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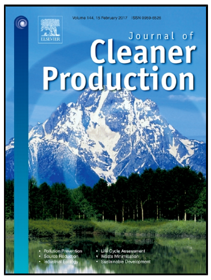

Social network analysis reveals that communication gaps may prevent effective water management in the mining sector

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Article Title: Social network analysis reveals that communication gaps may prevent effective water management in the mining sector

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ABSTRACT

Sustainability issues are often difficult for companies to manage because they require communication across organisational departments and divisions. This paper provides some of the first empirical evidence that communication "silos" exist within the mining sector, and that they may be impeding effective water management. Results of a social network analysis at a mining company revealed gaps in direct communication about water-related issues between the two largest production departments. This gap was particularly surprising because the departments were connected in the other communication networks studied, namely: information, ideas, problem-solving and friendship. The Health, Safety and Environment department played a crucial brokerage role within the water network, suggesting that water is primarily perceived as an environmental issue. A lack of direct communication between the major production departments could pose a barrier for recognising and responding to production-critical water risks. The work also found that the water network was characteristic of a core-periphery structure, such that communication was vulnerable to the removal of central "hubs". These hubs were dominated by senior management, which may present a risk for responding promptly to water-related crises. Further research is needed to investigate the impacts of a siloed communication structure for managing other sustainability issues including energy and community development.

KEYWORDS:

Mining; water; social network analysis; cleaner production; business strategy; sustainability; industrial ecology

1 INTRODUCTION

Globally, mining is a major engine of economic development to such an extent that the annual revenue of some mining companies exceeds the GDP of some of the countries in which they operate. Partially on account of this economic power, the industry plays a central role in the global quest towards sustainable development (World Economic Forum et al., 2016). However, at a local level, the extraction of minerals can pose unacceptable social and environmental threats. Mining executives increasingly recognise the need to engage in a new conversation with society, acknowledging the potential role of the industry as an engine of social development (Cutifani, 2013). However attaining this shift will require disruptive innovations to yield step-change improvements in social and environmental performance without compromising productivity at the mine site level.

Moran and Kunz (2014) presented a maturity framework to guide the mining industry on a four-stage journey towards *Operating Sustainably,* whereby resource extraction is undertaken in an environmentally, socially and economically responsible manner. These four stages are: (1) Profit Maximising; (2) Efficiency focused; (3) Integrating by Connecting; and (4) Adaptable and Resilient. The authors analysed a sample of 80 papers from a recent special issue within the Journal of Cleaner Production on *The sustainability agenda of the minerals and energy supply and demand network: an integrative analysis of ecological, ethical, economic, and technological dimensions* (Moran et al., 2014), to investigate the emphasis of current research efforts. The need to improve communication was highlighted as a key constraint for the industry to progress towards the latter stages of the maturity journey (Moran and Kunz, 2014).

Communication is crucial for the mining sector to manage sustainability issues both within and beyond the company fenceline. Within the fence, many companies already have complex organisational structures, comprising of rotating shift rosters, and fly-in-fly-out (FIFO) or drive-in-drive-out (DIDO) workforces (McKenzie, 2011). These structures can pose challenges for the effective management of social and environmental issues, which typically require collaboration across organizational boundaries, including departments and management levels. In future, the introduction of technological innovations to access and process lower-grade orebodies – such as mass mining techniques (Wood et al., 2011) and Mine-to-Mill (Powell and Bye, 2009) – may contribute to organisational complexity, making it even more important for companies to coordinate work practices. Beyond the company fence, mining companies are also under pressure to improve their communication with surrounding stakeholders. Earning a "social license to operate"– and particularly from indigenous groups – is increasingly a precondition for resource access (Lacey et al., 2012). A recent study found that project delays owing to conflicts can result in substantial costs, estimated at up to US$20 million per week in net present value terms (Franks et al., 2014).

Of the many sustainability issues facing the industry, water has emerged as one of the most critical (Corder and Moran, 2006; Kunz and Moran, 2014). The resource is an essential input for production, but also has significant economic, social and environmental value to surrounding communities (Moran, 2006). Ineffective water management has led to considerable costs for many companies, including production losses due to droughts and floods, and eroding trust with local communities.

Grasping a comprehensive understanding of how water moves through a mining site is challenging because the tasks that use water are interconnected and interdependent. Variations in water quality and/or quantity in one task can have upstream/downstream implications, both within and beyond site boundaries. Mining operations typically span large geographical areas whereby overall inputs and outputs of water to/from site are closely coupled to the climate. The emergence of water issues across temporal and spatial scales means that it is often unclear where to intervene to achieve desirable outcomes. High-level systems models are promoted to assist decision makers in gaining an overall understanding of mine site water balances (Côte et al., 2007; Côte et al., 2010; Gunson et al., 2012). While these models are useful for identifying desirable interventions, implementation can prove challenging due to the need to coordinate the actions and decisions of diverse actors across departments and management levels. While coordination challenges have previously been acknowledged as a potential constraint to improving water performance in the mining sector (Moran et al., 2006), this has not yet been formally characterised.

