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Cracking the Code of Process Safety Culture with Organizational Network Analysis

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Abstract

Organizations in the chemical process industry invest considerable amounts of time and resources managing change and implementing best practices to maintain safe operations and achieve operational objectives. Consequently, most executives and senior managers responsible for performance rely on formal organizational structure to achieve these objectives. However, front line employees responsible for ensuring safe operation of hazardous chemical processes are often influenced more by the informal than the formal organization in their daily activities. The dynamics of informal networks among workers are critical determinants of strong operational discipline (OD), process safety culture, and business performance. Yet, organizational social networks are often overlooked or not well understood by management. We discuss how organizational network analysis (ONA) may improve our understanding of process safety culture. We also share results from our exploratory study that used a novel survey instrument to measure OD at the individual level in conjunction with a social network survey indicating interaction for the exchange of job task performance and process safety advice, respectively.

1. Introduction: Process Safety Culture and Networks

Process safety is focused on the prevention of major accidents involving hazardous chemical processes. More broadly, process safety is a subset of major accident hazards involving operations that have the potential for catastrophe (e.g., aviation, mining, oil drilling, etc.). Due to the infrequent nature of these types of accidents, a special focus is required by organizations to successfully manage these hazards. Contrary to typical personal safety programs that are focused on the reduction of more frequent and less severe incidents, excellence in process safety requires an awareness of subtle warning signs and a robust corrective response to improve the associated management systems. In fact, too much of a focus on personal safety incidents has been shown to contribute to complacency about major accident hazards [1]. Consequently, it is imperative that the process safety culture be managed separate from other personal safety initiatives and with a continuous improvement philosophy [2]. In order to improve the process safety culture, it is first necessary to define culture generally and provide characteristics of those that are successful. Many attempts have been made to describe culture and although definitions vary, it has been commonly described as [3]:

> *Shared values (what is important) and beliefs (how things work) that interact with an organization's structures and control systems to produce behavioral norms (the way we do things around here).*

Strong cultures are aligned and disciplined leading to decisions that are consistent with organizational values, behaviors, and norms from the highest levels of senior management all the way down to the front line worker. Setting the organizational tone from the top, management leadership is critical to establishing strong process safety culture and OD. However, leadership does not necessarily reside solely in the formal chain of command as defined by the organizational chart. Ultimately, all workers should assume a level of leadership within their teams when called upon in order for a process safety system to be effective. Good leadership includes an element of empowerment which enables each and every employee to act in a manner consistent with the values of the organization. Strong process safety cultures that exhibit OD [4] are more likely to recognize abnormal events and consistently "do the right thing" when confronted with unprecedented situations. Another trait is that individuals proactively consider internal and external learning opportunities that are shared and incorporated throughout the organization in a systematic manner to prevent future incidents. The hearts of strong process safety cultures endure because individuals are connected in a continuous cycle of commitment, understanding, managing, and learning over the life of the organization. Like a state of grace, a safety culture is something that is striven for but rarely attained…the virtue, and the reward, lies in the process rather than the outcome [5].

The strength of safety cultures has been assessed by organizations through various frameworks and considered in the context of progression through maturity levels. The Energy Institute has published a toolkit [6] that describes a five step process (pathological, reactive, calculative, proactive, and generative) to improving safety culture. In collaboration with the Shell Group, the Energy Institute provides a set of tools and techniques that can be deployed by organizations to assess and improve the safety culture of organizations. Similarly, the DuPont Bradley Curve [7] illustrates four stages of maturity consisting of reactive, dependent, independent, and

interdependent where empirical evidence suggests a decreasing relationship with incident rate as organizations progress along the curve. We postulate that as organizations shift from a reactive to a proactive culture that employee relationships within the organization become more interdependent and collaborative leading to an increased connectivity that can be measured through organizational network analysis.

It's been said that if the formal organizational structure is the skeleton of the company, then the informal is the central nervous system [8]. Few would argue against the importance of formal reporting structures that establish clear accountability and responsibilities for managing decisions and risks in any organization. However, one may offer a sensible argument that informal relationships are equally important factors required to achieve successful execution of organizational objectives. For example, evidence of unconventional strategies used by informal leaders who do not have formal leadership authority in the company has been discussed by Berger [9] based on experience and anecdotes from process safety professionals. In recognition of the importance of informal relations to organizational effectiveness, this study applies fundamental management science concepts commonly utilized to understand informal networks and measure cultural indicators of process safety and OD. Much of the existing guidance published in the literature on process safety culture focuses on the performance of management systems and attitudinal responses toward these systems. This study takes a more relationship-based approach to understand communication patterns and the flow of process safety information through a manufacturing network. By identifying informal leaders in the organization and clusters of process safety excellence, this technique can equip leadership with actionable insights to better manage organizational change, transfer of knowledge, and efficiently implement risk reduction programs.

2. Organizational Network Analysis

2.1 History

Even new employees quickly realize that formal structure, the official relationships described by official chains of command and accountability, does not fully describe how things get done within the organization. Indeed, it has now become a well-established fact that informal networks, the patterns of interaction and relationship that develop among people in a manner independent of officially specified relationships, can make big differences in how groups of people perform and how they experience their work. [8, 10-11]. Actually dating back at least to the seminal work of Moreno [12], social network analysis (SNA) has expanded dramatically in more recent decades to provide insight into a broad range of social phenomena including many critical to organizational effectiveness such as advantage within career contexts [13], creativity and innovation [14], organizational identification [15], information transfer [16], and organizational change [17].

