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Tailoring ties:
Leadership in the spaces between — When safety and efficiency are essential

L. Vederhus

Leaders, decision-makers and practitioners often face challenges to their organizational visions, decisions, and behaviors, due to the uncertainties of outcomes in an increasingly complex and interconnected world. The necessity for robust and resilient organizations in rapidly changing contexts has also led to a shift in leadership theorizing. The more recent complexity leadership theory (CLT) acknowledges the dynamics of the realities in which organizations and leaders operate, and emphasizes adaptive behavior of the whole system for coping in changing circumstances. This generative model displays an adaptive space that is coexisting with, and balancing, exploratory-innovative/entrepreneurial initiatives and administrative-bureaucratic/operational needs of organizational life. Enabling learning opportunities in the adaptive space is the most crucial feature of this model. Some critical issues have been raised regarding complexity leadership theory. One question has been whether CLT is complex enough, with the main argument that CLT fails to integrate the leaders themselves within the organizational complexity where they are inevitably embedded. This can have the consequence of leaving us with a kind of truncated version of the reality, and therefore not quite fathoming complexity. Understanding that leadership is co-constructed within organizations' evolving story enables us to visualize and apply concepts of self-organization and adaptation with far more confidence. Furthermore, addressing leadership as an emerging property of collective agency indicates that the outcomes depend on whole systems. Thus, the total system is put to the foreground, into the figure, forming a dynamic space on the background of constituent individuals and the connectedness between them. Behavioral characteristics of such large structured entities emerge by the way this dynamic organizational space meets, aligns with, adapts to or acts on surrounding challenges.

This approach contrasts previous theories of leadership that primarily have a focus on the person holding the position defined as leader. Leadership theories have favored a position-centered approach for decades, with the focal point being the leader, and the idea being that this position employs unique powers for different ways of leading, often in hierarchically organized structures. A whole-systems approach offers the opportunity of using network methods in guiding leadership in the spaces between, integrating the formal leader position inside the structure, and facilitating people's performance by better routes of information flow and exchange, where workload becomes visible, and potential threats can be mitigated by adjustment and rearrangements for problem-solving and learning. However, different organization types encounter various kinds of challenges in their contexts. This calls for more refined and custom-made methods in order to be able to guide adaptive behavior. Of particular interest for this article is organizations dealing with risk and immediate consequences of behavior and performance. Due to the possible magnitudes of consequences, extending into the physical environment and people external to the organization, safety becomes significant. Further, like for most organizations, a competitive worklife also accentuates certain demands for efficiency.

Based on the presented challenges and the quest for ways of dealing with complexity, this article outlines some topics related to structural awareness in organizations facing both complexity and risk. Social network analysis (SNA) equips us with a conceptual framework for interpreting properties of structures. Assuming that awareness of such properties enables organizations to analyze, learn, and adapt in their

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circumstances, we should try to understand how different types of organizations can tailor the ties within their own structures to meet situated challenges, and start a discussion that allows for explorations of such ties in non-risk situations — real or simulated. To tune into some research problems, for this text they can be stated as follows: What metrics of network properties can reflect safety and efficiency, and how can network structures be optimized for safety and efficiency purposes?

LEADERSHIP IN DIFFERENT TYPES OF ORGANIZATIONS

In a framework for examining leadership in extreme contexts, a differentiation of four types of organizations based on context and responsibilities was found useful. *Trauma* organizations conduct work in for instance hospital emergency rooms and ambulances, where saving lives is the core occupation. *Critical action* organizations may have a more active role in creating the extremity of the context, like in military combat units, SWAT, or fire, search and rescue teams. *High-reliability* organizations (HRO) depend fundamentally on avoidance or prevention of extremity that could develop into crises and massive catastrophes, and in this category is both normal police, organizations operating in air, space and at the seas, and other organizations in risk conditions, like nuclear power plants. In the final category, all other organizations were labelled *naïve*, meaning they have no initial role in an extreme context but may be exposed to such extremity for other reasons, be it tornados, fires, attacks, and so on. Complexity theory can contribute conceptually and analytically (or possibly rather by synthesis than by analysis) as a useful approach for understanding and conducting leadership in all these types of organizations. The argument for CLT builds on the part of complexity theory that emphasizes *open systems* — the complex adaptive systems (CAS). CAS provides a broader access for advancements of leadership and several other organizational and societal aspects. Since both devices and virtual spaces interconnect us ever faster, and the dynamics of the fields that emerge can appear as a threat to control-depending systems, the current position held by many is that we need advanced models to handle future challenges. Complex adaptive systems have features of connectivity, autonomy, emergence, non-equilibrium, non-linearity, self-organization, and co-evolution, which are concepts that enable us to understand the challenges better, but also opens our understanding of coping by forming and transforming learning processes. Although CAS can be valuable for application in organizations, I urge that we should keep in mind the importance of another part of complexity theory, complex physical systems (CPS). The rapidity in our exploring and exploiting the physical world around us also adds to the complexity. Even if elements stand fixed in CPS, as opposed to those learning and adapting agents in a CAS, we still have to acquire a lot of knowledge about fundamental building blocks, and the laws, states, powers and forces we interact with in CPS contexts. The future perspectives of physical systems capable of learning by artificial intelligence also calls us to exercise caution and beware of agency, and consider intertwining CAS and CPS. Ideas from actor—network theory, where living and non-living elements are integrated by relevance, may thus be beneficial adding to the social network theory approach from which this text elaborates.

This text is motivated by the particular challenges in leadership of HROs today. New concepts and technologies that are generated for our time, like the knowledge era, environmentalism, industry 4.0, unmanned or autonomous vehicles and vessels, and so on, challenge our representations of reality and work life. HROs already have to merge the properties of CAS with the context of CPS, thus encompassing multiple layers of factors challenging performance, but also holding many optional dynamic processes for coping, some immediate, and some medium- to long-term. Typical for HROs is the need for safety and efficiency for performance outcomes. Threats may arise from the context that surrounds their activities. This could be weather, waves, oceanic currents, wind, fog, icing etc. Pressures and stressors from stakeholders, owners, customers, and others, could further intensify extremity in the physical proximity of risks. Other demanding factors are present through technology, both when the technology is too complicated in its outfits, and in cases of failures or weaknesses. The most prevalent root cause when accidents occur is however still ascribed to the human element. Although the separation of human and technology in accident investigation may not be very helpful, the inherent agency and learning capability of human beings points to a responsibility we (yet) cannot assign to, or ground in, technology, and the human ability of adapting to new contexts leaves us with the agentic powers of prevention anyway.