Against this background, the work presented in this paper involves a descriptive approach to investigate whether a formal social network analysis can identify opportunities for improving water management at a mine site level. The following section justifies the decision to focus on a single site, and explains the approach for data collection and analysis. In the results and discussion, we arrive at recommendations to assist the site management team in improving the implementation of their water strategy. We conclude that social network analysis may also be valuable for addressing other sustainability challenges facing the mining sector.

2 METHOD

2.1 Study Design

A detailed case study at a single mine site, that is part of as large multi-national corporation, was selected for analysis. Yin (2009) describes five rationale for when such a research design can be justified, including the *revelatory case* in which an investigator gains access to a phenomenon to which few scientists have previously been privileged. To the best of the authors' knowledge, this research project represented the first empirical network analysis at the level of a mining site, and was thus a unique opportunity. An advantage of focussing on a single mine was that it facilitated the adoption of multiple methods of enquiry (including primary/secondary data, observation, survey research and interviews) so that findings could be triangulated as research progressed. It may be described as an "embedded" case study design because a number of subunits were analysed within the larger study (Yin, 2009). Lozano and Huisingh (2011) argue that the case study approach is useful for examining contemporary events where behaviours cannot be manipulated and phenomena cannot be separated from their context, providing the potential for more meaningful examination of real life events than cross-sectional or longitudinal studies. In this paper, we focus on the results of a social network analysis. However the research conducted during the broader study (Kunz, 2013; Kunz et al., 2013) assisted in designing the approach for data collection and in interpreting the results.

Water was an important strategic priority at the case study site; the mine is located in an environmentally pristine region and water has strong cultural value to the local indigenous community. The corporate strategy emphasised responsible water stewardship as important for business. Site-level management had set ambitious targets to reduce the quantity of water taken from the environment, to minimise off-lease discharge, and to maximise the efficiency of water use across the production chain. The site had made notable progress towards these goals, however they were ambitious to further improve. It was recognised that collaboration was important for managing water issues across the site which is evidenced through the development of a cross-department water committee and the delegation of water champions across different parts of the business. However previous research found that the committee was not operating as effectively as it could have been (Kunz et al., 2013).

2.2 Creating the network dataset

A *network* (or graph) is represented as a set of *nodes* (or vertices) connected by *edges* (Newman, 2003). In an organisational context, nodes typically represent individuals and the edges correspond to relationships (e.g. trust, knowledge) between nodes. Network visualisation facilitates improved understanding of how communication takes place, while statistical analyses allow a quantitative assessment of how a network is functioning relative to a desired set of indicators.

Within the business literature, social network analysis (SNA) has become an established methodology for analysing communication patterns between diverse sets of actors and developing strategies to improve collaboration (Angwin et al., 2009; Cross et al., 2006; Krackhardt et al., 1993). The mathematical foundations stem from graph theory (Newman, 2003) and are similar to those applied for engineering applications such as analysing ecological networks (Yang et al., 2012) and modelling river flows (Kisi, 2004). Roome (2001) suggested that improved understanding of social networks could facilitate the management of environmental and sustainability issues by firms, however with the one exception of Meese and McMahon (2012), applied studies at a firm level are notably absent from the literature.

Many datasets can be used to construct a social network including email chains, meeting minutes, or self-reported ties via surveys (Butts, 2008). In this study, SNA data were collected via an online survey and all 425 employees were invited to participate. The survey was designed by the authors and refined through discussion with four employees of the company (three site-based and one corporate). The questions pertaining to the SNA were based on an earlier study by Kastelle and Steen (2010). Their study focussed on understanding how a firm's network structure influences its innovation capability, and questions were based on a qualitative research period. Information, ideas and problem-solving networks were expected to be most important for facilitating innovation. It was further hypothesised that innovative project-based firms would be characteristic of a small world network, and that there would be differences in the way that individuals searched for information, ideas and to solve problems. We therefore included these same questions within the current study. In addition, based on the initial qualitative interviewing on site, questions about water management and friendship were added. Water was included because that is the focal topic of this study, and friendship was included because that is an issue that was consistently raised as having an impact on communication patterns.

Once the survey was assembled, colleagues from our broader research team with previous experience in SNA research were invited to comment on the survey and test its functionality prior to deployment. This served a dual purpose: (1) to ensure that the survey would operate on different web browsers and computers, and (2) to ensure that questions were adequately explained.