2.2 Fundamentals

Essential to our discussion of SNA is the understanding of relationships (ties) between specific pairs of people. As intuition suggests, a tie between two individuals indicates a specific relation operating between them. For example, it may be of interest to understand who is going to whom

for advice on how to properly perform tasks within a working group. A network analysis might then examine the relation called "task advice" and obtain from each person the list of other people that person turns to for advice at work. Figure 1 depicts an advice tie between hypothetical persons John and Jim.

Figure 1: Depiction of directed and undirected network ties for an advice network

It is important to note here that Figure 1 provides examples of both a directed network tie and an undirected network tie. For understanding advice relations, directed networks are most useful when we consider the question of exactly who is indicating whom as the target of a certain kind of interaction is of particular importance. We can also do analysis based on *undirected* network ties in cases where we are only concerned with whether a given kind of relationship exists between two individuals. Figure 1 illustrates the simplest *dyadic* relationship, but identifying and understanding larger structures comprised of multiple relationships calls for more sophisticated methods than the basic visual analysis we have engaged in thus far. Even a very simple social network that involves multiple relationships (Figure 2) can be sufficiently complex so as to make important observations hard

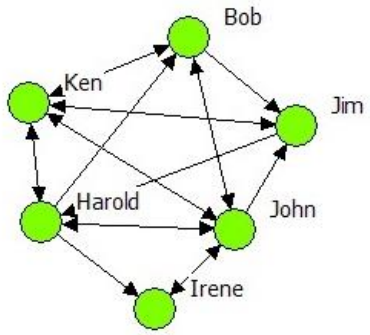

Figure 2: Depiction of a network tie

to uncover without the use of network analysis tools and techniques. Our further examination of social network structures and their relevance to understanding the relational underpinnings of process safety may be more clearly understood with some basic metrics from ONA kept in mind. Figure 3 provides a structural example we will use to describe each of these measures in turn. Many other centrality measures exist, but we shall focus on some of the most commonly applied.

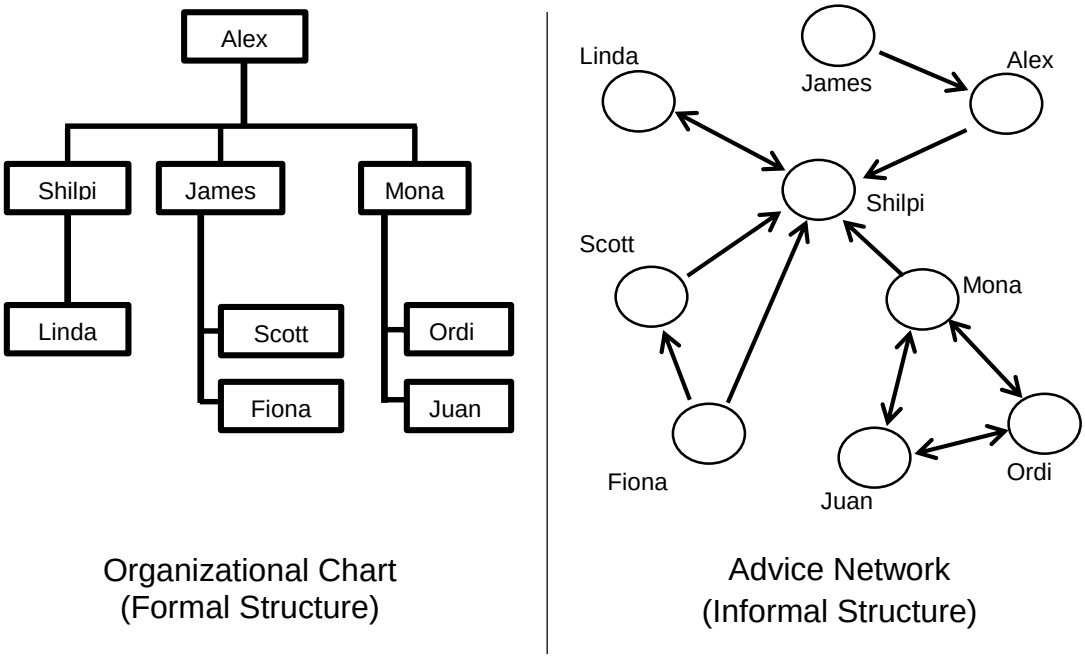

Figure 3. An example organizational network with corresponding formal organizational structure