The perspective shift in leadership, from the one focal point of power to complete networks exhibiting adaptive behavior, allows us to reflect on the usefulness of network approaches for HROs. How can we assess safety and efficiency by means of adaptive network properties?

First, for the organizations, simply drawing diagrams could be of great value — charting the relations of the people (or positions of alternating people, as is often the case in around-the-clock work of HROs) by visualizing the lines connecting them. These lines, or ties, can be further explored, for instance looking into directionality, weight, type or quality. A joint session with the focus being the network can help establish shared mental models of baselined and restructured networks, and can have major impact on the representation and understanding of the workload in the system, and possible information transfer deficits. Modeling structures and envisioning how work actually loads on persons by the amount of connections, the coordination and communication required, and the risk of shortcomings in information transfer, may spark initiatives of rearrangement and adjustments coherent with adaptive needs of the context. Because risk can accelerate into crisis quite fast and unnoticed, it should be vital to establish redundancies within the whole network, to form functionality for different phases. Exemplifying with different scenarios and simulating how the distribution of information and the assigned decisions affect outcomes can be worthwhile investment. Basic features of our organizations may be in concordance with our convictions, but we could easily imagine some surprises here. Lack of information, or unclear communication, both impairing decisions and performance, are often stated as the most influential causes of incidents. Bringing the formal leader into an integrated flexible position may also enhance performance by envisioning more rapid restructuring to elicit the full coping competence of the whole system. This also means that such relational knowledge and skills become a complex network property (a “swarm intelligence”) rather than a mere summation of individuals’ competencies. The type of organization, the purpose of the activities, and the kinds of challenges, will however influence explication of success criteria.

Second, for the scientific audience, analyzing network patterns and their outcome spaces have a clear scientific interest for understanding safety and efficiency in organizations. Although systematics is a virtue of science, studying complex adaptive systems may reveal some inherent resistance to systematics. Studying the emergence of processes may be a more interesting purpose than constructing transitory typologies, taxonomies, or “truths”. Products like taxonomies of patterns can have a short shelf life with a dynamic worldview, and sharing knowledge of processes may be of higher interest than generalizability of patterns that could not be achievable within other particular organizational frames. There are major differences in the purposes and the scope of action for different kinds of organizations. Using network methods to understand processes and functionality of structures for specific organizations may therefore have limitations for decontextualized application. Knowing a range of such structural functionality, and dysfunctionality often pointed out in accident investigations, can still contribute to actually transferring ideas for adaptive spaces by exploring contextual boundaries.

THE PROPERTIES OF NETWORKS

Social network analysis (SNA) and network metrics originated in a conception of the “social organism”, and this is one of the areas of continued efforts to match the needs for understanding social and societal development with appropriate methods. Although applied as sociometry and a method of investigating group dynamics, the measurements, or metrics, now reaches wider audiences, and the potential of these methods are far from fully utilized. In social network analysis, entities are represented as points, and the relations between these entities are represented as lines. The naming of points and lines appear in much variation, as points are described as nodes, ego and alter, vertex (pl. vertices) and so on. Lines are referred to as connections, ties and edges, among others. The SNA-metrics are duplex, which means you can have a focal point in the network and arrive at several measures of *centrality* for this vertex, or find *centralization* measures for whole networks. In a safety perspective, the role of the node as a person will be to have full competence to do the operative work this position demands, and to be able to communicate with other persons within the operational environment according to the needs of the situation both present and in future. The representation of the situation is reflected in ideas of situational awareness, and representations of the operative totality by the concepts of mental models and shared mental models. The impact of representing the operative network as a mental model, and the ways of overcoming obstacles to safety within this network, seems underestimated, however. Clarifying and conceptualizing the network properties and constituents of the ties that enable safe and efficient work is therefore based on the advantages of SNA in analyzing complex networks.

Network visualization can be seen as a static formation of points with just as static lines, and it could therefore be argued that SNA is inappropriate for understanding the complex dynamics of operative work. This is however a premature attitude. Any simulation of dynamics presupposes visualization of the constituent parts, and changes in the visual constellations should mirror the developments in real networks. This calls for other dynamic metrics, but the conceptualizations of networks must have an initial explicit design. Any description can return a reduction, so further elaboration and refinement of concepts are necessary. It is possible to compare different network structures, and contrast their structural measures, either of node-metrics or network-metrics, that enable us to understand what distinguishes efficient and safe structural properties from other properties.

With complexity leadership and network methods as points of departure, hoping the reader now clearly visualizes a feasibility line between those two points, this article will now turn to a discussion of existing metrics for one specific high-reliability organizational context, where safety and efficiency are essential. This can also help contribute to develop the metrics further, by exploring measurement needs in order to have process- and outcomes-oriented leadership guided by such methods. Fundamental to any coping strategy is the understanding of the organizational structure — that is, the network — and its properties in any challenging situation. “Tailoring the ties”, which primarily means enabling organizational connections and communication that is adequate for different phases and purposes of the work, may have great impact on the flow of the work (efficiency) and the workload being handled within limits (safety). For leadership, we still need positioned decision-making for safety and efficiency purposes. To catalyze such leadership in the spaces between, we also need more elaborate research and development of network methodology.

SAFETY AND EFFICIENCY IN HRO

For high-reliability organizations and operations, where risks may emerge in complex ways, safety has been of major concern, also stimulating various approaches in scientific discourse. Authorities and governing bodies involve in the practicing industries by regulations and laws for performance and control systems, serving protection of people, material, organizations, environments and future aims. However, in competitive industries, workers and organizations may be put under strain on safety, since the more efficient bidder may be preferred when that is cost-effective for the buyer. After all, money talks also in operative businesses. For short-term activities, efficiency measures may have different constituents than for wider-reaching activities, where effectivity (the total goal achievement) can be reached in many ways, more or less efficiently. Safety can be thwarted by the quest for efficiency in terms of time and cost reduction, but the paradox lies in the same measures potentially enhancing safety by making the performing workers more alert and aware. It is assumed that risk increases in routine situations where you lower and limit concentration and awareness, whereas a highly aware and focused person may be less prone to harm.