Respondents were first prompted to confirm their demographic data and to indicate (from a drop-down list of all 425 employees at the site) with whom they interact as part of their day-to-day work. Next, they were asked to indicate how often (1=Never; 2=Rarely;

3=Sometimes; 4=Often; 5=Very often) they contact each person identified in Section 1 for:

- Information you need to accomplish your work? *(Information network)*
- New ideas that change the way you approach your work? *(Ideas network)*
- Help in solving problems that arise in your work? *(Problem-solving network)*
- This project has a particular focus on water-related issues. How often do you contact this person about water-related issues that are relevant to you and your job? *(Water network)*

The third section of the survey asked respondents to indicate the nature of their relationship with each person on a 5-point scale from *distant* to *close*. The following question was used:

- Can you please indicate how close a personal relationship you have with the following individuals? *(Friendship network)*

The survey was left open from 18th August 2011 until 30th September 2011 to ensure that all shift rosters had the opportunity to complete it. It was important to leave the survey open for at least one month because shift rotations occur on a 28-day cycle. Preliminary trials were conducted in the two weeks prior to survey release to optimise its usability. A reminder email was sent to all employees on 26th September. The period of survey deployment was characteristic of normal operation and there were no major water-related events (e.g. flooding, drought).

2.3 Data analysis

To prevent survey responses from being attributable to individuals, each employee was designated to a department and management level during data analysis (Figure 1) following advice from the Human Resources department. We distinguished between nine departments: Production Processing; Mining and Mobile Maintenance; Engineering; Logistics & Infrastructure; Health, Safety & Environment; Regional Participation; Security; Human Resources; Other (this category encompasses departments that had five employees or less). Individuals were also assigned to one of five management levels, reflecting differences in pay scales and thus relative negotiation power (employees who occupy higher levels of the management hierarchy have greater access to resources and decision making authority). A distinction was also made between the "shift" and "professional" workforce because these two groups had notably different attributes (Table 1).

Figure 1. Classification of nodes according to management level and department.

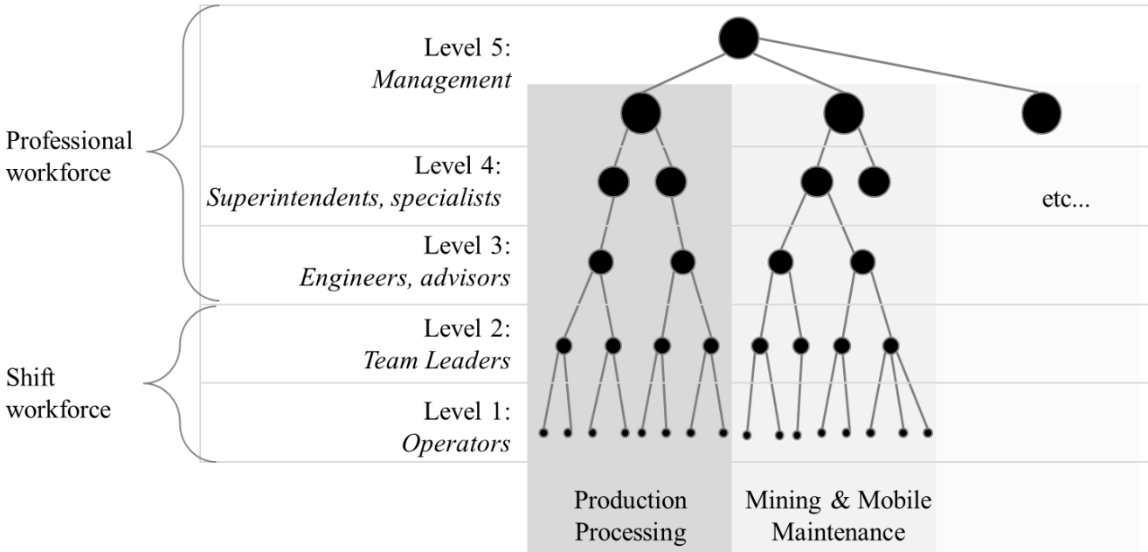

Table 1. Characteristics that distinguish the shift and professional workforce

	Shift workforce	**Professional workforce**
Main roles	Operators, technicians, mechanical and electrical trades, plumbers, apprentices, team leaders etc.	Engineers, advisors, geologists, superintendents, managers etc.
Roster	Primarily work day/night shifts Work over weekends	Daytime shifts Primarily work weekdays
Access to computers	Limited computer access Majority of time is spent working directly with engineering equipment	Frequent computer access Large proportion of time spent in the office
Training and education	Generally low literacy/numeracy	Higher level of education/training
Formal water accountabilities	No formal accountabilities for water	Formal accountabilities over pumping, monitoring, maintenance and licensing of the site water system are all assigned to members of the professional workforce
Number of employees	289	136