2.3 Social Network Metrics

2.3.1 Describing Individuals

Degree centrality is the simplest of the network centrality measures. This describes literally how many direct connections (ties) a given individual has within a given network. Like other centrality measures, degree can be considered in both directed and undirected forms. If direction of the tie is not considered important, then each link a person has with another person contributes to the value of degree centrality. For example, in Figure 3 we can observe that Shilpi interacts with 5 other people, and so we can describe her undirected degree centrality as 5. Through similar reasoning we can see that Alex has undirected degree of 2, Ordi has undirected degree of 2 and James has undirected degree of 1. Undirected degree centrality does not consider the directions of ties, but in many case the direction a tie is going is important to an interpretation. Figure 3 depicts an advice network, so the direction of a tie may tell an important part of the story regarding who is an important source of information for other people or who is most active in seeking useful information for doing work tasks. For example, 5 people turn to Shilpi for advice while no one in this network goes to James for advice, suggesting rather different impact of these individuals' respective expertise. Already we are beginning to see how social network centrality may provide insight regarding which people in the network may have greater influence, be more important to the transmission of information, or represent a critical point of failure in communication to name just a few possibilities. *In-degree* is a term used to describe how many network ties are directed to a given actor, so Shilpi's in-degree is 5, James's in-degree is 0, and Scott's in-degree is 1. *Out-degree* is the metric used to describe how many ties a given actor is sending outward (e.g. Ordi's out-degree is 2).

Betweenness centrality is generally understood to be the most predictive measure within social networks when it comes to power and influence within groups [18-19]. This measure describes the extent to which a given individual is along the shortest path between pairs of other actors within the network. Referring to Figure 3 again for an example, the fact that Shilpi is along any path from Linda to anyone else in the network contributes to Shilpi's betweenness centrality. When members of the network have shorter paths to others without going through a given individual, that individual's betweenness is reduced. Betweenness can correlate highly with the ability to form a bridge between important groups that are otherwise disconnected from each other or to act as a broker for information.

2.3.2 Describing Groups and the Network as a Whole

Often social network analysis aims to describe groups of people within the network or the network as a whole. Good examples of this that we also illustrate using data from our exploratory study are the network *density* and *E-I Index*.

Network density is a network level measure that is simply the ratio of the number of network ties present in the network to the number of network ties possible. A sparse network has relatively few people connected with each other while a dense network has very many people connected with each other. A very dense network may reflect abundant communication, sharing of knowledge and collaboration. At the same time, a very dense network may be interpreted as reflecting some extent of inefficiency since it may be possible to provide many of the same benefits of density through appropriately placed hubs of communication within the network. Notably, the word "appropriate" can bring with it very challenging questions as sparser networks may be more prone to single points of failure and key individuals may be experiencing communication overload.

The *E-I Index* [22] is a group measure that describes the difference between the number of within-group ties and the number of between-group ties among a set of people. E-I index can be a very useful metric of how likely it is that ideas or knowledge are being shared across subgroups whether those subgroups are a result of formal structure (e.g. departments, teams) or a consequence of emergent or other natural affiliations (e.g. interest groups, communities of practice, common demographics). A group characterized by the lowest E-I index possible (-1) only has ties within the group with no ties between group members and others outside of the group. Such a group is likely to be in some sense an echo chamber in which the same ideas or same pieces of knowledge are always in play. Such a completely closed group may also have a harder time understanding or influencing the broader picture for the larger organization or collective that the group is a part of. Groups with higher E-I index values (up to a maximum value of 1) have more external ties than internal ones and may be more integrated with the broader organization or community. High E-I index has been associated with more effective response to crisis [22] as well as the facilitation of successful organizational change [23]. For further insight helpful in understanding the foundations and formulations of these and other common social network centrality measures, the reader may wish to consult Freeman [18] or Brass [21].

3. Case Study of a Manufacturing Facility

3.1 The Site

The site selected for this study is a chemical production facility located in North America. At this location, there are approximately 120 full-time employees that directly or indirectly support five separate production units with nine auxiliary support departments. This facility is strategic to the North American business region due to the flexible production processes and contribution to company profitability. Of the overall employee population, 87 participants involved in directly managing the process engaged in the voluntary survey, whereas the remaining non-participants primarily consisted of indirect support roles.

3.2 Data Collection

3.2.1 Social Networks

Data for this study were obtained via a survey instrument designed to collect information related to advice networks and elements of individual OD. Our objective was to elicit responses that would indicate communication ties between individuals when they are seeking information related to job task execution (Technical Advice Network) and information related to hazardous conditions (Safety Advice Network). For each network, the survey questionnaire asked participants to indicate whom they interacted with from a site roster, and the strength of this interaction was indicated by the respondent's specification of a frequency. For example, participants were asked to place a checkmark by the name of the individuals and select whether this interaction was approximately once per day, week, month, year, or not at all. Exhibit 1 provides a representation of both surveys used in the study.

Technical Advice Network

1) Below you will find a list of names of many people who work here. Some of these people you may seek advice from quite frequently; others you may not go to very much at all.

In this section we are interested in who you go to when you need **task-related information, technical advice, or help executing job tasks**.

More specifically, try to recall who you go to **daily, weekly, monthly, yearly, or not at all**. This may be in person, by e-mail, or on the phone.

Please indicate your answer by placing **a single checkmark** that corresponds to the frequency you go to that person: daily, weekly, monthly, yearly, none, or N/A.

Review each name and place a checkmark to the right of each name.

Examples

1. If you go to John 1 or more times per day, then check "daily".
2. If you go to Jane about 1 to 2 times per week, then check "weekly".
3. If you go to James about 1 to 2 times per month, then check "monthly".
4. If you go to Jessica about 1 to 6 times per year, then check "yearly".
5. If you do not go to Julian, then check "none".
6. If you do not know Jennifer, then check "not applicable".

