994). Brass (1984), for example, investigates the relationship between an actor's influence and his/her location within an organizational network. Organizational researchers have also used SNA to investigate the relationship between an actor's position within a network and an actor's job performance (e.g., Mehra, Kilduff, and Brass 2001) and promotion within the organization (e.g., Seibert, Kraimer, and Liden 2001). Despite the potential value of SNA, we are unaware of any logistics research employing SNA to examine either organizational or interorganizational contexts.

Interorganizational Research

We review the interorganizational work here to provide a more complete introduction of SNA to the academic logistics audience, and as a background for the last section of the paper where we outline suggested avenues for future application of SNA to logistics research. Most of the existing interorganizational SNA research has occurred in the strategic management arena, where researchers have examined the interrelationships among organizations in a variety of social networks, including supplier relationships (Dyer 1996), interlocking directorates (e.g., Pettigrew 1992), and horizontal alliances (Nohria and Garcia-Pont 1991). Much of this SNA research has focused on strategic alliances.

Gulati (1995) notes that interorganizational social networks can promote trust and reduce transaction costs by enhancing the ability of firms to gather information about each other, and by reducing the likelihood of opportunistic behavior. This latter benefit can occur due to the reputational effects afforded by networks. Opportunistic behavior can not only damage the specific alliance in which it occurs, but other alliances within the network as well. Further, such opportunistic behavior can damage the potential to form future alliances, since new alliances often arise for firms through their existing network of alliances (Gulati 1998).

The social network in which a firm is embedded can be likened to a set of inimitable and non-substitutable resources (e.g., Barney 1991; Wernerfelt 1984). Gulati (1999) refers to these as "network resources," and, along with Burt (1992, 1997), likens these resources to the concept of social capital that had previously been applied to networks of individual actors. Gulati, Nohria, and Zaheer (2000) suggest that the ability of an organization to access key resources through its network of strategic alliances can allow the firm to enhance its competitive advantage. Dyer (1996, p. 271) examines buyer-supplier alliances in the automobile industry and provides empirical evidence that the

creation of "valuable and non-imitable specialized assets ... in combination with other firms" can improve firm performance.

Hite and Hesterly (2001) develop a conceptual framework, which submits that networks and firms within networks evolve over time. The authors propose that as new firms grow, they might begin to more intentionally manage the networks in which they are embedded. Uzzi (1997) conducts an ethnographic study of 23 organizations, and finds that initially, as the embeddedness of interfirm networks increases, benefits such as increased transaction efficiencies accrue to the firms that are embedded within these networks. However, these positive effects reach a peak, at which point further embeddedness actually begins to decrease financial performance by "making firms vulnerable to exogenous shocks or insulating them from information that exists beyond their network" (Uzzi 1997, p. 35). Uzzi (1996) also uses archival data from the apparel industry to demonstrate that embeddedness yields positive economic returns only to a certain extent.

The field of supply chain management has seen very limited application of SNA to interorganizational issues. Some recent exceptions here are the work of Choi, Dooley, and Rungtusanatham (2001) and Choi and Hong (2002). Choi and Hong map the complete supply networks for the center console assembly for an automobile of three separate automobile assemblers. The authors introduce propositions concerning the operations of supply network structures, relating to the structural characteristics of formalization, centralization, and complexity.

Choi, Dooley, and Rungtusanatham (2001) propose that a supply network is more than a simple system, but rather a complex adaptive system consisting of both material and knowledge flow among the upstream firms in a value system. This complex adaptive system differs from more traditional definitions of supply networks, in that Choi, Dooley, and Rungtusanatham view supply networks as emerging rather than resulting from purposeful design. These authors provide conceptual support, however, for the assertion that firms, which understand and deliberately develop their supply networks, will outperform firms which do not do so. While Choi, Dooley, and Rungtusanatham indicate that it may not be possible to establish boundaries for a complete supply network, which would include second, third, fourth tier suppliers and beyond. However, it may be possible to model the network of first tier suppliers, or multiple tiers of suppliers for a key component, using SNA.

The field of logistics, in particular, has been basically devoid of the application of SNA to either organizational or interorganizational contexts. In the next four sections of the paper the authors provide an example of the application of SNA within an organizational, logistics context. First we introduce a conceptual framework and hypotheses regarding the effect that both informal social networks and formal organizational factors might have in socially responsible logistics projects. Afterwards, we describe the SNA methodology and results of testing these hypotheses, and we discuss the implications of our findings.

CONCEPTUAL FRAMEWORK

Informal communication and decision-making in an organization often occur within discrete communication networks (Mintzberg 1979). The influence that an individual (called an actor in the SNA nomenclature) exerts within such a communication network is likely based on the informal position that this actor has within the communication network, as well as formal, structural factors such as the actor's tenure and formal rank within the organization (Brass 1984; Fombrun 1983; Kanter 1979; Pfeffer 1981; Ronchetto, Hutt, and Reingen 1989). We explore the theory behind these factors next.

Emerson (1962) defines power within a dependency framework, where the power of an individual, A, over another individual, B, is "equal" to the degree to which B is dependent on A. Brass (1984) notes that SNA is particularly suitable to the investigation of influence within an organization, since influence involves a social relationship and interdependence among actors. Kanter (1979) has contended that an individual's position, rather than personal characteristics relating to that person's expert or referent power (French and Raven 1959), determines influence. Similarly, Pfeffer (1981) maintains that influence is primarily a structural phenomenon. This paper adopts a similar perspective, which is that while personal attributes of an actor may affect influence, influence is largely determined by both formal and informal structure.