The overall response rate was 37% (Table 2). Although lower than our target, it was almost twice that obtained in similar surveys deployed at the site (~20%). The low response from the shift panels may be explained by infrequent computer access and lower rates of numeracy/literacy. The implications of the low response rate were given extensive consideration during data analysis. For example, the structural properties of the full network (37% response rate) were compared against those of the professional cohort (63% response rate). The distribution of key structural characteristics was found to be similar across both networks, and for all types of communication – i.e. *water, information, ideas, problems, friendship* (Kunz, 2013). It was thus concluded that the low response rate does not preclude understanding about the overall structural features within the networks.

Table 2. Survey participation statistics

	Number of employees	Number of respondents	Response rate
Employee type			
Shift workforce	289	71	25%
Professional workforce	136	85	63%
Department			
Mining & Mobile Maintenance	128	34	27%
Engineering	22	13	59%
Production Processing	142	40	28%
Logistics & Infrastructure	27	8	30%
Health, Safety & Environment	23	17	74%
Regional Participation	10	3	30%
Security	32	12	38%
Human Resources	26	18	69%
Other (e.g. Business Improvement, Finance)	15	11	73%
Identified as important for water management during prior qualitative interviews and field research	54	41	76%
TOTAL	**425**	**156**	**37%**

From the survey data, five social networks were analysed (information, ideas, problem-solving, water and friendship). Nodes represent the employees at the site and edges indicate that there is a relationship between nodes. A range of statistics can be quantified about a network, with each exemplifying a structural characteristic of interest. Our analysis focussed on five statistics (number of edges; inclusiveness; network density; efficiency; and hierarchy); detailed descriptions of each can be found in Kastelle and Steen (2010). The *number of edges* measures the total number of network ties and reflects the extent of communication taking place. *Inclusiveness* is the ratio of connected nodes (i.e. excluding isolates) relative to the total number of nodes. *Network density* is the ratio of actual edges relative to the total number of possible edges. *Efficiency* considers the number of redundant links within a network, while *hierarchy* indicates the extent to which a network has a hierarchical character (if all members of a network have the same number of connections then the value for hierarchy would be zero). Network statistics were calculated on binary ties for each directed network, whereby isolate nodes were included except in measuring hierarchy. Calculations were performed using automatic routines within the NetMiner program (SNU Research Park Innovation Centre, 2011).

Additionally, we investigated whether the water network was characteristic of a "small world". Such structures have a sparse number of connections but it takes only a few steps to reach anyone in the network (Milgram, 1967; Travers and Milgram, 1969 - popularly coined as "six degrees of separation"). Small world structures are expected to serve advantages in organisations by efficiently connecting heterogeneous communities of actors (Kastelle and Steen, 2010), and have been associated with greater rates of innovation and creativity (Fleming and Marx, 2006).

A small world network is characterised by low *path length* and high *clustering*. To determine if the water network can be characterised as such, the properties of the observed network were compared against those of a randomly generated network with the same number of nodes and edges (Kastelle and Steen, 2010; Uzzi and Spiro, 2005; Watts and Strogatz, 1998). A *small world quotient* was then quantified using the below steps. The larger the small world quotient, the more characteristic the network is of a small world.

1. Calculate the path length (PL) and clustering coefficient (CC) of the observed graph.
2. Generate a random graph with the same number of nodes and edges as the observed graph. Generate a series of random graphs and calculate the average PL and CC across the set. In this case 100 graphs were generated.
3. Compute the "small world quotient"= $\frac{PL\ of\ actual\ network / PL\ of\ random\ graph}{CC\ of\ actual\ network / CC\ of\ random\ graph}$

In addition, a detailed analysis was conducted on the water network to investigate the attributes of actors who played central roles as "hubs" (those people connected to many others). Hubs were identified according to their in-degree, i.e. the number of incoming edges connected to a node. In-degree was used rather than degree (which quantifies both incoming and outgoing edges) to avoid skewing results towards those with a high out-degree (because some respondents had reported a large number of outgoing ties).

3 RESULTS

The descriptive analysis of network statistics (Table 3) revealed that water-related issues are discussed the least, as observed from the small *number of edges*, low *network density,* and low *inclusiveness*. This is unsurprising because water might be considered a marginal issue compared to the other interaction networks studied. But it was interesting to find that the water network is highly *efficient* (most links are non-redundant) and has a strong *hierarchical* character (the network has a disproportionate distribution of connections). These features are characteristic of a core-periphery structure wherein a small number of nodes form a hub at the centre of the network and connect to a larger set of nodes at the periphery (Anklam, 2007).