Lastly, if someone is NOT on this this list and you do go to them for advice, please write their name at the bottom and check the appropriate frequency.

First Name	Last Name	Daily	Weekly	Monthly	Yearly	None	N/A
Amanda	Smith						
Brian	Jones						
Chris	Doe						

Safety Advice Network

2) Below you will find a list of names of many people who work here. Some of these people you may seek advice from quite frequently; others you may not go to very much at all.

In this section we are interested in who you go to about **safety-related matters or when you observe a potentially hazardous situation and it needs to be addressed**.

More specifically, try to recall who you go to **daily, weekly, monthly, yearly, or not at all**. This may be in person, by e-mail, or on the phone.

Please indicate your answer by placing **a single checkmark** that corresponds to the frequency you go to that person: daily, weekly, monthly, yearly, none, or N/A.

Review each name and place a checkmark to the right of each name.

Examples

1. If you go to John 1 or more times per day, then check "daily".
2. If you go to Jane about 1 to 2 times per week, then check "weekly".
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5. If you do not go to Julian, then check "none".
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Lastly, if someone is NOT on this this list and you do go to them for advice, please write their name at the bottom and check the appropriate frequency.

First Name	Last Name	Daily	Weekly	Monthly	Yearly	None	N/A
Amanda	Smith						
Brian	Jones						
Chris	Doe						

Exhibit 1: Example of the Survey Instrument for the Technical Advice and Safety Advice Networks

3.2.2 Operational Discipline

Operational discipline was assessed by asking each survey participant to answer twelve process safety-related questions focused on elements of commitment, knowledge, and awareness [4]. The survey was designed to measure the strength of individual OD by assigning points to each question. A representative set of questions were developed based on site experience and relevance to current safety training programs. Commitment element was evaluated by questions intended to probe attitudes toward safety responsibility and adherence toward standard operating procedures. The knowledge component was assessed based on the correctness of responses to requirements for personal protective equipment (PPE), restricted occupancy zones, and fundamentals of process safety. The awareness component was assessed based on questions related to flammability hazards and safeguards including fire mitigation systems. The following is a representative sample of questions included in the questionnaire for each of the elements of OD: (A) commitment, (B) knowledge, and (C) awareness.

A. Which of the following statements do you agree with the most? Check one.
    - ☐ Individuals are responsible for ensuring their own safety.
    - ☐ Safety is a matter of luck and accidents are just a part of the job.
    - ☐ Supervisors are responsible for ensuring the safety of individuals.
    - ☐ Employees are responsible for ensuring one another's safety.
B. Where do you obtain hazard information and PPE needed for tasks you perform?
C. Are you aware of any potential ignition sources in your area that could cause a fire? If so, please list them.

The survey instrument was deployed by the co-authors and completed in small groups with participants from each of the operating units or departments. The personal nature of the face-to-face interaction was preferred over an electronic survey mechanism in order to provide more transparency, minimize distractions during the survey, and improve the quality of the responses. Although manual data collection and subsequent digitization was significantly more resource intensive, the benefits of personal engagement with each employee exceeded the efficiency gains of an electronic survey. Engaging with each employee that participated in the survey proved to be an effective means for demonstrating leadership commitment and providing a forum for discussing the importance of a strong safety culture. Furthermore, being present during the survey allowed participants to seek clarification before, during, and after the survey that improved the quality of the data collected. The survey requested demographic information (e.g., name, department, and tenure) from each participant, but all survey data was coded anonymously so that confidentiality could be maintained in the future when sharing the results in large groups.

It should be acknowledged that this ONA was coordinated jointly with a safety culture maturity assessment that evaluated the organization relative to the cultural "ladder" model [6]. The safety culture assessment consisted of a two-part study: 1) anonymous electronic questionnaire and 2) subsequent on-site small group feedback sessions. The ONA was conducted during the on-site feedback sessions but in separate group meetings. This joint approach was valuable since it established a baseline of safety culture which can be used to develop correlations over time between informal network interactions and overall safety culture maturity.

3.3 Network Analysis

Social network data were examined using a combination of analysis options found in UCINET 6 [25] and network analysis routines provided by the open source statistical programing language known as R. The network measures discussed earlier in this paper were performed on both the Technical Advice and Safety Advice networks obtained through two respective social network questionnaires. All results presented here were obtained using network data in dichotomized form. This means that a threshold value was applied to the tie strengths provided by the network questionnaire respondents, with ties having strength lower than or equal to that threshold being recoded to zero and tie strengths above that threshold being recoded to 1. The threshold tie strength chosen corresponds to the determination that, for a network interaction to be of interest for our analysis, daily (tie strength = 5) and weekly (tie strength=4) frequencies of interaction were expected to be the most meaningful within the organizational context.