A few studies have investigated the relative effect of informal and formal structure on individual influence. Here, formal structure is defined as the formal rank and tenure that an individual has within an organization, whereas informal structure is delineated by the social networks that develop within organizations. Researchers have empirically demonstrated that rank (Fombrun 1983; Ronchetto, Hutt, and Reingen 1989), network centrality (Brass 1984; Fombrun 1983; Ronchetto, Hutt, and Reingen 1989), and to a lesser degree tenure (French and Rosenstein 1984) affect influence. These researchers define centrality based on Leavitt's (1951) conceptualization as the extent of participation of actors within a network, and utilize Freeman's (1979) dimensions of centrality (degree, betweenness, and closeness) which have been widely adopted within SNA research (Scott 2000). In Appendix A, we provide an explicit illustration of these concepts, which are new to the field of logistics and supply chain management.

Informal Structure and Influence

The empirical research of Brass (1984), Fombrun (1983), and Ronchetto, Hutt, and Reingen (1989), however, has focused on every-day, on-going patterns of communication and workflow. Their findings may differ when applied to a relatively short-term project, particularly within the social responsibility arena. Evidence concerning environmental and social responsibility initiatives suggests that these are often driven by individuals whom Drumwright (1994) calls 'policy entrepreneurs' – individuals who are personally committed to an initiative and have the drive, the political savvy, and connections to oversee the undertaking through to its completion. Drumwright also notes that most of these policy entrepreneurs are not senior managers, but rather middle level employees.

Carter and Jennings (2004) find empirical support for Drumwright's case study conclusions. Thus, for informal projects and initiatives to which one has a high level of personal commitment, formal structural variables such as an individual's rank within the organization may be less important than the person's ability to embed him/herself within a network.

The literature which examines power in organizations also proposes that influence can be derived though the control of information (Mechanic 1962; Pettigrew 1972; Pfeffer 1981). As noted by Brass (1984), actors who are centrally located within a network are more likely to control valuable information and thus more likely to have greater influence. Based on the findings reviewed above, we introduce the following hypothesis:

H1: The centrality of the position of an actor within an organizational network is positively related to the actor's influence in informal logistics projects.

Formal Structure and Influence

We consider two facets of formal structure: formal rank and years of tenure with an organization. Formal rank within an organization can be considered to be equivalent to what French and Raven (1959) term 'legitimate power' – the power that is associated with one's formal position within an organization. While some conflicting evidence exists (Podsakoff and Schriesheim 1985), numerous studies have found a positive relationship between legitimate power and influence. For example, Yukl and Falbe (1991) find that legitimate power is the most important reason why subordinates respond to requests of their supervisors. Brass and Burkhardt (1993) find that an individual's level within an organizational hierarchy relates significantly to others' perceptions of the person's influence. Within the context of a social network, Fombrun (1983) and Ronchetto, Hutt, and Reingen (1989) find empirical evidence that an individual's rank within the organization is positively related to attributed influence. Based on this prior research, we introduce the next hypothesis:

H2: An actor's formal rank within an organization is positively related to the actor's influence in informal logistics projects.

Organizational culture, which consists of multiple, diverse layers (Schein 1984; Trice and Beyer 1984), can be defined as a set of values, beliefs, assumptions, and ways of thinking that are shared by organizational members and taught to new members of an organization (Barney 1986; Chatman and Jehn 1994; Smircich 1983; Wiener 1988). This definition suggests that organizational cultures are complex, and that it can take time to decipher and learn how to maneuver within these systems. One logical assumption is that the longer an actor has been a part of an organization, the better able that actor is to maneuver within the organization, and to exert influence. Some empirical support for this assumption is provided by French and Rosenstein (1984), who found a significant correlation between influence and tenure in a study which examined organizational identification and job satisfaction within a firm which had converted to employee ownership. Conversely, Fombrun (1983) found that seniority was not significantly related to an individual's influence in a social

network of a high technology medical instrument corporation. This theory and these mixed empirical findings lead the authors to tentatively introduce the study's third hypothesis:

H3: An actor's number of years of tenure within an organization is positively related to the actor's influence in informal logistics projects.

METHODOLOGY

Identification of Firm and Project

We used critical case sampling to identify the project for this research. Critical case sampling is a type of purposive sampling (Neuman 1991) that looks for cases that are "particularly information rich or enlightening" in relationship to the questions under consideration (Kuzel 1992; Yin 1994). We identified the SNA project through contact with the Global Environmental Manufacturing Initiative (GEMI 2004), and a request for participation by an organizational member of GEMI which had recently completed a logistics-related environmental, health, and safety (EHS) initiative.

A high-technology firm in the electronics and communications industries, hereafter referred to as Alphexo, subsequently contacted the researchers, indicating a willingness to participate in the research, using an exception reporting (ER) system it had developed as an example. The researchers screened the project by talking to a high-level executive of EHS at Alphexo. That person put the researchers in contact with two of the individuals considered to be among the primary drivers of the project. Several telephone conversations with these two actors ensued, lasting a total of about 4 hours, during which the two actors more fully explained the project. Based on these conversations, the researchers and the EHS executive agreed to proceed with the study.