Table 3. Selected network statistics.

	Information	Ideas	Problems	Water	Friendship
Number of edges	3277	2452	2550	1078	1678
Inclusiveness	0.96	0.875	0.861	0.718	0.885
Network density	0.018	0.014	0.014	0.006	0.009
Efficiency	0.929	0.945	0.942	0.972	0.964
Hierarchy – excluding isolates	0.776	0.768	0.755	0.846	0.821

Results of the small world analysis are presented in Table 4. The *small world quotient* is greatest for the water network, indicating that it is most characteristic of a small world. Although the absolute value for the *path length* is higher for the water network when compared with other exchanges, it is considerably smaller than would be expected random chance (observe the path length ratio between the observed vs. random network). The water network also has a high level of *clustering* indicating that once a message reaches a cluster, it is disseminated promptly to neighbouring nodes.

Table 4. Small world calculations

	Clustering coefficient (CC)			*Path length (PL)*			*Small world Quotient*
	Actual	**Random**	**Ratio**	**Actual**	**Random**	**Ratio**	**CC/PL**
Information	0.503	0.054	9.26	2.924	3.16	0.92	10.01
Ideas	0.505	0.040	12.61	3.115	3.53	0.88	14.28

Problem solving	0.517	0.042	12.24	3.058	3.48	0.88	13.91
Water	0.446	0.018	24.61	3.814	5.36	0.71	34.60
Friendship	0.386	0.028	13.61	3.958	4.18	0.95	14.38

Exemplar study - Kastelle and Steen (2010)

	Clustering coefficient (CC)			*Path length (PL)*			*Small world Quotient*
	Actual	**Random**	**Ratio**	**Actual**	**Random**	**Ratio**	**CC/PL**
Generic interaction	0.567	0.192	2.95	5	2.479	2.02	1.46
Information	0.488	0.066	7.39	7.3	3.505	2.08	3.55
Ideas	0.39	0.053	7.36	8.7	6.228	1.40	5.27
Problem-solving	0.449	0.059	7.61	6.8	6.236	1.09	6.98

The core-periphery and small world structure of the water network suggests that communication is reliant on central actors. An analysis of the in-degree distribution by management level (Figure 2) found that Level 4 and Level 5 employees are playing important roles as hubs. They are the only management levels with individuals who have an in-degree value above 15, and these cohorts have the highest median in-degree (closely followed by Level 2).

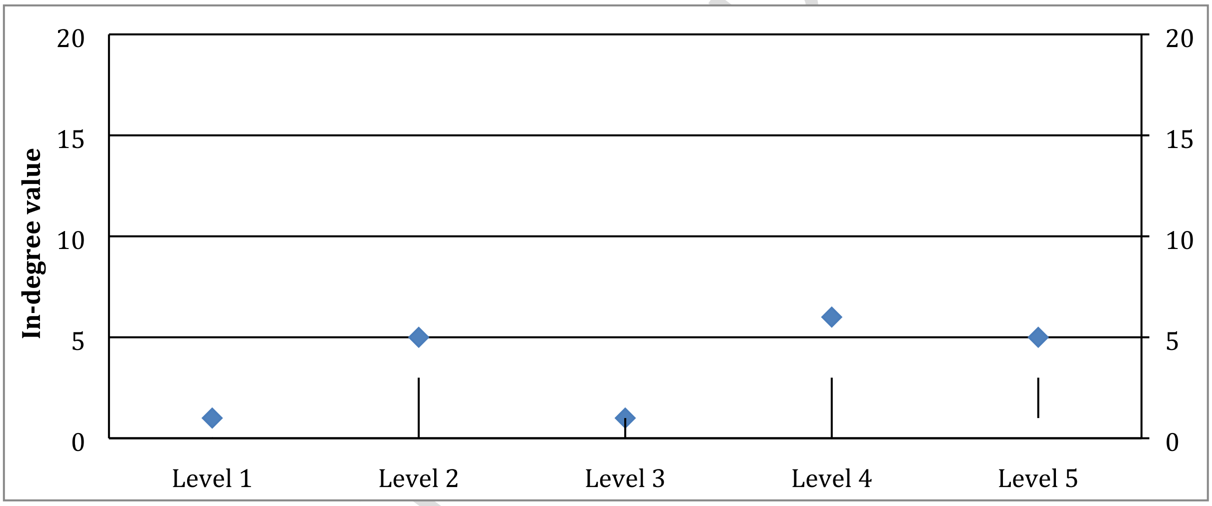

Figure 2. In-degree distribution by management level (N=425)

In addition to identifying network hubs, we also sought to understand how communication occurred across different departments. Visual interrogation of the water network revealed a complete direct communication gap in the frequent (i.e. within the last week) exchanges between the two largest production departments (i.e. Mining & Mobile Maintenance and Production Processing) (Figure 3). This gap was particularly significant because it did not occur for any of the other networks (information, ideas, problem-solving and friendship) (Figure 3). The Health Safety and Environment department was found to play a crucial role in brokering water-related exchanges between production departments (Figure 4).