3.4 Findings

3.4.1 Network Observations

Networks as a Whole

Figures 4 and 5 are visualizations of the Technical Advice and Safety Advice networks, respectively. These figures are color-coded to indicate different departments that respective individuals belong to. A visual inspection of the two networks indicates well what the data in Table 1 shows. The Technical Advice network is the denser one, containing 556 more ties with slightly more ties crossing departmental boundaries than are observed in the Safety Advice network, as indicated by E-I index. Not surprisingly, most of the frequent communication occurring within the organization under examination is related to the performance of work tasks with considerable but less communication being centered around matters of safety. This does not necessarily indicate any weakness in the organization's knowledge sharing with respect to safety.

A possible explanation for the difference in network density is that interactions regarding safety are concentrated around highly deliberate events such as periodic training or safety meetings within the organization. It may also be that safety discipline is powerfully instilled in the workforce and concrete resources are sufficiently available for consultation that seeking advice from others on related topics is deemed less necessary for most people. Another consideration that could explain the differences in network density is the frequency of tasks that require safety interactions to be a necessary aspect of the job. A program intended to increase these types of informal interactions is a behavioral-based safety observation program. It is reasonable to expect that as the number of safety interactions increases within the network, individuals would have more connections to others throughout the organization. This would be especially true in programs where behavioral-based safety observations are mandatory and require individuals from different departments to engage in positive interactions with co-workers. These positive interactions can lead to increased cohesiveness within the network and a higher probability of knowledge transfer.

