Managing in a Post-COVID-19 World: A Stakeholder Network Perspective

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Abstract—*This article argues that technical leaders in a post-COVID-19 world should adopt stakeholder-oriented management techniques tailored to complex, chaotic, and disordered domains. In part, this is because the unprecedented breadth of the novel coronavirus's impact has required organizations to strengthen their stakeholder orientation, given the second-order, network effects of management decisions during a global pandemic on unseen, unknown constituencies. In part, this is because even our causal models and modes of group sense-making have been affected by the suffering and uncertainty caused by the pandemic. This article draws from ongoing research on complex stakeholder networks, applying recent advances in graph theory to establish that organizations with more resilient, more efficient, more globally connected stakeholder networks better satisfy the claims of their stakeholders, across an array of financial and environmental, social and governance metrics. This research can be extended into postcrisis, chaotic, and disordered domains by adapting the Cynefin framework, from the Welsh word for "habitat," and applying it to the stakeholder theory literature. This stakeholder network perspective yields surprisingly simple and relevant tools for managers, as shown by a case study of the real-world performance of large US firms during the period of COVID-19's initial diffusion and impact.*

Key words: Assortativity, clustering, COVID-19, cynefin, network resilience, social networks, stakeholders, supply networks

I. Introduction

THIS article argues that leaders in technical organizations in a post-COVID-19 world should study and deploy stakeholder-oriented management techniques tailored to complex, chaotic, and disordered domains. It provides a rubric for identifying such techniques in the complex systems and stakeholder theory literatures, and offers an example of ongoing, novel research in this area, based in network science, specifically the concept of percolation as developed in graph theory and statistical physics, and shows that this sophisticated technical literature yields surprisingly simple and relevant tools for managers. Finally, it offers a case study exampling how stakeholder analysis for unordered domains, rooted in the study of social and technological networks, can predict the real-world performance of firms and organizations in a period of radical disorder.

At a high level, the particular challenge of the COVID-19 pandemic is three-fold. The first is one applying to epidemic contagions generally: they spread along social networks, which are robust, adaptive, and efficient, but we seek to defeat them with hierarchical, technical organizations, such as the Centers for Disease Control and Prevention or World Health Organization, which show characteristics of technological networks, and are, thus, inherently less resilient and more liable to break down in a crisis situation [1], [2]. The organizational resilience concern "is particularly salient for large and often multinational organizations with broad mission requirements," since "such organizations with operational and organizational complexity are increasingly exposed to systemic threats, where a disruption to one component of an organization's systems can trigger losses and disruptions throughout the larger organizational body," [3]. We, thus, need ways of making the collaboration networks within technical organizations more social, and less technological, in a post-COVID-19 world.

Second, the extremely high transmissibility of the novel coronavirus, with the attendant social distancing requirements, means that we cannot easily architect new social networks to combat its spread. This is because innovation and diffusion of innovation initiatives are themselves "complex contagions," requiring thicker webs of personal interaction and teamwork than broadcast communication mediums such as Zoom can provide [4], [5], and so we must seek out the distinctive characteristics of successful virtual teams and innovation networks [6], [7].

Third, the unparalleled breadth of the pandemic's impact means that managers must respond to an even wider range of diverse, disparate stakeholder populations than normal, certainly beyond merely their funding sources. Indeed, even an April 2020 S&P Global Ratings statement declares that "the coronavirus pandemic is highlighting why stakeholders matter," since paying insufficient attention "to all stakeholders in decision-making is backfiring on a number of companies" while "other businesses are taking actions that may ultimately strengthen employee engagement, brand, and reputation," with the result "that differences in stakeholder management will ultimately play into a number of future rating actions," concluding that "corporations that better embed stakeholder considerations in their decision-making and strategy will likely limit unintended consequences and be more resilient over time" [8]. Managers are facing unprecedented challenges precisely because of the potential second-order network effects of doing business as usual during a global pandemic on unseen, unknown stakeholders. Tools and methods for identifying and accessing such "hidden" stakeholders are, thus, necessary [9], [10].

The net result is that organizations need to rethink their network structure, to better serve and interact with their stakeholder constituencies, choosing configurations that are both more efficient and less dense than commonly found in social networks in real-world managerial environments. The research presented here has implications for the work of rearchitecting such stakeholder networks.

II. Literature Review

Complexity was an object of study from the outset of research on systems and organizations, as in the work of Nobel Prize winner Simon [11], [12]. Simon was himself influenced by the business executive and management theorist C. Barnard, whose 1938 work explicitly addressed the problem of organizational complexity in the context of the network combinatorial explosion effect [13]. In turn, Simon and, especially, Barnard have been identified as the earliest adapters of the stakeholder concept by R. E. Freeman, the modern management scholar most responsible for the rise and diffusion of stakeholder theory [14, pp. 48-49]. The association is natural, since modern organizations are complex precisely because their stakeholder systems are large, heterogeneous, and dynamic [15]. Furthermore, complexity is a particularly relevant concept for managers in technical organizations charged with building and maintaining complex technical systems since, as Ashby's famous law of requisite variety suggests, the control mechanism of an organization should be as varied or complex as the entity it controls [16].