The ER project involved the development of an information system that provides real time reporting to both Alphexo employees and its suppliers regarding any discrepancies with inbound deliveries – whether it be incorrect items or quantities, damage, or even incorrect packaging or palletizing. This information system was developed because Alphexo had an extremely large number of injuries at its distribution center. When it conducted root cause analysis, it discovered that the injuries were primarily due to problems in supplier palletizing. Suppliers used out-of-specification pallets that caused injury due to poor quality and breakage. In addition, Alphexo had to store pallets for disposal, and employees became injured trying to work around the pallets. Workers palletized products improperly and injuries ensued in the re-palletizing process. The improperly sized pallets also damaged storage racks, causing hundreds of thousands of dollars in damage. Further, Alphexo recognized that these issues had environmental implications, as the company needed to pay for disposal of the pallets and purchase additional pallets rather than reusing inbound pallets.

In order to better track supplier performance and communicate supplier quality issues, such as out-of-specification pallets, the ER system was proposed as a solution. This was a complex task that began as a grassroots EHS effort, cutting across the functions of finance, EHS, purchasing, transportation, warehousing, information technology, packaging engineering, and quality. The ER system

that was developed allows Alphexo to track all supplier non-conformance, including delivery problems as well as pallet issues. It has resulted in over $1 million in savings during the implementation period, and is expected to achieve $5 million in savings in the first full year of its use. We next describe the data collection process used to map the social network that developed within Alphexo to define, create and implement the ER system.

Data Collection

The study's interview protocol is displayed in Appendix B. Data collection began by conducting an initial set of interviews. During the interviews, a technique known as snowballing (Moriarty 1983) was used to identify other actors within the network. Actors were asked to identify other actors whom they had communicated with on at least a monthly basis, on average, during the course of the ER project. Interviews were then scheduled with these additional actors. The network was bounded based on the criteria: *1)* of at least monthly communication with at least one other actor in the network, and *2)* that the actor was an employee of Alphexo located in the organization's North American division. The interviewing continued until no additional actors were identified within the network boundary. Using this process, 33 potential network actors were identified and interviewed. These interviews were conducted both in person at the two primary facilities where the ER project actors were located (one facility in the upper Midwest, the other in the lower Midwest) and via telephone.

Based on the two criteria above, 30 of the 33 initial actors were included in the network. The interviews were tape recorded and then transcribed. Respondents were assured that their replies would be kept confidential. Afterwards, each transcription was compared to the taped interview to ensure accuracy. The interviews ranged in length from between 30 minutes and two hours, with most interviews taking 30 to 45 minutes. In addition to the snowballing technique described above, we further validated the bounding of our network through an open discussion with the core ER team, who suggested that we were not missing any actors within the project.

As shown in Table 1, the functional affiliations of the actors within the network include logistics, information technology, quality, and finance. The term "Supply Chain" in Table 1 refers to actors who are responsible for the management of multiple tiers of facilities within Alphexo's supply chain, whereas "Logistics" and "Purchasing" refer to actors who are primarily responsible for the operations of a single facility.

TABLE 1

FUNCTIONAL AFFILIATIONS OF NETWORK ACTORS

Actor	Functional Affiliation
Actor 1	Information Technology
Actor 2	Purchasing
Actor 3	Logistics (Warehousing)
Actor 4	Logistics (Transportation)
Actor 5	Logistics (Transportation)
Actor 6	Information Technology
Actor 7	Logistics (Transportation)
Actor 8	EHS (Environmental, Health, and Safety)
Actor 9	Supply Chain
Actor 10	Quality
Actor 11	Purchasing
Actor 12	EHS
Actor 13	Packaging Engineering
Actor 14	Purchasing
Actor 15	Logistics (Transportation)
Actor 16	Quality
Actor 17	Logistics (Transportation)
Actor 18	Finance
Actor 19	Supply Chain
Actor 20	Logistics (Warehousing)
Actor 21	Purchasing
Actor 22	Purchasing
Actor 23	Logistics (Warehousing)
Actor 24	Purchasing
Actor 25	Quality
Actor 26	Logistics (Transportation)
Actor 27	EHS
Actor 28	Logistics (Warehousing)
Actor 29	EHS
Actor 30	Purchasing

Independent and dependent variables

We used UCINET 6 (Borgatti, Everett, and Freeman 2002) to calculate the measures of degree, betweenness, and closeness for each actor, based on his or her position within the social network. (Again, see Appendix A for illustrations of these calculations.) Formal rank ranged from a level of four to 15, and was provided to us by Alphexo. The data for an actor's years of tenure with Alphexo were collected during the course of the interviews with each actor. We assessed influence via a four-

item Likert scale (Question 14 of Appendix B) based on the work of Ronchetto, Hutt, and Reingen (1989), along with the number of nominations received by an actor (Brass 1984; Fombrun 1983).

RESULTS

Analysis of Network Data

Table 2 displays the summary statistics for the independent and dependent variables. The interrelationships among the actors in the ER network are displayed in the sociogram in Figure 1. The sociogram helps to illustrate the relative centrality of the actors within the ER network, and complements our quantitative analysis. The figure shows that some actors, such as Actors 8 and 23, are centrally located within the ER network, while other actors, such as Actors 14 and 16, have low centrality.