Efficiency can be seen as a ranking- and selection factor of organizations competing for assignments in for instance offshore industries, which is the chosen case for illustration in this text. Due to the practice of tender-preparations in such contractual industries, with a multitude of parties involved in the final operative activity, the buying operator chooses among bidders, or hire entities based on for instance availability, or preferences for special equipment or conditions. The constellation of a multitude of organizations may therefore be unique in every offshore operation and, adding to the complexity and risk comprehension, it must be noted that new workers are recruited continuously, and people relocate within these practices as in others, so any network established for performance of an offshore operation may be novel to all those involved. The ties may therefore be novel in any operation, if not completely then at least to some extent, where ties connect positions manned by new crew and crew unknown to one another. Communication and all kinds of information exchange are present — or absent — between the positions involved. These ties are the fundamental condition for safe and efficient execution of high-reliability work in integrated operations. In many organizations, recruitment focuses much on the capability of the person, and to a lesser extent on the ties that go along with the practices. Skills in cooperation and communication are often explicitly expected as a safety prerequisite, but rarely addressed for evaluation of the operative network.

Dimensioning of manning for offshore operations is beyond the scope of this text, but should be mentioned. The number and diversity of positions have some importance for safety due to the structuring of work and the redundancy that may be needed if there are highly critical consequences when one person has a workload that exceeds possible handling, or if a person ought to be functionally set completely out of the loop during the operation. An example can be from aviation in the number of pilots and co-pilots for long-distance flights. For example will severe illness in one airline pilot effectuate another pilot to take possession of the tasks, and the possibility, plausibility or probability of such events underlies the redundancy considerations.

A social network analysis approach to question safety and efficiency does not imply that a node must be a position or person. Approaches may consider nodes as whole organizations, as departments within organizations, or even as the operations themselves, where organizations can be seen as units dispatched to such operations in a flow. More complex approaches, for instance by two-mode networks, can be of interest, where persons and diverse organizations in bipartite networks may be of importance to understand the empirical ties' mobility properties, depending on the purpose and ownership of the approach.

In high-reliability work, there is quite an amount of imperative safety regulations, but the continuous innovations in these fields of work, and extension and spread of operational areas around the globe, result in a delay for authorities to identify the risks arising, and to advance preventive initiatives to mitigate such risks. A network approach may assist in understanding some of the risk factors that can set in.

It is vital to elaborate on the role of safety and efficiency as a whole, to make visible the balancing of issues for all involved parties. Leaders and decision-makers can contribute to optimize network strategies in work where relations and communication are essential. The simple elements of nodes and connections among these in networks are open to analysis through graph theory, algebraic approaches and spatial approaches. How to use the metrics for safety and efficiency purposes depends on the operationalization of the properties of the ties in such respects.

AN ILLUSTRATORY CASE: THE NETWORK ONBOARD IN ANCHOR HANDLING OFFSHORE OPERATIONS

The example chosen must be regarded as a small-scale network structure, allowing us to explore some basic features of network properties, building the ground for more advanced approaches to network methods applications for safety and efficiency in any high-reliability work.

In offshore operations, the physical surroundings are also complex, with a multitude of factors influencing the work. The weather window is for instance an interpretation of probability of changes in wind and waves, where the limitations for work also rests on the capacity of the vessel. Also, many vessels can be involved in the same operation, representing separate organizations in tandem operations like anchor handling. To further supplement the understanding of organizational complexity, there are also constellations of many organizations represented onboard one and the same large vessel for advanced subsea operations. Anchor handling operations and rig moves have been an extensive practice offshore for many years, where exploration of resources like oil and gas beneath seabed depends on moving drilling rigs into different oceanic areas. Such operations have been associated with particularly demanding work, where margins are small for severe outcomes. After the loss of the vessel Bourbon Dolphin during anchor handling in 2007, the Official Norwegian Report summarized recommendations to strengthen barriers for safety in future operations. Amongst these are the human elements aspects of training in simulators, certification of crew, familiarization in the vessel environment, start-up-meetings and communication, and extended responsibility between actors within the total operation due to them reciprocally acting in such operations. Collaborating, cooperating and communicating in demanding work environments can drain mental energy, but can also allow for removal of the workload by more adequate information flow and resource allocations to ensure all tasks are conducted in accordance to plans.

Even though organizational dimensioning is outside the scope of this article, the size of a network is crucial. One can choose to start analyzing the network *within each organization* or apply the complete *operational structure* for analysis, trying to identify components, clusters and cliques within those operative structures. The authority in different stages of operations alters, however, so in order to be applicable, the analysis could be organized for each leader position to be able to identify her or his net of liabilities and responsibilities as well as the complexity of the decision-making network. To exemplify, oil-drilling rigs may be in charge of the sequence of the unmooring from seabed previous to rig-moves, where for instance four different vessels are present to be coordinated in doing this work. An engineering- or consultancy company may be in charge of the scope to be followed for the operation. Each vessel is responsible for decisions regarding the break-down of the scope into manageable tasks and resource allocation onboard. Failures, shortages or deficits in any part of the integrated operation may branch off quite fast, as the connections support the flow and sequence in all other parts. An important procedural aspect today is the requirement, responsibility, and authority of every person regardless of position to use the word “stop” if needed during any operation (whether this applies also outside the Norwegian continental shelf is not known by the author). There can be some resistance to do so, since the consequences may be even more hazardous for the entire network if you impede the ongoing events, and, besides, can have far-fetching consequences for reputations of persons or organizations.