The Cynefin framework has been put forward as a heuristic schema for addressing complexity in modern organizations [17], [18]. In its most basic formulation, the Cynefin taxonomy aims to classify the different types of group sense-making by positing "five contexts defined by the nature of the relationship between cause and effect" [17]: simple, complicated, complex, chaotic, and disorder, the last being simply the state where it is unclear, which of the first four fundamental contexts obtains. The framework seems, especially, relevant in the context of the COVID-19 pandemic, during which routine tasks have become complex, complex systems have crossed into chaos, and decision support technologies such as AI developed for ordered domains cannot be readily applied in a crisis or postcrisis context. Drawing on [17]–[22], a rough schematization of the Cynefin framework can be given in Table 1.

The Cynefin taxonomy has been validated as a useful paradigm in the engineering management literature for areas such as emergency management, human reliability analysis, the selection of decision support processes, sustainable supply chain management, and the selection of systems engineering methodologies [19]–[22]. However, it has not yet been applied to stakeholder management research. A recent survey suggests that most stakeholder research in management science has focused on methods suitable primarily to ordered domains [19], [22]. This is also true for most real-world organizations, which use tools suited mainly for ordered domains, even when not appropriate [15, ch. 5]. Consequently, especially in the aftermath of the COVID-19 pandemic, there is a manifest need, on the part of both researchers and practitioners, for further study and innovation of stakeholder management methods in the complex, chaotic, and disordered domains. Drawing on the work of Freeman and his collaborators [14], [15], an overview of stakeholder management strategies within the Cynefin taxonomy can be given in Table 2.

This offers a framework for understanding which stakeholder management strategies are suitable to unordered domains. Examples in engineering management research literature might include set-based design [24], whereby a range of potential solution alternatives is collected collaboratively, and only narrowed down to a point solution later; high-fidelity system virtualization, model-based systems engineering and technical storytelling [25], to spark dynamic, cooperative stakeholder interactions in the design of complex technical systems at the earliest stages; and tools to measure the effects of stakeholder interaction such as system dynamics [53] and real options analysis [24]. The research presented here complements such approaches, and similarly focuses on interactions, which as described in Table 2 are of particular importance in complex, chaotic, and disordered domains, to better identify their manifold risks, possibilities, and potential stakeholder conflicts and spur both brainstorming and bargaining [17].

III. Sample Methodology For Unordered Domains

A foundational 1957 paper by Broadbent and Hammersley posited the need to study not only stochastic diffusion processes, but also cases where the medium itself manifests randomness, coining the term percolation to describe the behavior of a random, or disordered, medium, as opposed to a disordered process [26]. In fact, many treatments of percolation explicitly characterize it as essential to understanding the macroscopic behavior of disordered media and as one half, along with the random walk, of the study of disordered systems [27], [28]. Research at the intersection of complex systems and stakeholder theory has occasionally used models based on stochastic processes, for instance real options [24], or financial options analysis [14, p.133]. Thus, one way to apply stakeholder analysis to unordered domains in the post-COVID-19 world is to study contexts where “the stochastic mechanism resides in the medium rather than in the particle,” as for instance in large, dynamic webs of organizational interactions. The original 1957 paper specifically referenced the spread of disease as a percolation phenomenon, and percolation has been used as tool within mathematical epidemiology to model infectious diseases in addition to, more generally, the connectivity of cooperative systems defined on networks [26], [27].

In ongoing research conducted by the authors of this article, previously presented at industry conferences [29], [30], and submitted for further publication, a framework has been

Table 1. Cynefin Taxonomy of Domains.

Domain	Simple	Complicated	Complex	Chaotic	Disordered
Phenomena	Known knowns, cause, and effect relationships stable and clear to all.	Known unknowns, cause, and effect relationships not clear, but knowable by teams of experts.	Unknown knowns and emergence, causality knowable only in retrospect.	Unknown unknowns, crisis and emergency, no discernible relation between cause and effect.	Multiple perspectives jostling for prominence, cacophony rules, meeting overload.
Management techniques	Best practices, standard operating procedures, AI, command-and-control, process re-engineering.	Expertise rooted in data collection, AI, statistical inference, predictive modelling, operations research, structured techniques.	Pattern-identification, experimental approaches pursued concurrently.	Pattern formation missing, so decisive action needed to reduce turbulence and stabilize situation.	Collaboratively gain consensus from key leaders as to which of the four primary domains obtains.
Challenges	Categorizing correctly, avoiding complacency on the part of leadership, through continuous monitoring.	Lack of analytics, groupthink, analysis paralysis, maintenance of incorrect assumptions.	Seeking to tame complexity with command-and-control, not seeking multiple perspectives.	System must be brought back towards order, but this may favor authoritarian, dominant leaders.	Factional leaders argue with one another, seeking to steer system toward their favored domain.
Need for interaction	Need not be extensive because disagreement is rare, needs can be anticipated.	Brainstorming, role playing, scenario planning, etc. with non-experts validates technical expertise.	Most important, should be democratic, interactive and multi-directional.	Communication should be of the most direct, “broadcast” kind, to reach broadly.	Should be economical as possible, filtering out the noise.