TABLE 2

SUMMARY STATISTICS OF INDEPENDENT AND DEPENDENT VARIABLES

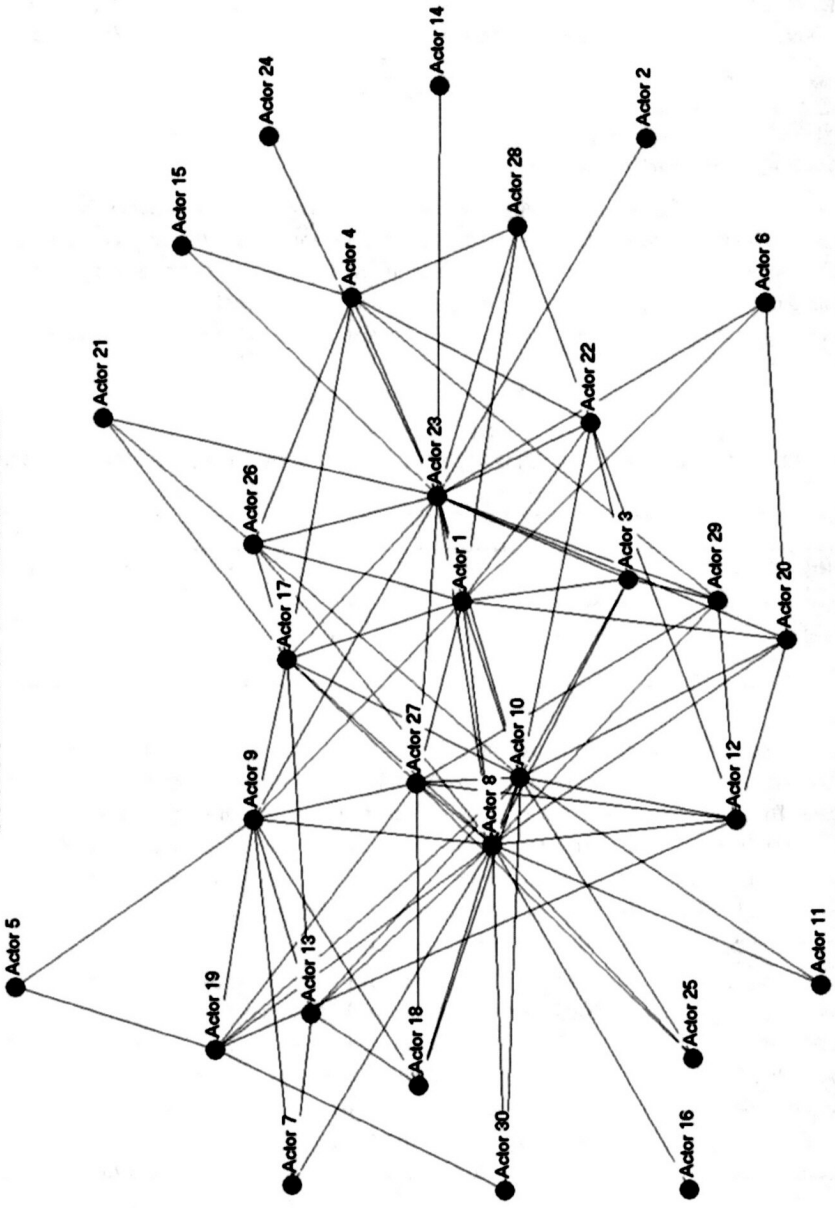
	Mean	Standard Deviation
Network centrality	0.2576	0.1117
Number of years with Alphexo	10.8333	8.3422
Rank	10.0333	2.9651
Influence	2.6632	2.6165

An examination of the correlations between the three measures of network centrality (degree, closeness, and betweenness) indicated very high and positive correlations, of between 0.82 and 0.98. To more formally examine the potential interrelationships among the three measures of centrality, we performed an exploratory factor analysis (EFA) of the three measures, and found that they loaded highly on a single factor which explained 92.28% of the variance. Like Ronchetto, Hutt, and Reingen (1989), we therefore calculated the average of the measures of degree, closeness, and betweenness to create a single, overall measure of centrality.

We performed a confirmatory factor analysis (CFA) of the four-item influence scale, using the CALIS procedure in SAS, Version 8.2. (A total of 118 nominations were received from the interviewees – an average of 3.9 nominations per interviewee.) This CFA indicated a high, positive normalized residual between the third and fourth scale item. An examination of the actual scale items, together with the high normalized residual, suggested that respondents may have viewed these items as being too similar (Gerbing and Anderson 1988). The fourth scale item had a lower factor loading than the third scale item, and for this reason it was dropped from further analyses.

FIGURE 1

SOCIOGRAM OF THE ER NETWORK



Since a CFA cannot be conducted on a single scale with only three items, the remaining three scale items were next subjected to an EFA. The value of the Kaiser-Meyer-Olkin measure of sampling adequacy was equal to 0.74, in excess of the 0.50 recommended minimum. The results of the factor analysis indicated the presence of a single factor, with all factor loadings at or above 0.90 and far above the 0.40 (Hatcher 1994) and even the 0.50 threshold (DeVellis 1991) for an EFA. In addition, the single factor explained 83.95% of the total variance. Scale reliability was also high, with Cronbach's (1951) coefficient alpha value equal to 0.90, far in excess of the 0.70 recommended minimum for established scales (Churchill 1979; Flynn et al. 1990; Van de Ven and Ferry 1978). Finally, in line with Ronchetto, Hutt, and Reingen (1989), we weighted the average responses to these scale items by the number of nominations received.