Working around the clock means that persons that hold the positions alter according to their shift routines. In a 24-h period, some have six hours on and six hours off continually, (and skew it six hours for the next turn offshore to part the burden of the nightshift), others have 8 h shifts on and off, and others have even longer periods. This work schedule stands for four weeks on, and then they have four weeks off, or, for some organizations, two weeks on and four weeks off. The focus on team and team qualities for safety in high-reliability work can thus be seen to be cultivated within each operation, but encounter resistance between operations. However, networks of friendships and other linkages appear between crew also when onshore. Furthermore, specifically prepared team training courses are conducted in simulators for offshore crew, recognizing the role of the teams in enhancing safety. The contents of these are, among other things, some theories on personality, team, risk, and safety regulations, some practical exercises on safe job analysis and execution of tasks, and debriefing and evaluation of the simulated tasks. The frequency of such team training courses may not keep up with the needs evolving from recruitment and replacement practice of people in different positions, but team training courses for complex operations can be expensive, and may thus not turn out favorable among a multitude of other safety interventions within organizations.

The importance of the ties is, however, unquestionable. The ties constitute team qualities, and the operational network can be assessed if safety- and efficiency measures are clearly expressed.

The network formation that “provide a natural counter-balance in social exchange” is said to be the triad, but we shall also consider dyads. Some constellations in operative work are made up of combinations of departmental dyads and triads, such as onboard these anchor handling vessels with a manning of three on the bridge, a manning of three on deck, and likewise two or three in the engine rooms, as well as two or three in the service functions. This is of course almost doubled as total, as new shifts take over. For special operations there are also other expertise personnel serving the cranes, ROV-equipment, and so on. The buyer is often represented onboard, as well as other accompanied resources for different parts of the scope or services.

A visual representation of the involved positions and their roles, as well as the names of all people attending will enable a map of the ties that eventually underlie the operative phases. Any network changes must consequently be represented in the minds of involved resources.

Those involved, though, may multiply realize the network structure that can be formed. They may represent people according to the formal positions or departmental affiliation, to operational sequences’ connectivity, to statuses, their length of service, personal preferences, and so on. The existence of idiosyncrasies of networks may be countered positively for involved crew by emphasizing the complexity in more formally apparent networks by means of aggregated networks and further by multiplexity. Aggregated ties exist within one network where some ties have several qualities. Multiplex networks are comprised of ties with plural realizations where the same people attend two or more networks. The concept of rich ties carries these properties of people knowing each other by a multitude of information networks, enabling understanding of both each other and the tie, to the level of a strength that may aid both safety and efficiency purposes.

In this way, ideas that are already present in team theories for safety purposes, like those of organizational safety cultures, experience diversity, common operational service, duration of experience, language comprehension and difficulties, cultural diversity, to name some, can be modeled into the structure of ties.

PROPERTIES OF SAFETY TAILORED TIES

Ties in complex networks can be analyzed by the direction or bi-directionality of the lines, and a reciprocal tie may not necessarily be a better tie for all purposes. Being able to receive information may be as important as being able to give information, to request, or command, during an operational phase, and to do so from or onto the location(s) where either the information or the act imposed by it has significance. Closed-loop communication has however become custom in HROs. Due to the enormous amount of information, any worker capable of establishing a picture of all others’ ties as well as own, may be able to adjust quickly if there are breakdowns of any sort that may influence the flow, or in cases of emerging hitherto unfamiliar situations that doesn’t comply with incorporated paths of information. Agreed-upon paths of information flow often follow the hierarchical structure, and this may well have an efficiency advantage (to be discussed in the next section), but might obstruct safety because of the distance from senders to receivers.

The ties have metrics of in-degree and out-degree in SNA, observed by direction. These are basic measures, but the metrics is complicated by ideas of strength, weight, intensity, distance, path alternatives and circularity, as well as the importance of the sign of such quantifications. Ideally, one could argue that a neutral tie is a better starting segment than a valued tie of either positive or negative value. In real life, “likes and dislikes” among people make a mark on relations, and these need neither be reciprocal. The negative sign of a relational line also puts strain on the other relations, well-known in the SNA literature of triads.

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A leader who understands the importance of relations is often able to balance the triads by establishing triads that seem to have rich and positive signed ties. This makes the distance between nodes minimal in departments who work in same shifts, and deep knowledge of each other relieve human resources to keep full attention to the important signals in the environment, also essential for safety. It may also be added that such short-distance- and rich ties enables efficiency, as behavior can be speeded up when you don't have to stop for demanding articulations and explanations towards your significantly tied nodes.

Node arrangement is therefore an adjustment based on real-time challenges to safe behavior, to optimize the possible ties of exchange. A new worker or trainee might for instance be met either as an interruptive node, weakening safety in an established triad, or she or he could be involved in a triad for learning by shadowing either of the nodes, or by successively following each node.

The most important safety ego-metrics may well be the richness of ties in triads, based on analysis of each ego in the organization. However, safety depends on the whole network, and centrality of the connective leader-role must be emphasized. Each department in anchor-handling operations may have a leader-role to bridge the information between various departments. Between these, there is also a connection by the leader of the whole operation, or by the representing node of this position. The ability to give immediate messages also across bridges are of utmost importance for safety purposes, and the centrality of this position as well as the centralization measures of the network are essential. Centralization is overall-measures of relations. Quantification of the relations is also important, since calculations build on assumptions of scales of equal intervals, and the degree measure cannot reflect any safety qualities of a network in itself. Rather, the fields, or spaces between, that reflect the forces for optimal information flow with regard to safety and efficiency point to closeness- and betweenness metrics, as well as density metrics.

The geodesic, shortest-path, measure is therefore also a necessary analysis in this complexity. To be able to arrive at information for decisions to be made, there is an advantage of short paths for information exchange, and a tight structure will reflect this property. Decision making has locations within networks, and for decisions to be based on available information, the paths and flow of information must be explicit. Naturalistic decision making is different from traditional concepts of decision making, being characterized by doubts and uncertainty in real and complex situations. Three different uncertainty situations have been suggested: inadequate understanding (owing to equivocal information, owing to novelty, or owing to instability), incomplete information (complete lack of information, partially lacking information, or unreliable information), and undifferentiated alternatives (equally attractive outcomes, conflict among alternatives, or incompatible role demands). The structure cannot in itself compensate for the uncertainties, but it can contribute to information exchange where more information, more precise information, fuller descriptions or more reliable sources are needed for decisions to be made.