proposed for analyzing and managing complex stakeholder networks. It studies two important topological metrics readily captured in existing network statistical computing packages. The first is assortativity, or degree correlation, the tendency of nodes to attract, or repel, other nodes with a similar number of connections, or degree. The second is transitivity, or clustering, the tendency for one to be connected to friends of one's friends in a transitive fashion, in the context of a social network, completing a triangle. Assortativity and transitivity, which are found to be higher in social and lower in technological networks, are then tied, through both simulation and analytical derivation, to the percolation threshold. This is the level of link reliability or, equivalently, transmission likelihood, above which a connected cluster forms, putting into communication, or infecting, a group of nodes large enough to span the network or push the system above the epidemic threshold, allowing a contagion to sustain itself, rather than die out, with a lower percolation threshold equating to a quicker tipping point into connectivity [1], [2], [27], [31].

This particular mathematical framework, connecting bond percolation to the network statistics of assortativity and transitivity, while finding some application in mathematical epidemiology, has not previously been applied to problems in stakeholder analysis or engineering management. An empirical approach to validate this framework has been identified, allowing the creation of large, heterogenous high-fidelity stakeholder networks for US publicly traded firms. This approach identifies a firm's stakeholders and their interactions utilizing stock-holding filings, industry peer relationships and, most importantly, a massive supply-chain relationship database validated in the engineering management literature as a high-value data source [7], [32]. Applying this methodology to the constituents of the OEX100 index, as of June 2019, a group of one hundred of the largest US-traded firms, yields a valuable dataset of real-world complex stakeholder networks, each with dozens of stakeholder nodes and scores or even hundreds of stakeholder relationship edges. Evidence using both financial and environmental, social and governance (ESG) metrics was found for the thesis that, other things being equal, firms with lower percolation thresholds, signaling greater connectedness and resilience, and higher assortativity and lower transitivity, signaling greater efficiency in achieving connectedness, relying on global connectivity rather than local density,

Table 2. Cynefin Taxonomy Applied to Stakeholder Analysis.

Domain	Simple	Complicated	Complex	Chaotic	Disordered
Stakeholder Phenomena	Stakeholder needs are taken as given, as in well-defined and delimited projects and serial, waterfall development processes and other arm's length, formally contracted approaches.	Stakeholder needs are unknown but knowable, can be found through agile processes iteratively incorporating feedback, or by accessing expert knowledge, and can be ranked for impact.	Cause and effect relationships between entity and stakeholders not clear, value and importance of stakeholders are emergent, from network.	Identity of both stakeholder needs and stakeholder themselves may be unknown, relations between stakeholders are noisy and unreliable.	Multiple stakeholder factions jostling for prominence, those with urgency may demand simple approach, others a more complex approach.
Stakeholder Management Techniques	Identification, mapping and monitoring, definition of needs and requirements, optimization.	Structured elicitation and engagement, stakeholder classification and maps, tradeoff analysis to balance between preferences.	Pattern-identification in stakeholder networks, soft OR, multicriteria optimization.	Focus on keeping stakeholders involved in system, rather than dropping out due to dissent or dissatisfaction.	Collaboratively create consensus by connecting key leaders (those with most connections).
Stakeholder Management Challenges	Firms may have a purely PR approach, or simply ignore stakeholders.	Subject matter experts becoming entrenched in assumptions, failure to categorize stakeholders.	Valuing only financial metrics, emphasizing tradeoffs, slicing up pie, not enlarging.	Preserve integrity of the system and create semblance of order, goal is to bring state of the system back towards complex.	Filter out noise generated by competing stakeholder perspectives, by pruning density of connections.
Need for Stakeholder Interaction	Communication can be largely one-sided, without interactive, iterative approach. Interaction not important.	Emphasis is on keeping lines of communication open between focal entity and stakeholders accessed directly.	Interstakeholder communication vital and constitutes vital resource to firm.	Broadcast approach to reach as many stakeholders as possible, even indirectly.	Should be economical as possible, avoiding overload, while connecting key faction leaders.

were more stakeholder-oriented and better able to deliver value to their stakeholder systems in both financial and nonfinancial terms.