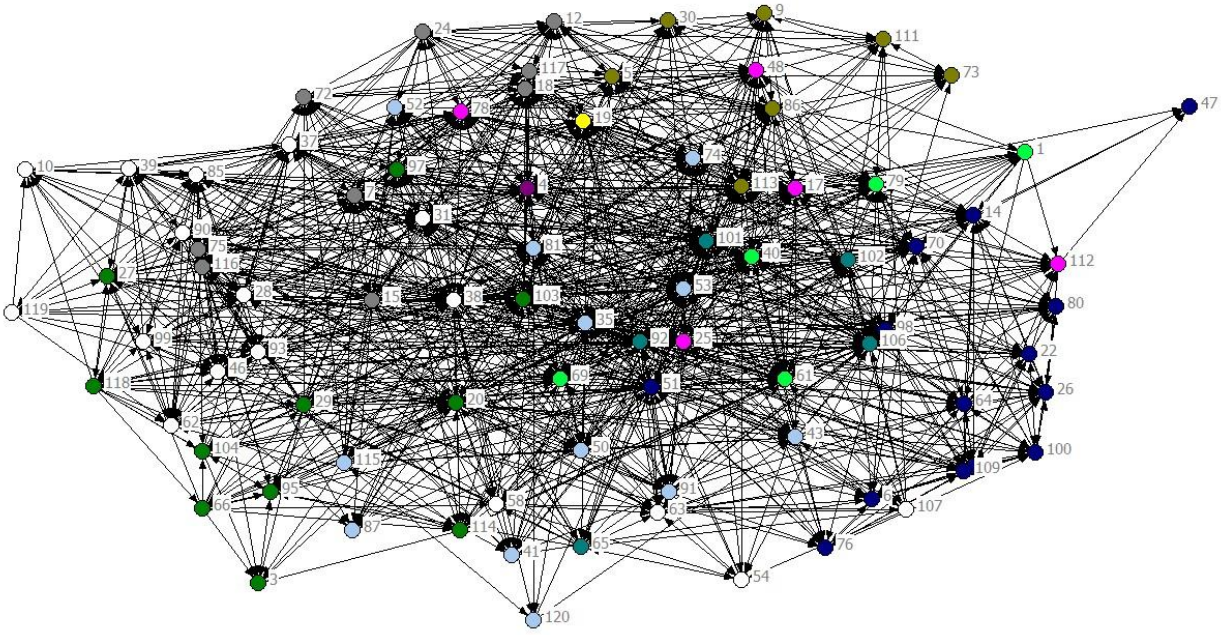

Figure 4. Technical Advice Network

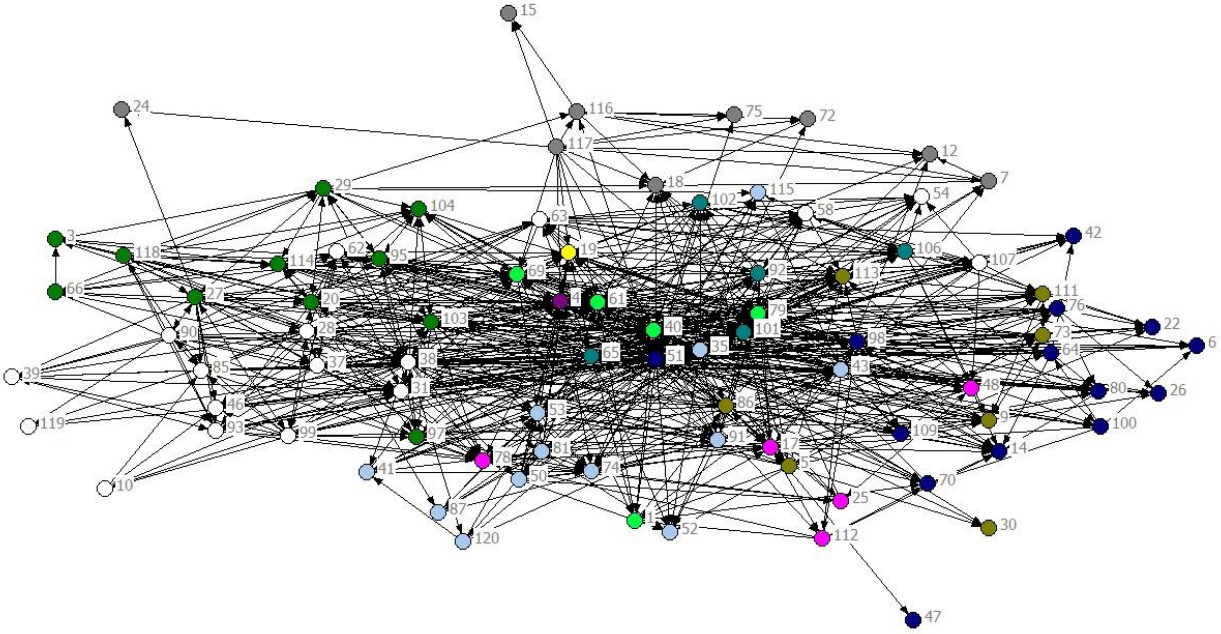

Figure 5. Safety Advice Network

	Technical Advice Network	Safety Advice Network
Number of Ties	1431	875
Average Number of Ties Per Person	16.448	10.057
Density	0.191	0.117
E-I Indext	-0.549	-0.099

Table 1. Whole Network Metrics for Technical Advice and Safety Advice Networks

Network Metrics at the Individual Level

At the individual level, social network analysis can yield insight into who the high-impact players are and how those people differ with their colleagues with respect to given types of relations. Indeed, there are key network roles that individuals may have that management and others concerned with understanding and influencing the organization better would do well to identify such as central connectors, information brokers, and boundary spanners [8]. These roles are largely defined (structurally) in terms of the centrality metrics we have discussed above.

High betweenness centrality may correspond with a person being an important waypoint for information or ideas within the network as they work their way from one member to another. People high in betweenness may also be able to exert significant control over the awareness others can develop through informal connection, acting as gateways that can be more or less willing to share or that can modify content as it passes through. High-betweenness individuals may also enjoy both political and knowledge advantages over some others in the network due to their bridging or gateway positions. Figure 6 depicts the Safety Advice network, with the network nodes (again, representing people within the organization) sized to reflect relative differences in betweenness centrality.

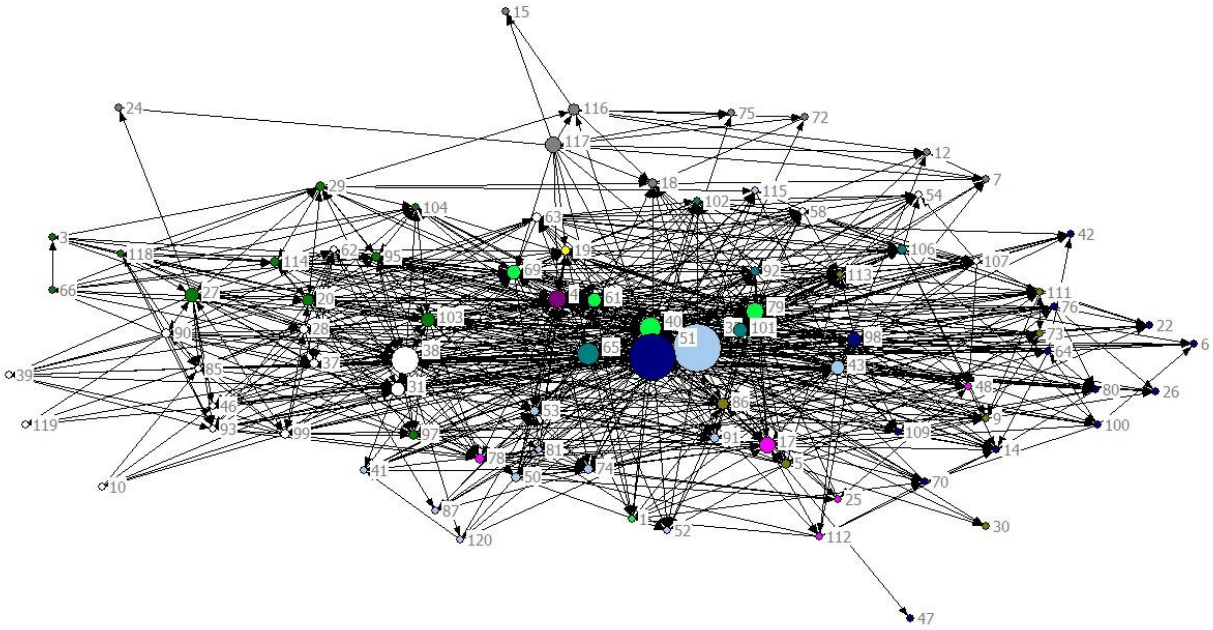

Figure 6. Betweenness Centrality in the Safety Advice Network

Figure 6 reveals three individuals of particularly high betweenness centrality, ID numbers 35, 38, and 51. Already in the formal role of "Team Leader," ID 38 likely has ample opportunities to apply the benefits of his or her network centrality in performing this official role and is likely to be both more aware and more capable of accessing richer sources of information and support. Perhaps more revealing of the influential dynamic within the informal organization is the observation that ID 35 and ID 51 are operations and maintenance technicians, respectively, who do not have formal leadership authority. It is apparent that these individuals given their high betweenness measures serve as conduits of information throughout the technical and safety advice networks. Furthermore, ID 35 was an operations technician with over forty years of experience who had retired shortly after the survey. This demonstrates the importance of succession planning and the insights of this network analysis to maintain continuity of the operation.