Another aspect in dealing with safety purposes is the redundancies systemized into structures. Equipment and technology have a wide range of redundancy systems, and although human resources can be substituted by technology to some extent, there are tasks that depend on human behavior and adjustment abilities. Building redundancy into network structures means that a node may have to take over other nodes' work if they for any reason become "un-tied" within the network. Replacing entities automatically and immediately is named warm redundancy. Cold redundancy means that some signal has to be given before another node is substituting. These re-arrangements may carry risk and delay in the system, depending on the path to be travelled for the information to be processed and a signal to be decided on and passed along a path further on. The terms of active and passive redundancy are also important in a network approach, as the active implies that the substitute is already active within the network, whereas the passive has to be activated into the network as a new person on the position.

So, redundancy by alternative paths and replacing nodes is also central in preventing issues to escalate into crises.

Two final comments on safety: workload has a major impact on the ability to transfer information, and in stressful situations, it has been argued that any verbal effort may lead to overload and risk. This must be mentioned because relieving the load of nodes by minimizing the need for information exchange enhances safety by balancing the workload for the involved parties. The quality of the ties and the implicit knowledge that constitutes these can thus be a strong safety element. The other point to make here is that the idea of trust may lead to misconceptions of the situation. Trust can reflect a valuable reliance between people, and characterize the ties in a network. A high level of trust may not necessarily be a good measure of safety, though. Trust can also be completely irrational and based on other aspects of a tie than the organization network requirements. People may be considered trust-worthy in parallel and private networks, and still be the node that breaks the chain or flow in a more demanding workload situation.

EFFICIENCY CONSIDERATIONS

Using the available resources in the optimal way to reach goals is one way of describing efficiency. An organization can be effective in the meaning that they reach their goals, but this may be achieved in an inefficient manner. To compete for contracts in the high-reliability industries, safety and efficiency are interweaving now. High efficiency has been seen as a potential risk-contributor, by rushing progress rather than make sure and certain that all involved entities and processes keep the pace. Overview of the totality is necessary to be able to identify discrepancies, risks, and issues that may pave the way for a lurking crisis. Management is thus necessary in at least three different phases that can be segregated for operational purposes. As mentioned earlier, some agreed-upon paths may be less efficient when deviations occur, and this may often be the case. Adapting to the reality of network changes means that further modifications of the network or the paths for information flow must be prepared to be instantly effectuated.

First, risk management is the baseline condition for any operation in HROs. This may call for a specific network structure, optimal for safety and efficiency purposes, as discussed earlier by distance (geodesics) and centralization with high in-degree values for leaders to identify any potential issues of concern. Preventing harm can be built into all practices in this phase.

Next, if any kind of arising issue has to be managed to prevent a further crisis, a decision may be made to switch the network structure into a redundancy structure until a safe state has been achieved and the issue can be handled. The nature of this problem brings centrality measures into call, to focus resources where needed.

Third, a crisis phase may evolve — either suddenly or sneakingly — and crisis management may call for still other structures, depending on the number of abled nodes to engage and the dispatching procedure of the remaining resources in such a situation. The priorities must always involve a realistic mental model of the nodes and ties, to lead a phase like this efficiently. The role of a leader position is to enable the reduction of the already apparent disaster through such resource dispatching.

To sum up some of the ideas, short paths enable fast and precise communication, serving both safety and efficiency. Density may lead to information overload, so structuring with clusters of triads and bridging nodes from each triad to central nodes between triads, seems theoretically advantageous. However, this presumes that ties are cultivated into positively signed and rich edges within the triads, and into positive and rich bridges between the different triads as well as between triads and central decision makers or leaders. The bridging nodes must have specific properties as catalysts in the flow, enabling the connections to deliver information without being asked, when this is necessary. Key positions may thus be identified not necessarily by their ability to give and receive information, but by the way they operate to enable others to do so — a property that may be contrary to ideas from some other SNA-studies, but quite in accordance with complexity leadership theory. Also, initiating nodes may be dispersed according to the specificity of the tasks in integrated offshore operations, and centrality measures for both safety and efficiency purposes may therefore beneficially be applied besides for instance an object-oriented flow-chart approach, where the scope is broken down into subsets of the tasks to be done.

Social network analysis has an advantage in operationalizing ideas from team theory in high-reliability work and complex networks. Leaders and decision makers should stress the node arrangement and tie quality measures beyond the qualitative approach that is principal today.

ILLUSTRATION: AN ANCHOR-HANDLING VESSEL CONFIGURATION

The structure of positions (Fig. 1) in the example of an anchor handling operation will typically be four departments of triads. The captain, chief officer, and second officer are on the vessel's bridge. The chief engineer and two more engineers are organized for the machine/engine room and electrical equipment. A catering officer and two additional service crew constitutes a third department, and a foreman with two additional able seamen are at the vessel's deck. The chief officer is often in charge of maneuvering the vessel

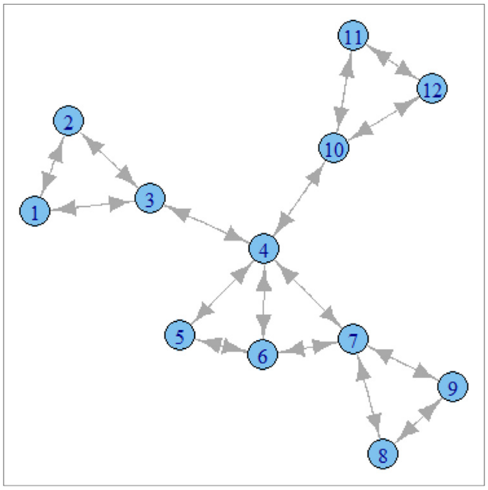

Figure 1 Arrangements of a communication structure onboard a vessel during a demanding operation of anchor handling of an oil drilling rig. Nodes 1—3 are engine crew, nodes 10—12 are catering crew, and nodes 7—9 are deck crew. The (hierarchically more central) nodes 4—6 are bridge personnel onboard the vessel

and communicating with the deck and engine personnel, as well as with catering if necessary during operation (since these often have some medication access). The captain keeps monitoring all activities, but may mostly be interacting through the other two bridge crew as long as this suffices (however, all work permits are signed by the bridge personnel, and in demanding operations the captain also do this during operation, and she or he also keeps all contact onshore throughout operations). The second officer may be responsible for the main tools, the winches, during operation, constantly watching both deck activities, bridge instruments and camera-monitors, to understand the forces acting upon the vessel when connected both to seabed or anchoring arrangements, and to a rig that is also bound to other vessels.