Data Analysis for Hypothesis Testing

We performed a multiple regression analysis of the 30 actors in Alphexo's ER social network using SAS, to analyze the multivariate relationships posited by the study's hypotheses. This sample size of 30 met the minimum required sample size of six to ten observations per independent variable (Neter, Wasserman, and Kutner 1990). We assessed the occurrence of multicollinearity among the independent variables through an examination of the variance inflation factors (Fox 1991). The largest variance inflation factor was less than 1.4; thus multicollinearity did not appear to be a serious problem.

The results in Table 3 show an adjusted R^2 value of 0.36, which is significant at 0.0019. The standardized parameter estimates and their associated t values are also displayed in the table. While all three parameter estimates are positive and thus in the hypothesized direction, only network centrality is significant with a p-value equal to 0.0002. The results from the regression analysis thus lead to the support of H1, and to the rejection of H2 and H3.

TABLE 3

RESULTS OF REGRESSION ANALYSIS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	85.3449	28.4483	6.53	0.0019
Error	26	113.1924	4.3536		
Corrected Total	29	198.5373			
R-Square	0.4299				
Adjusted R-Square	0.3641				

Parameter Estimates

Independent Variable	Standardized Estimate (β)	t Value	Pr > |t|
Network Centrality	0.6565	4.35	0.0002
Years with Alphexo	0.0894	0.52	0.6054
Organizational Rank	0.0369	0.21	0.8332

DISCUSSION

Research Implications

Our findings are similar to those of Ronchetto, Hutt, and Reingen (1989) and Brass (1984), in that a significant positive relationship was found between centrality and influence (Hypothesis 1). Thus, "being in the right place" appears to be significantly related to an actor's influence. Here, SNA was useful in supporting existing theory. Unlike Ronchetto, Hutt, and Reingen and Fombrun (1983), we do not find a significant relationship between influence and formal rank within the organization. An examination of the sociogram in Figure 1 provides representative illustrations of our empirical findings for a rejection of Hypothesis 2. Actors 8 and 23 have relatively low formal rank while Actors 10 and 27 have comparatively high formal rank; yet all of these actors are relatively central within the ER network. Conversely, at the periphery of the network, Actors 2 and 24 are fairly low in formal rank, while Actors 16 and 30 have relatively high formal rank. These findings demonstrate that SNA can provide interesting and possibly counter-intuitive insights to current theory, when applied to contexts that have not been previously tested. In this case, the new context was an informal project rather than a formal, on-going environment.

Our lack of support for Hypotheses 2 and 3 may well be due to the environment within which the hypotheses were tested. Fombrun (1983) suggests that contextual sources of power exist – that is, that the sources of power, both formal and network, may vary depending upon the context in which they are measured. As opposed to the extant studies, which investigated these relationships within the context of an overall and ongoing, formal buying system or organizational concern, we examined these issues at the informal project level within an EHS context.

The lack of support for Hypothesis 3, which states that an actor's number of years of tenure within an organization is positively related to the actor's influence in socially responsible logistics projects, may be further explained by the high, average tenure of network participants. The mean number of years of tenure within the social network was almost 11, with a range of 2 to 37. Thus it is possible that even actors with only two years of tenure had had enough time to decipher the organizational culture and learn how to maneuver and exert influence within Alphexo.

Our results suggest that in the case of informal logistics projects, network centrality is far more important than either an individual's formal rank or years of tenure within an organization. Our finding of no relationship between influence and formal rank is aligned with the findings of Carter and Jennings (2004) and Drumwright (1994), who found that environmental projects are often developed and managed as informal, grassroots initiatives by "policy entrepreneurs" from the middle ranks of an organization. This is corroborated by our interview findings. For example, when asked about the outcomes of the ER project, Actor 5 stated, "To improve a process, it doesn't have to be this formalized, top-down thing. I was really impressed with these people who took it upon themselves to push this through."

The interview or survey data gathered in the course of SNA can be used to identify other factors that may be associated with an actor's influence or success in a social network. For example, Drumwright notes that policy entrepreneurs are usually skilled at motivating others and "making the system work for them," outside of their formal job roles. The policy entrepreneurs also frequently have high levels of energy and tenacious determination. In the case of Alphexo, Actors 8 and 23 were particularly tenacious and unafraid of contacting others within the organization, while Actor 10 had the political savvy, along with a similar, strong conviction and dedication, to seeing the ER project through to fruition. Several actors within the network recognized these characteristics of the ER project's most centrally located actors:

> The key success factors...I would say the determination and dedication of [Actors 1, 8, 10, and 23] ... their unwillingness to accept 'no' for an answer, I mean their really dogged determination (Actor 13).
>
> Because [Actor 8] was the glue, the passion, the follow up, the diligence, to keep this thing moving. I lent the team some direction and removed some barriers and did some socializing (Actor 10).
>
> They [Actors 8 and 10] stuck with it from day one until now. They have single-handedly been determined to push it through (Actor 11).

It is important to note, however, that it not just the passion of these actors that lead to their ability to wield influence, but rather their central positions within Alphexo's social network.

Another advantage of SNA is that it allows researchers to augment traditional quantitative data collection and analysis techniques with graphical data and an expansion of the unit-of-analysis beyond the individual or even the dyad, to the network. Further, the graphical representations of networks allows a richness and realism that is often lacking with more traditional "quantitative approaches" such as survey and simulation, yet does not force the researcher to surrender this vividness for statistical power.