Individuals high in degree centrality may also be important in facilitating the rapid spread of information or ideas within a network. Their numerous connections mean that a larger number of people can engage in exchange with them within a given period of time and that more people in general are likely to be exposed to the content of their communication. In this case study, it so happens that the same individuals who were in the top three with respect to betweenness centrality also formed the top three in degree centrality using undirected ties.

3.4.2 Knowledge Question Results

A key component of this exploratory study was the deployment of an OD questionnaire. The questions administered were not intended to be an exhaustive assessment of personnel knowledge levels and preferences. These questions were administered in order to provide some basis for the comparison of groups and individuals with respect to general understanding of standard safety definitions and procedures. For evaluation, each of the twelve OD questions was assigned a level of points (0, 1, or 2) for a maximum of 24 points. Table 2 provides descriptive statistics for the 87 participants that completed the survey.

n	87
Mean	13.2
Standard Deviation	3.2
Minimum	8
Maximum	20
95th Percentile	19

Table 2. Descriptive Statistics for the Operational Discipline Questionnaire

In order to understand whether centrality within social networks has any correlation with OD in our data, we plotted degree centrality and betweenness centrality as a function of OD (Figure 7). In this analysis, we don't suggest a direct causal relationship between centrality measures and OD but entertain the idea that a correlation exists between these factors. Consequently, an apparent pattern emerged by differentiating the two dimensional plot into four quadrants representing various degrees of OD and network centrality. Analogous to a two dimensional risk matrix, it's interesting to consider the influence/OD matrix in the context of how frequent and impactful interactions are within network. The first quadrant (I) consists of individuals that have low OD and low influence. The second quadrant (II) consists of individuals with low OD and high influence. The third quadrant (III) consists of individuals with high OD and high influence. The fourth quadrant (IV) consists of individuals with high OD and low influence.

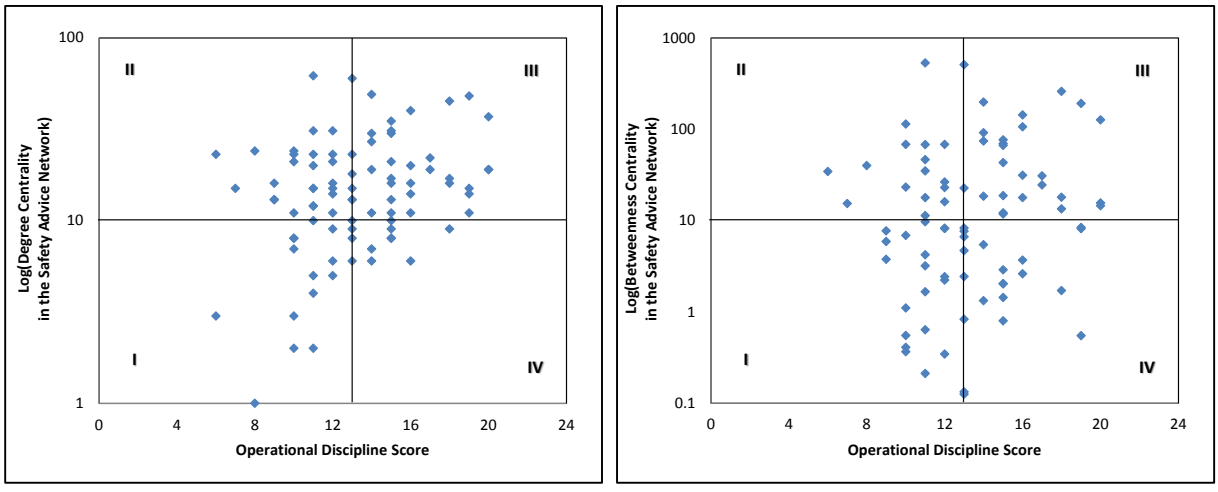

Figure 7. Degree and Betweenness Centrality Measures as a Function of OD Scores

This approach, and others like it that explicitly incorporate a relational perspective by quantifying social structure, could drive the next generation of developmental interventions for increasing operational discipline. For instance, individuals in quadrant I could be targeted through periodic refresher training and more frequent interactions by individuals more central to the network (e.g, quadrant III individuals). These quadrants may even represent key network roles that support both broader and deeper examinations of the state of process safety culture and risk vulnerability within organizations.

Considering Subgroups: The Example of Departments

ONA provides excellent capability to examine subgroups within organizations, and departments are a common kind of subgroup of interest. Departments typically have their own areas of specialization, their own leadership, and their own functional roles with respect to the broader objectives of the organization. Figure 8 provides a visualization of social structure with emphasis on departmental membership using data from our study.