Illustrating the communication or connection workload based on the degree centrality of the nodes, Fig. 2 shows the role of the chief officer (the largest node), but the physical and monitoring workload is not highlighted in this illustration. Attention is also affected by the need to articulate and make a conversation. This particular structure may guard against such safety-stressors for crew with heavy physical workload or little experience.

The average shortest-path-length, the geodesic, of the vessel network is 2.45.

The clustering is of medium size, due to the triadic structuring into four different departments, with a measure of .47 (Table 1).

The structure of a small network like this is based on substantial and fundamental characteristics of the task-specificity of the positions, and the need for redundancy and backup in each triad. It is possible that the real network structure onboard vessels could be organized otherwise, and also, that they function otherwise in other phases of work than what is ideal when they enter the 500-m safety zone encircling the drilling rig. Examples of other structures may include star graphs, ring graphs, full graphs and tree graphs

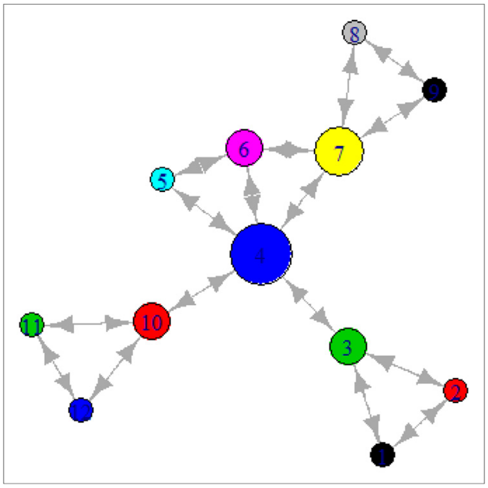

Figure 2 The deck foreman (7), and the chief officer (4) are central during the actual anchor handling phase of an operation. As long as everything follows the scope without errors, the operative workload of the captain (5) can be relieved for other leadership tasks, including the connection to other vessels and rig, as well as onshore communications. This is rarely the case, due to the uncertainties of both natural forces, complexities in equipment and unforeseen events that emerge

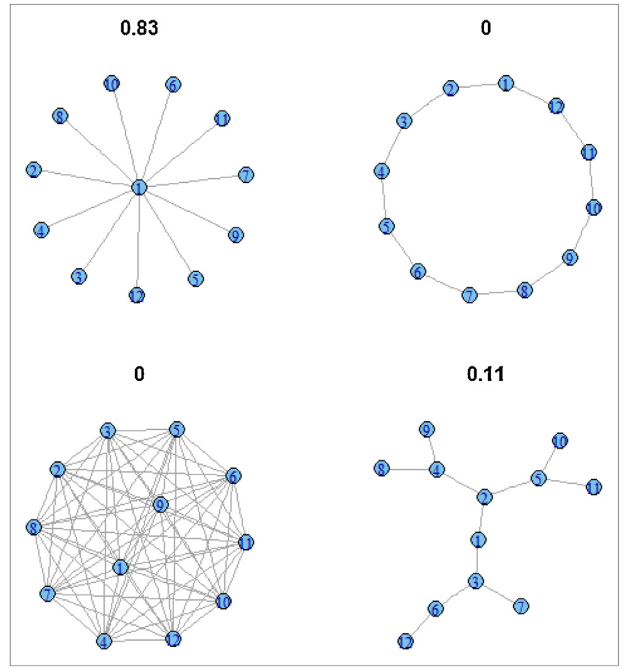

Figure 3 Four structures of 12 nodes and their centralization measures. Top left: star graph, top right: ring graph, bottom left: full graph, bottom right: tree graph

(Fig. 3). The centralization and clustering (transitivity) measures for these 12-node examples can be compared to the vessel measures in Table 2. Varying between 0 and 1, we see that the degree centralization on the vessel, as based on the variability of all actor indices, is not very high. Furthermore, the clustering is medium in size, as would be expected due to the quadruple triadic structure.

Other centralization measures are also of interest. In addition to the measure of degree (.23), representing the normalized amount of adjacent alteri for all vertices in the network, the betweenness (.65), closeness (.26) and eigenvector (.62) measures express, respectively, the extent to which any and all actors is bridging any two other actors in the network, how close all actors are on average based on paths, and how connected any and all are to highly-connected nodes.

Using Watts—Strogatz random graph generation modeling enables some comparison of these measures to other measures of graphs having small-world properties.

Examples of two randomly generated networks are given in Fig. 4, and the total of 100 randomly generated graphs in Fig. 5.

Probability modeling (Fig. 6) shows that the assumed efficiency measure by using geodesic in the vessel network is not very low (2.45) compared to the completely randomly generated graphs (measures for all 100 in Appendix A). The interaction arrangement into triads with a central department can hardly be more cogent, but in reality, the edges will have different interaction qualities, and quantifying these qualities into directed and valued (may be also signed; that is, opening up to negatively valued relations) graphs, may add important information to the complexity of the operative interactions and thus to understanding of induced risk and safety interventions.

This would also entail altered clustering of the crew. The clustering measures for all 100 randomly constructed graphs (to be found in Appendix B) have a range from .07 to .60, as compared to the achieved .47. It is difficult to predict the effect of valued and directed connections on the clustering, as we could expect quite some variations onboard different vessels. The safety culture would probably matter a lot, and safety-orientation may counteract polarization and disorganization, and isolates would quite likely quit the employment situation and seek other work and vessels.