Managerial Implications

In addition to providing a framework for understanding and applying SNA within logistics, our research provides timely insights into the operations of an organization's internal social network. In particular, in today's business environment, many initiatives are "project" oriented, where a team of people come together to complete a specific task or activity for the benefit of the organization. This could be a six sigma quality project, process redesign, an outsourcing activity, or any other number of team efforts, which are increasingly used in logistics and supply chain management (Lambert, García-Dastugue, and Croxton 2005). The findings from this research tentatively support the notion that factors other than those associated with formal organizational structure may determine the success or failure of these sorts of projects as well.

Our findings have important implications for managers and executives who oversee logistics initiatives within their organizations. In orchestrating logistics initiatives, particularly informal initiatives, managers must understand that an actor's position within a social network is likely to be more important, in terms of deriving influence, than is his or her formal position within the organization. Management must then have at least some comprehension of their organization's social networks in order to effectively leverage this phenomenon. The structure of social networks is not always obvious to managers, or even to the actors within such networks, and executives tend to mismanage or even ignore these networks (Cross and Prusak 2002). Thus logistics managers may need to perform SNA within their organizations in order to gain a greater understanding of what Krackhardt and Hanson (2000) call the "company behind the chart."

Indeed, the use of social network analysis in business is a growing phenomenon. A recent *Business Week* article highlighted this growth, pointing out that such analysis is a good way to find out how things are "really done" in an organization (McGregor 2006). In addition to determining who would be a good logistics project leader, especially when informal networks are important to success, logistics managers and general managers can use SNA to help manage change by choosing leaders who have the respect of peers; to help with succession planning; to identify influential people who may not have position power to informally lead projects; and to discern opportunities for collaboration (McGregor 2006). There is a rich potential application of SNA in logistics and in management in general.

Our description of the application of SNA to the ER project, along with the material in Appendices A and B, provides a fundamental background of this methodology. Additional detailed, introductory information for both managers and researchers regarding how to conduct SNA can be found in texts such as those of Degenne and Forse (1999), Scott (2000), and Wasserman and Faust (1994). An understanding of their organization's social network can help managers to identify and select individuals who are central within these networks to spearhead socially responsible logistics initiatives. These centralized actors have the ability to span the boundary among multiple functions, and can act as brokers in social networks.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Retrospective reports, such as those utilized in this study, are commonly used in supply chain management surveys and case studies (Carter and Ellram 2003), as well as in related fields such as strategic management and organization theory (Miller, Cardinal, and Glick 1997). Evidence from Miller, Cardinal, and Glick (1997, p. 189) suggests that the use of retrospective data is a viable research approach, "... if the measure used to generate the reports is adequately reliable and valid." The authors' use of a structured interview approach helped to achieve internal validity by assuring that responses were measured comparably across actors (Weller and Romney 1988). In addition, the authors maximized reliability by reciprocating interactions in the measures of centrality (Fombrun 1983).

The generalizability of the results of our study is limited, since we examine the social network within a single organization. However, the resources required to gain access to and perform similar analyses with a large number of informants in a firm would have been prohibitive with multiple organizations. Further, this methodology is consistent with prior social network studies which have examined the relationship between structure and influence at the ongoing, organizational level within a single firm (Brass 1984; Fombrun 1983; Ronchetto, Hutt, and Reingen 1989). While we take the perspectives of Pfeffer (1981) and Kanter (1979), that influence is primarily a structural, rather than an individual phenomenon, it is possible that individual characteristics also affect the degree of influence that an individual can exert in a supply chain initiative.

The primary limitations associated with the use of SNA are the potential time and resources associated with data collection. For example, the Vice President of Supply Chain Management for Hewlett-Packard utilized SNA to better understand how to enhance integration between the two subunits which reported to him (Interview 2005). The Vice President stated that while this analysis involved approximately 1,400 labor hours, the benefits were extensive:

> Many of our costs are sunk, and where else should we be spending our time if not on more group productivity? ... The organization was able to pass along details of process innovations throughout the world, much more quickly. We became a more cohesive team. We probably spent over $300,000 on it if you count all of the labor, which is sunk. But it gave me a real tool of who to watch in the organization and who to cultivate. And particularly if a very central person in the organization network left, then I could try to do something to prevent pieces of the organization from becoming isolated.

The fact that the value of SNA can outweigh the costs is further supported by its growing application in business, and the recent formation of a 53 company roundtable of SNA users (McGregor 2006). In addition, it is important to note that in the course of the data collection process with Alphexo often requiring 30 - 45 minutes for each interview, the researchers asked actors to share their perspectives about several project attributes which were outside of the scope of the paper's research. SNA can be efficiently utilized in many organizations by administering a briefer, 10 - 20 minute survey (Cross and Prusak 2002). Depending on the type of data that needs to be gathered, it may be possible to administer a brief, on-line survey to facilitate participation. Finally, SNA is not a technique

which is limited to large organizations; in fact it is in some ways easier to implement SNA with a smaller, known universe of potential network participants.

There are a number of logistics and supply chain managerial applications of SNA besides those provided by the current study and by Hewlett-Packard. An organization might electronically capture email communication between its suppliers and its own members including purchasing, engineering, and operations. SNA could then be employed to better understand whether the purchasing function plays a gate-keeper role between organizational members and suppliers (and, if so, which members of the purchasing function are most central to the network) or whether more direct lines of communication exist between suppliers and internal user groups such as engineering and manufacturing.