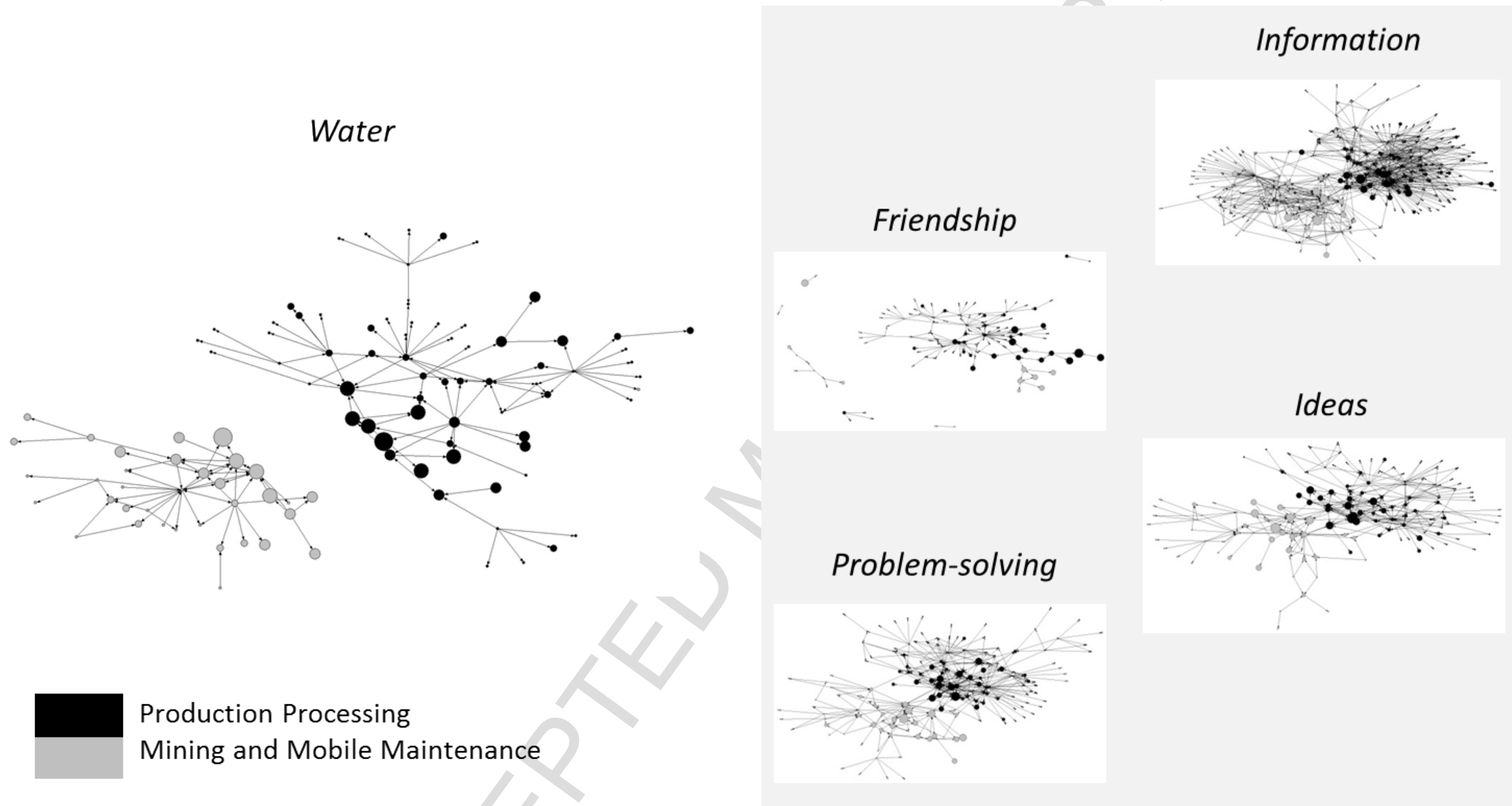

Figure 3. Frequent (i.e. within the last week) water-related interactions between Production Processing (black) and Mining/Mobile Maintenance (grey). Circles represent individual; size indicates management level; arrows show direction of communication. Network visualisations performed in Netdraw (Borgatti, 2002).