The layout applied in Figure 8 illustrates very easily how some departments may differ in terms of how many members they have who have broader influence within the organization. We can also note that many departments seem to have a single prominent individual with respect to network centrality, and those people may be particularly critical to the effectiveness of the department as well as important to the network as a whole.

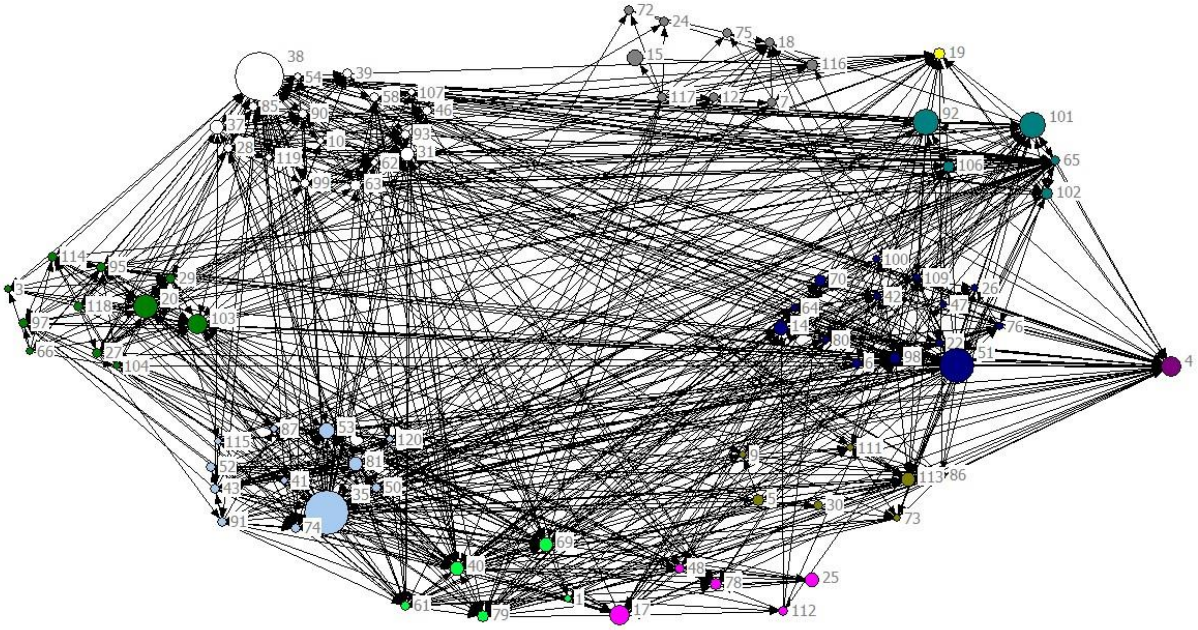

Figure 8. Betweenness Centrality in the Safety Advice Network, Departmental Layout

A departmental level analysis may also include consideration of the E-I index of each. A very low E-I index for a department may indicate a group of people who need more engagement with

the broader organization in the interest of allowing departmental members to develop a high level of understanding regarding organizational level goals or other developments elsewhere in the organization. This is particularly relevant in organizations where operational decisions require approvals from various departments. For example, management of change (MOC), pre-startup safety reviews (PSSRs), hazard identification and risk analysis (HIRA), and planned general inspections (PGIs) are process safety management systems that often entail review and approval from different departmental representatives. In network analysis, very cohesive groups that engage in more isolated decision making have a tendency to exhibit Group Think behavior in that they fail to consider alternative viewpoints and external opinions. This can be detrimental to the performance of the organization as was the case in the Challenger Space Shuttle disaster and is a phenomenon that contributes to other major accidents. Alternatively, instituting organizational management of change policies to cross-pollinate individuals across departments is an effective strategy to increase network ties, reduce silos, and improve organizational decision making.

4. Conclusion

We present a relational perspective on operational discipline to the process safety community along with a case study in applying organizational network analysis (ONA) to develop deeper insight into key leverage points for affecting knowledge and shared values with respect to process safety culture. ONA frees organizations from the restrictions and blind spots that come with overly emphasizing formal authority structures and official roles in driving and interpreting organizational behavior. Using such knowledge, managers and other planners can do a better job of identifying key points of contact within the workforce for spreading important ideas, procedures, and priorities in keeping with organizational strategy. Leaders and managers seek to foster the growth of positive, mission-effective cultures, and awareness of social network structure can be very supportive of this objective. Combined appropriately with knowledge of other business and social contexts, ONA may also greatly aid the accurate interpretation of events that have bearing on organizational performance.

As an exploratory work, the current study has limitations that need to be addressed by future research. While our survey data represents a 72% response rate, we must always be concerned about missing data given the number of network tie possibilities that are represented by each additional person who participates in a study. Our analysis and interpretation could also be greatly enhanced by additional understanding of business and organizational context. Future work should attempt to include more detailed information about departmental functions and individual roles in the workplace. Content, structure and participation associated with official safety-related training and discussion should be incorporated in our analysis of where knowledge is strongest or attitudes most positive regarding OD within the network. These and other limitations notwithstanding, it seems quite clear that efforts to take operational discipline to levels of higher quality and enhance safety culture maturity can derive great benefit from organizational network analysis.

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