At a broader level, organizations could map first and second tiers of their upstream supply chains, as done in a limited way by Choi and Hong (2002). A buying organization might map all of its key suppliers (perhaps defined as suppliers over a certain dollar threshold of purchases, or sole source suppliers) and then ask those suppliers to in turn identify *their* key suppliers (on some predetermined criterion). The creation of such a network might allow the original buying organization to identify the spend of *its* suppliers, and to negotiate volume discounts with second tier suppliers which its first tier suppliers could then take advantage of.

There are also a multitude of potential applications of SNA to future research in supply chain management, including the application of social comparison theory, the development of supplier relationships from a portfolio standpoint, and extending the current, dyadic perspective of interorganizational trust. We conclude by discussing each of these applications of SNA to logistics research.

Social comparison theory (Festinger 1954) and in particular Bott's hypothesis (Bott 1957) suggest that the roles of husbands and wives within a marriage depend on the network of family and friends that surround the couple. If a married couple is embedded in a sparse network, with few friends and family members to rely upon, they tend to help each other by taking on each other's roles to some extent. Similarly, dyad members with relatively few ties may be more willing to cooperate and develop behaviors that benefit both members of the dyad, as opposed to dyad members with greater network ties. Conversely, a buyer-supplier dyad that is centrally located within a network of alliances might have lower levels of opportunistic behavior, due to greater information flow and transparency, and because reputational effects might be magnified for more centrally-located dyads (Gulati 1998). Future research could examine the social networks surrounding buyer-supplier, manufacturer-distributor, or shipper-3PL dyads, to examine the effects of centrality on dyadic cooperation and perceptions of opportunism. For these sorts of studies, actors would consist of dyads of organizations in the supply chain rather than individuals within an organization.

Another application of SNA would be to examine how organizations manage their portfolio of supplier relationships. The resource dependence perspective conveys the importance of the manner in which a focal organization establishes connections with other organizations (Pfeffer and Salancik 1978). More recent work by Uzzi (1996, 1997) has suggested that firms can enhance their

longevity if their interorganizational network consists of a *mix* of both collaborative and arm's length relationships. At the organizational level, Gargiulo and Benassi (2000) find that cohesive communication networks were *less* likely to adapt to changes in new assignments. Logistics researchers could build upon these themes in an interorganizational context, by examining how close, existing relationships between shippers and their carriers might improve performance or, conversely, constrain performance by hindering the establishment of relationships with new carriers. Future research might also expand on the work of Uzzi (1996, 1997), by examining how different portfolios of governance structures within supplier networks relate to the performance of buying organizations.

Finally, an additional area for further research would be to investigate the role of trust within a network context. While the extant literature discusses trust between buyer and supplier organizations (e.g., Doney and Cannon 1997; Ganesan 1994; Johnston et al. 2004; Moberg and Speh 2003; Morgan and Hunt 1994), this interorganizational trust may be at least partly due to personal liking (Nicholson, Compeau, and Sethi 2001; Zaheer, McEvily, and Perrone 1998). Uzzi (1996), for example, found that an individual in one organization who maintained links to two individuals in two separate organizations could act as the go-between and help to create direct trust between these two separate individuals.

In conclusion, SNA is a methodology to collect alternative types of data. In contrast to most of the existing logistics and supply chain management research, SNA focuses on the *relationships* among actors as the unit of analysis rather than on the actors themselves. Social network analysis can thus move our understanding beyond individuals, organizations, or even dyadic relationships between organizations, to a relational model. Our hope is that this paper will stimulate additional logistics research which utilizes this broader, network perspective.

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APPENDIX A

NETWORK CENTRALITY

Networks can be represented by graphs, as displayed in Figure A1, or matrices, as shown in Table A1. The figure, called a sociogram, and the corresponding matrix, called an adjacency matrix, display the communication pattern among five actors. This social network and its actors could represent communication among, for example, households within a neighborhood, individuals within an organization, or organizations within a supply chain.

Notice that the matrix is symmetrical. It is assumed that if Actor 1 communicates with Actor 3, then Actor 3 communicates with Actor 1. Matrices can also be asymmetrical. For example, in the case of affect, if Actor 1 "likes" Actor 3, Actor 3 might not like Actor 1.

FIGURE A1

SOCIOGRAM OF A FIVE-ACTOR NETWORK

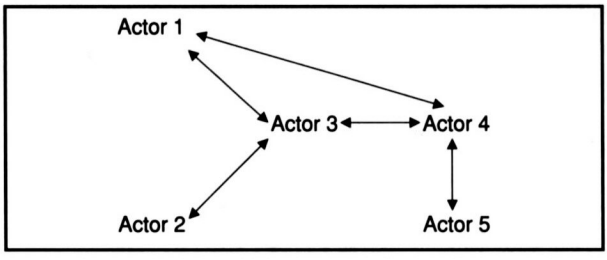

TABLE A1

ADJACENCY MATRIX OF FIVE-ACTOR NETWORK

	Actor 1	Actor 2	Actor 3	Actor 4	Actor 5
Actor 1		0	1	1	0
Actor 2	0		1	0	0
Actor 3	1	1		1	0
Actor 4	1	0	1		1
Actor 5	0	0	0	1	

One of the most important uses of social network analysis (SNA) is the identification of those actors that are most central within the network. Centrality is a structural attribute of the relations among actors in a network rather than an attribute of the actors themselves. The term centrality was defined by Leavitt (1951) as the extent of participation of actors within a network. More recently, Freeman (1979) clarifies this definition through his conceptualization of centrality as measures of degree, betweenness, and closeness. These measures have since been widely accepted by and utilized within SNA (Scott 2000).