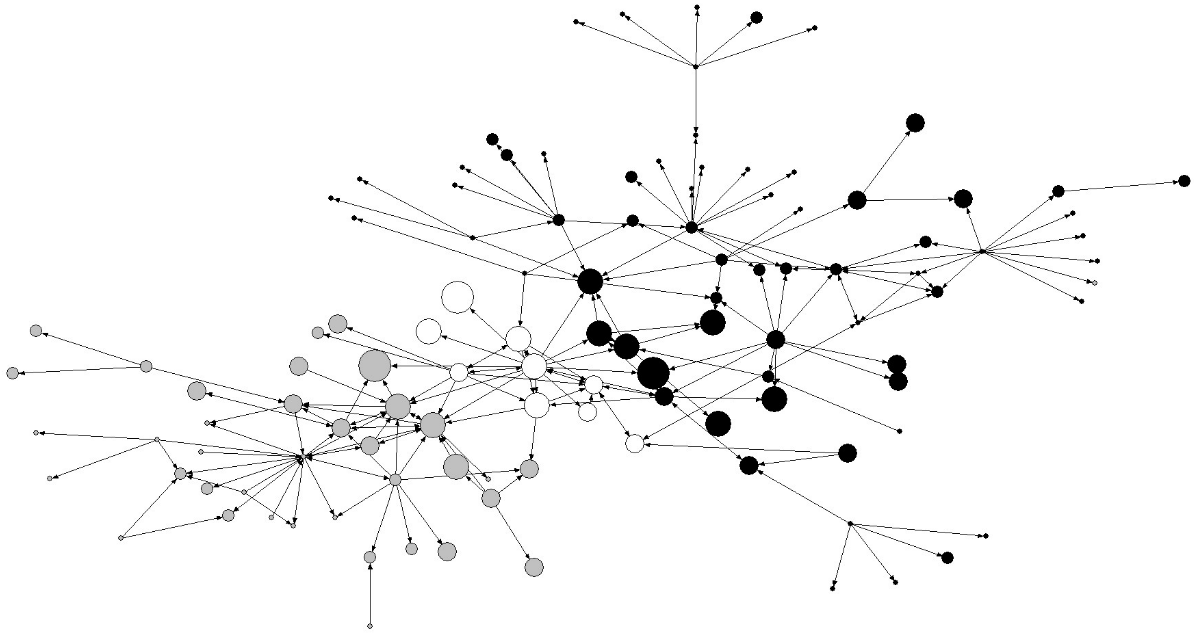

Figure 4. HSE (white) played an important role in brokering frequent water-related exchanges between Production Processing (black) and Mining/Mobile Maintenance (grey). Network visualisations performed in Netdraw (Borgatti, 2002).

4 DISCUSSION

Adopting a more systemic and strategic approach to water management at the level of mining sites represents a well-known challenge (Kunz and Moran, 2014; Ringwood, 2006). We contend that part of this challenge arises due to the need to improve communication across departments and management levels. In this paper, we undertook a formal analysis of social network structures to investigate opportunities to improve water management at the level of a mining site. From our exploratory case study, we arrive at recommendations for how the site management team could harness social networks to better achieve its goals.

By comparing the water network with other forms of communication, we found that water was the least common reason for communication at the site (e.g. the information network had almost three times as many ties). This presents an opportunity for the champions of the site water strategy to become smarter about how messages are communicated. For example, to disseminate a message to all site employees as fast as possible, it would be more effective to frame it as a message about "information relevant to day-to-day work" rather than a message about "water". This is consistent with comments made by employees during field research: water was generally regarded as a peripheral issue and there must be a "burning platform" for it to be prioritised. This conclusion mirrors the findings by Kemp and Owen (2013) in their work on community relations and development (CRD) in mining – another crucial sustainability issue for the industry. They found that CRD was perceived as less important than production objectives in a day-to-day operational context, describing it as "core to business – but not core business". This scenario created frustration for practitioners at a site level seeking to drive improvements in CRD as part of the organisation's long term sustainability strategy (Kemp and Owen, 2013). We thus reach a concluding hypothesis that water-related issues would be given more attention if they were communicated in the language of business risk rather than environmental stewardship or regulatory compliance.