DISCUSSION AND CONCLUDING REMARKS

This text have outlined some basic issues when approaching complexity with a network model, assuming that the leadership is embedded within the structures and co-constructed through entire performances. The organization type may

Table 1 Sum up of local and global centrality measures of all nodes in a vessel network in operative phases

Ego no.	4	7	3, 6, 10	5	8, 9	1, 2, 11, 12
Global centrality (shortest distance to all other alteri)	17	22	23	26	31	32
Local centrality (absolute number of adjacent alteri)	5	4	3	2	2	2
Local centrality as a relative measure of maximum possible connections	.45	.36	.27	.18	.18	.18

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Table 2 Overall centralization measures for some networks of the same node size and the illustratory vessel-network

Measure Graph type	Degree centralization	Clustering
Star	.83	.00
Ring	.00	.00
Full	.00	1.00
Tree	.11	.00
Vessel	.23	.47

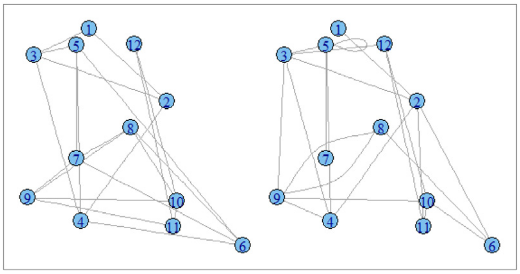

Figure 4 Two 12-node networks based on Watts—Strogatz graph generation

define contextual necessities for analysis, and the chosen focus on specific demands for safety and efficiency in complex and demanding environments can just serve as a starting point of more advanced and empirically grounded analyses of networks in high-reliability work. Safety and efficiency may be incompatible properties for some industries, but the competition in the market puts pressure on the organizations to demonstrate both. The team interaction has a paramount function for highly specialized work in complex environments, and indicators of functionality may facilitate both training and other safety interventions like barrier management. Further work should expand the measures-portfolio and construct a range of data-collection instruments for a selection of interactional qualities that affects the safety and efficiency in high-reliability work. The focus on structures rather than processes may limit the scope of leadership agency, so knowing that structure formation is a dynamic process with adaptive aims to meet challenging circumstances and risks should enable organizations with more opportunities of explorations for utilizing the potential of the network properties. Furthermore, event history modeling could also be advantageous when we establish an understanding of complex adaptive systems and the possibilities and limitations of social network metrics in assessing our organizations.

Leadership may certainly be understood as an emerging property of the organization, but can not be understood as

Figure 5 The total of 100 generated 12-node networks (Watts—Strogatz graph generation model)

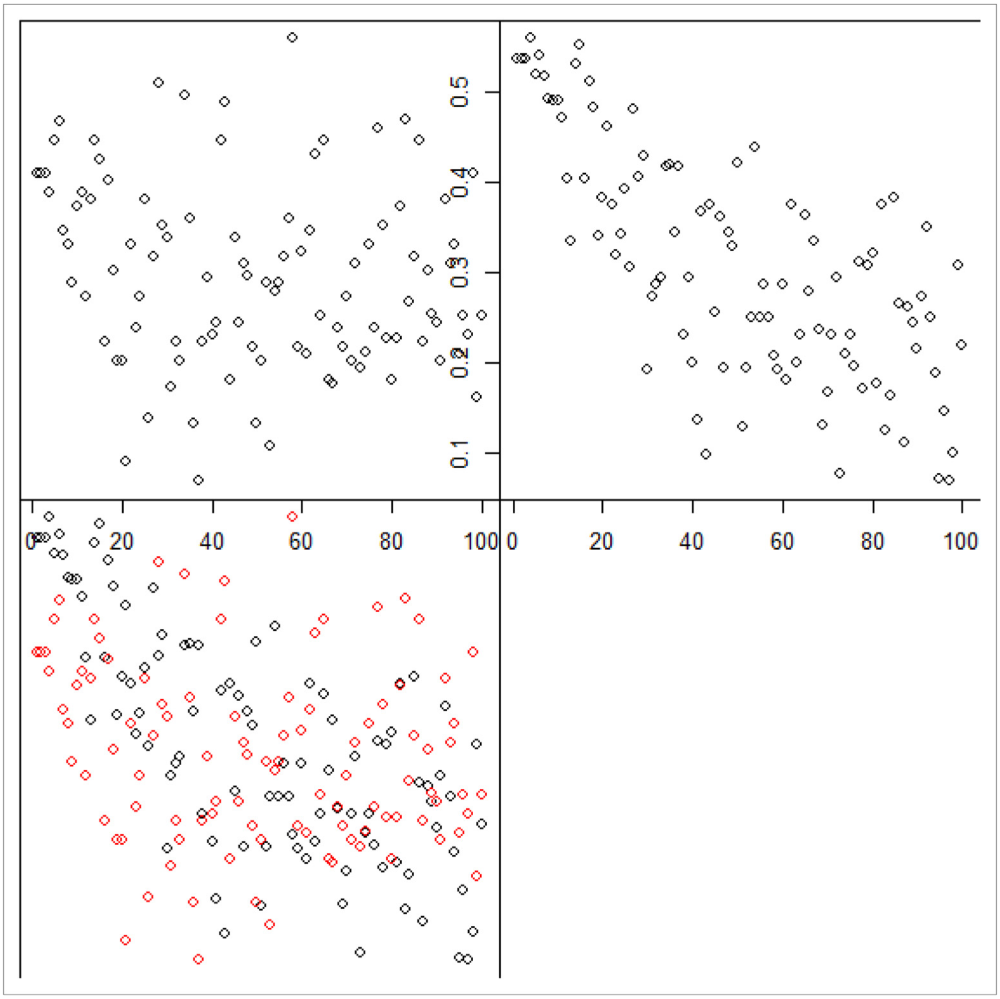

Figure 6 Top left: average geodesics for Watts—Strogatz randomly structured graphs with 12 nodes for varying probabilities (between 0 and .99), top right: clustering (transitivity) for the same random graphs. Bottom: normalized values of clustering (black) and geodesics (red) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article)

separate from decision-making. Any act, any performance, is a manifest decision — whether intended and conscious or not — and a network approach allows us to analyze the ways structures affects such decisions. It also allows us to establish networks that enable learning opportunities in the adaptive space. Such learning opportunities may need simulations in high-reliability organizations, where real-life explorations can have hazardous consequences. Forestalling, anticipation and imagination may be necessary to equip an organization with adaptive capacity in complex environments, and testing the robustness of the organizational structure by pushing the demands and pressures may be beneficial, but should always go along with ethical considerations and potentials for erroneous learning.