Degree refers to the number of ties an actor has to other actors. This can be determined by counting the number of links between a specific actor and the other actors in a sociogram, or by summing a row or column of an adjacency matrix. In the case of the above example, Actor 1 would have a degree of 2 while Actor 5 would have a degree of 1. The degree values for the remaining three actors in the network are shown in column 2 of Table A2. Following extant research in organization theory and SNA (e.g., Brass 1984; Borgatti, Everett, and Freeman 2002; Ronchetto, Hutt, and Reingen 1989), we normalized each of the centrality measures in our study. Normalized degree is calculated by dividing the degree of an actor by N-1, which is the greatest possible degree of an actor in an N by N network. The normalized degree for Actor 1 is 0.50 (2/(5-1)). The normalized degree values of the remaining actors are displayed in column 5 of Table A2.

TABLE A2

MEASURES OF CENTRALITY FOR FIVE-ACTOR NETWORK

Actor	Degree	Closeness	Betweenness	Normalized Degree	Normalized Closeness	Normalized Betweenness
Actor 1	2	6	0	0.50	0.67	0.00
Actor 2	1	8	0	0.25	0.50	0.00
Actor 3	3	5	3	0.75	0.80	0.50
Actor 4	3	5	3	0.75	0.80	0.50
Actor 5	1	8	0	0.25	0.50	0.00

Closeness is the sum of the shortest distance between an Actor and every other actor in the network. From the standpoint of communication and diffusion, a node that is closer to other nodes will likely receive information more rapidly than others. Actor 1 has direct ties with Actors 3 and 4, but must communicate with Actor 3 to reach Actor 2 (the shortest distance between Actor 1 and Actor 2), and must communicate with Actor 4 to reach Actor 5 (the shortest distance between Actor 1 and Actor 5). The sum of these ties generates a closeness score of 6 for Actor 1, as shown in column 3 of Table A2. The normalized closeness scores, displayed in column 6 of the table, are equal to the

theoretical maximum closeness score (N-1) divided by the closeness scores displayed in column 3. Thus for Actor 1, the normalized closeness score is equal to (5-1)/6, or 0.67.

Finally, betweenness refers to the number of paths that pass through an actor on the shortest paths connecting two other actors. Again, from the standpoint of diffusion of information, a node with high betweenness centrality can control communication flows and can potentially serve as a liaison between isolated areas of the network. In the above network, Actor 1 is not between any pairs of the other actors, and has a betweenness score of zero, as shown in column 4 of Table A2; Actor 3 is between Actors 1 and 2, Actors 2 and 4, and Actors 2 and 5, and has a betweenness score of 3. The normalized betweenness score for an actor is equal to the actor's betweenness score divided by the theoretical maximum betweenness score of the network, which is equal to $(N^2 - 3N + 2)/2$. The normalized betweenness score for Actor 3, as shown in column 7 of Table A2, is equal to $3/[(5^2 - 3*5 + 2)/2] = 0.50$.

APPENDIX B

INTERVIEW PROTOCOL

1. Will you please describe your personal role in the ER project?
2. Will you please describe your function's (e.g., the EHS, logistics, quality function, etc.) role in the ER project?
3. What were the drivers of the project?
4. What barriers have you encountered as you worked on this initiative?
   Probe: Were there any areas of disagreement across functions?
5. How were those barriers overcome?
6. What barriers still remain?
7. What were the outcomes of the ER project?
   Probe: Were there any negative outcomes?
8. What were the positive and negative aspects of working on this project?
9. What were the ER project's key success factors?
10. How long have you worked for Alphexo (fictitious name)?
11. How long have you worked in the electronics and communications industry?
12. How long have you worked in your functional area (e.g., logistics, quality, marketing, etc.)
13. Think back to your involvement in the Exception Reporting (ER) project **during the time period from January 2003 until the ER was fully functioning.** Please list all of the individuals with whom you have interacted, **at least once per month,** *on average,* **as part of** the ER project. This interaction could include formal communication (such as email and meetings), as well as informal communication (including phone calls and face-to-face conversation) surrounding the implementation and management of the project.
14. Please list the individuals whom you believe were influential in the ER project. In listing these individuals, please consider 1) direct personal interactions that you had during the course of the

ER project, 2) observations of the individual interacting with others, and 3) perceptions based on your understanding of activities related to the ER project.

Please also rate the individuals' level of influence, by placing a number in each of the four columns following the individuals' names.

How often was/did this individual ...

(1=Never, 2=Very infrequently, 3=Infrequently, 4=Sometimes, 5=Frequently, 6=Very Frequently, 7=Always)

	Item 1	Item 2	Item 3	Item 4
Name	sought out for advice about the ER project?	included in discussions about the ER project before decisions were made?	active in developing informal agreements among co-workers as part of the project?	influence co-workers to "stick together" in resolving problems surrounding the ER project?

ABOUT THE AUTHORS

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