The central role of the HSE team as a broker in water-related exchanges suggests that water is mainly perceived as an environmental issue on this site, and that there is minimal communication about water between the major production departments. This finding is validated through our broader field work – i.e. an analysis of the activities for the mine's water committee revealed that the Mining and Mobile Maintenance department did not participate, nor where they invited, to any of the water committee meetings (Kunz et al., 2013). A lack of direct communication between major production departments could contribute to a neglect of business-critical water risks. Mining and processing are the two largest users of water at this site and the water balance between these is connected, i.e. water generated during dewatering operations is later used as an input for the processing plant (Kunz and Moran, 2016). Therefore, changes in the quantity of water produced by the open cut mine could impede the long-term availability of water supply for processing. Changes in water quality could also have implications; for example, if oil or other contaminants are released during mining, this could build up within the processing circuit. The lack of direct interaction across the Mining/Mobile Maintenance and Production Processing departments could prevent such issues from being identified.

The core-periphery structure of the water network reflects a good use of time and suggests that each edge is playing an important role in connecting distributed actors. The trade-off is that the network is less resilient. If there are no redundant ties, the network is prone to breaking down when people or connections are removed. This lack of resiliency is a definite issue in knowledge-sharing networks in similar settings (Steen et al., 2011). A core-periphery network also implies that communication is highly reliant on a small number of network "hubs" at the centre of the network. The management team at this site should think carefully about how it delegates accountabilities for water, because our results found a surprisingly high representation of senior managers as network "hubs". This reflects a position of influence, but also denotes significant time investment. For example, the most central hub in the water network had an in-degree of 21 (i.e. 21 people relied on that person for water-related information) and an out-degree of 49. It might be argued that the time taken to act as a hub could preclude senior management from thinking at a strategic level. The high reliance on upper management could also represent a risk for responding promptly to water-related crises, especially during weekends when there is minimal attendance by the professional workforce. An investigation of communication patterns during a major flooding event at the same site indeed confirmed that the "response networks" were more dispersed and seemingly chaotic compared to the day-to-day interaction networks analysed during the SNA (Kunz, 2013). It may thus be argued that the network structures on this site were not resilient, because they were unable to maintain stability in the face of *unexpected* risks.

In considering the way that water is communicated across the site, the management team should evaluate the trade-offs between building a more densely connected network and the costs associated with doing so. High reliance on key individuals increases efficiency but it also increases vulnerability. This could be overcome by increasing the number of ties within the network and delegating responsibility, however many connections is costly because relationships require people's time to maintain (Carroll and Burton, 2000; Kastelle and Steen, 2010). This is why network structure is an important management issue – it is neither sufficient nor efficient to simply maximize the number of ties within a network.

There are several limitations of this work, which present opportunities for future research. Given the exploratory nature of this study, there was a greater emphasis on description rather than hypothesis testing. For example, we concluded that communication gaps might be preventing the site from effectively managing the strategic risks associated with water. The best way to confirm whether this is true is: (1) to compare this water communication network with others trying to achieve similar goals, or (2) to compare this network to itself over time as its outcomes change. A further limitation of our study is that we did not specify the type of water issues being discussed. During a staff feedback presentation, some employees suggested that team leaders and operators should dominate as hubs for day-to-day issues, while managers and superintendents should dominate as hubs for strategic issues. This represents an interesting starting hypothesis for future work.

Although this work focuses on a single mining site, recent work suggests that a lack of systemic thinking and the associated communication challenges are prolific within the broader mining sector (Mitchell et al., 2014). This is problematic for the sector's maturity journey towards Operating Sustainably because system efficiencies may be overlooked due to decision makers being disconnected, and companies may be unable to maintain resilience in the face of unexpected risks (Moran and Kunz, 2014). We therefore conclude that there are promising reasons to broaden applications of SNA, particularly in areas such as energy (Powell and Bye, 2009) and community development (Kemp and Owen, 2013), wherein a systemic approach to management is also recognised as crucial.

5 CONCLUSION

To our knowledge, the work presented in this paper represents the first attempt to empirically identify communication "silos" within the mining sector, and to investigate the extent to which they may be impeding effective water management. We find communication gaps at the case study site analysed in this research, and conclude that this may be preventing improved water management. A review of recent literature suggests that communication challenges may be widespread within the broader mining sector. This work therefore supports the argument posed in the introduction to this paper – i.e. communication may represent a key constraint for the mining sector to progress towards the latter stages of its sustainability maturity journey.

There are promising opportunities to extend the work from this paper; for example, to compare the water network from this site with other mining sites seeking to achieve similar goals. It would also be valuable to investigate changes in network structure over time to test whether specific interventions to change communication patterns could lead to improvements in water performance. The work may also provide a starting point for designing research studies to investigate the importance of social network structures for achieving other sustainability objectives within the mining sector, such as energy and community development. Likewise, the work could be compared to SNA studies performed on other large projects and in industrial sectors beyond mining.

6 ACKNOWLEDGEMENTS

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