SELECTED BIBLIOGRAPHY

There are amounts of resources in complexity theory, leadership theory, organization theory, social network analysis methods, and contributions regarding safety and efficiency that could be of interest to the reader. Also, there are a lots of empirical research contributing to developments on all these topics.

For *complexity leadership theory*, the article from Uhl-Bien, M. & Arena, M. (2017), Complexity leadership: Enabling people and organizations for adaptability, in Organizational Dynamics, Volume 46, Issue 1, Pages 9—20. ISSN https://doi.org/10.1016/j.orgdyn.2016.12.001; and from Uhl-Bien, M.; Marion, R. & McKelvey, B. (2007), Complexity Leadership Theory: Shifting leadership from the industrial age to the knowledge era, in The Leadership Quarterly, Volume 18, Issue 4, Pages 298—318. ISSN 1048-9843, https://doi.org/10.1016/j.leaqua.2007.04.002 have interesting points.

Some important questions to their approach have been raised by Tourish, D. (2018), in the article Is complexity leadership theory complex enough? A critical appraisal, some modifications and suggestions for further research, in Organization Studies. ISSN 0170-8406, https://doi.org/10.1177%2F0170840618789207.

Also, for elaborating on leadership emerging in different kinds of organizations, the articles by Hannah, S.T.; Uhl-Bien, M.; Avolio, B.J. & Cavarretta, F.L. (2009). A framework for examining leadership in extreme contexts, in The Leadership Quarterly, Volume 20, Issue 6, Pages 897—919. ISSN 1048-9843; and Hannah, S. T. & Lester, P. B. (2009). A multilevel approach to building and leading learning organizations, in The Leadership Quarterly, 20, 34—48, have interesting perspectives.

For *social network analysis*, there are useful resources in the books by John Scott (a starting point can be What is social network analysis, Bloomsbury Academic, 2012), as well as in the advanced book by Stanley Wasserman and Katherine Faust (Social network analysis. Methods and applications, from Cambridge University Press, 2009).

Naturalistic decision making referred to in the text can be found in the article by Lipshitz, R. & Strauss, O. (1997), Coping with uncertainty: A naturalistic decision-making analysis, in Organizational Behavior and Human Decision Processes, 69, 149—163.

Also, for the interested reader, the report following the loss of Bourbon Dolphin can be found here: NOU 2008: 8. The Loss of the "Bourbon Dolphin" on 12 April 2007. Report from a Commission appointed by Royal Decree of 27 April 2007. Oslo, Ministry of Justice and Public Security.

APPENDIX A

Table of randomly constructed graphs' geodesics

[1] 2.439394 2.439394 2.439394 2.393939 2.515152 2.560606 2.303030 2.272727

[9] 2.181818 2.363636 2.393939 2.151515 2.378788 2.515152 2.469697 2.045455

[17] 2.424242 2.212121 2.000000 2.000000 1.763636 2.272727 2.075758 2.151515

[25] 2.378788 1.863636 2.242424 2.651515 2.318182 2.287879 1.939394 2.045455

[33] 2.000000 2.621212 2.333333 1.854545 1.717949 2.045455 2.196970 2.060606

[41] 2.090909 2.515152 2.606061 1.954545 2.287879 2.090909 2.227273 2.200000

[49] 2.030303 1.854545 2.000000 2.181818 1.800000 2.163636 2.181818 2.242424

[57] 2.333333 2.757576 2.030303 2.257576 2.015152 2.303030 2.484848 2.106061

[65] 2.515152 1.954545 1.945455 2.075758 2.030303 2.151515 2.000000 2.227273

[73] 1.981818 2.018182 2.272727 2.075758 2.545455 2.318182 2.054545 1.954545

[81] 2.054545 2.363636 2.563636 2.136364 2.242424 2.515152 2.044444 2.212121

[89] 2.109091 2.090909 2.000000 2.378788 2.227273 2.272727 2.015152 2.106061

[97] 2.060606 2.439394 1.913043 2.106061

APPENDIX B

Table of randomly constructed clustering measures

[1] 0.53571429 0.53571429 0.53571429 0.55932203 0.51923077 0.54000000

[7] 0.51724138 0.49090909 0.48979592 0.48979592 0.47058824 0.40384615

[13] 0.33333333 0.52941176 0.55102041 0.40384615 0.51063830 0.48214286

[19] 0.33962264 0.38181818 0.46153846 0.37500000 0.31914894 0.34090909

[25] 0.39130435 0.30508475 0.48000000 0.40540541 0.42857143 0.19148936

[31] 0.27272727 0.28571429 0.29411765 0.41666667 0.41860465 0.34426230

[37] 0.41666667 0.23076923 0.29411765 0.20000000 0.13636364 0.36585366
[43] 0.09677419 0.37500000 0.25531915 0.36000000 0.19354839 0.34285714
[49] 0.32812500 0.42105263 0.12765957 0.19354839 0.25000000 0.43750000
[55] 0.25000000 0.28571429 0.25000000 0.20689655 0.19148936 0.28571429
[61] 0.18000000 0.37500000 0.20000000 0.23076923 0.36363636 0.27777778
[67] 0.33333333 0.23529412 0.13043478 0.16666667 0.23076923 0.29268293
[73] 0.07692308 0.20930233 0.23076923 0.19565217 0.31034483 0.17142857
[79] 0.30769231 0.32142857 0.17647059 0.37500000 0.12500000 0.16216216
[85] 0.38181818 0.26470588 0.11111111 0.26086957 0.24324324 0.21428571
[91] 0.27272727 0.34883721 0.25000000 0.18750000 0.06976744 0.14634146
[97] 0.06818182 0.10000000 0.30769231 0.21951220

L. Vederhus is an Associate Professor at UiT The Arctic University of Norway, Tromsø. Her professional and research interests are wide-ranging, originating in psychology, education, sociology, biology, and information science, and into complexity theory and systems sciences. She has also been teaching quantitative and qualitative research methods and theory of science for many years. Recent research focuses on leadership, safety, communication, learning, teaching, training and assessment in organizations (Norwegian University of Science and Technology, Norway; University of Stavanger, Norway; UiT The Arctic University of Norway, Norway. Email: lillian.vederhus@uit.no).

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