This research concentrated on firm performance in normal periods, tailored to strategists, supply chain managers, and technical leaders seeking to negotiate merely complex domains, where lower percolation thresholds correlate with larger central connected components and smaller islands of disconnected nodes, and thus larger, healthier stakeholder systems, as fewer legitimate interests are excluded from collaborative decision making, a key aim of stakeholder theory [9], [10], [14]. Higher assortativity and/or lower transitivity, for a given percolation threshold, meanwhile, imply greater efficiency and less density in communication, lessening the threat of collaborative overload [6], [25]. The Cynefin rubric shows that this threat is especially pressing in periods of deep uncertainty, as many organizations have experienced during the COVID-19 lockdown, when competing constituencies jockey for ascendancy, as those with "Zoom fatigue" can attest [17].

This research also identified a simple method for measuring the percolation threshold, which is not typically captured by network statistical packages, for finite networks evidencing the degree correlation and clustering characteristic of real-world networks [2]. While not the gold standard method, it has been found that the inverse of the leading eigenvalue of a network's adjacency matrix is a high-quality estimate of percolation threshold [33]. This means that managers seeking to better serve stakeholders in a post-COVID-19 world have at their disposal a simple stakeholder management tool. After mapping their stakeholder network, emphasizing the connections between stakeholders, as in [10], one may derive an adjacency matrix $\boldsymbol{A}$, with ones representing extant connections between stakeholders, and zeroes elsewhere and on the diagonal, essentially equivalent to an organizational design structure matrix, as in [5]. Configurations for which the largest eigenvalue of the adjacency matrix $\boldsymbol{A}$ is higher, and thus percolation threshold estimate is lower, are relatively more connected, while those for which the assortativity measure is higher, as calculated by standard software packages, achieve connectivity more efficiently.

IV. Case Study and Discussion

Connectedness in periods of stability, however, does not necessarily translate to clarity and unity of purpose in times of disorder, for example, during the recent pandemic lockdown and its aftermath. In such periods, according to the Cynefin literature, when the organization is not necessarily in crisis, but is facing deep uncertainty, communication should be as economical as possible, to filter out the noise created by different stakeholder factions competing for influence [17], [18]. Consensus should be arrived at by connecting key leaders and influencers, usually those who are themselves most highly connected, rather than a census of all stakeholders. The thesis, thus, emerges that organizations with more connected stakeholder networks, as measured by low percolation threshold, serve their constituencies more effectively in ordinary times, while those with higher degree correlation are both more efficient generally and better positioned to survive periods of disorder. Indeed, the earliest stakeholder theory identified both effectiveness and efficiency in serving constituencies as key to organizational survival, since individual stakeholders will drop out if their private needs are not effectively met, while the system writ large will not endure if the competing claims of its stakeholders are not balanced efficiently [13]. This thesis is validated by a case study of firm financial performance during the initial tipping point period of the COVID-19 pandemic, as contagion, social distancing and uncertainty diffused throughout the US, and equity markets fell from all-time highs in February 2020 to new recent lows, with attendant volatility measures achieving all-time highs, less than one month later. Building on previous empirical work described above, the hypothesis that stakeholder network statistics for OEX100 firms constructed at the end of Q2 2019 would provide independent variables of utility for predicting financial volatility metrics in Q1 2020, with more efficiently connected firms weathering the period of disorder relatively better, is confirmed in Table 3.

A linear regression of logged 30-day historical volatility as of February 19, 2020, the day the OEX100 index hit its then all-time high, shows that firms with more connected, resilient stakeholder networks, as measured by percolation threshold, calculated simply as the inverse of the leading eigenvalue of the adjacency matrix as mentioned above, had significantly less realized volatility than their peers, controlling for market capitalization and industry effects. For each one standard deviation increase in the percolation threshold measure, firms experienced on average a .259 standard deviation increase in short-term realized volatility. However, as the equity markets experienced unprecedented volatility, these same highly connected firms saw their realized volatility increase even more than their peers, as uncertainty pervaded the market, and the relevant Cynefin domain moved from complexity to disorder. Firms with percolation thresholds one standard deviation below the mean saw their volatility spike .395 standard deviations more than their peers, other things being equal. At the same time, firms with stakeholder networks one standard deviation more efficient than their peers, as measured by degree correlation, had volatility spikes .297 standard deviations less than their peers on average, showing the strengths of organizations with characteristics of social, rather than technological, networks [1], [2]. This is shown in Figure 1, with percolation threshold on the *x* axis, degree correlation on the *y* axis, and volatility spike over the peak to trough period, log-transformed, on the *z* axis.

V. Conclusion

This brief case study is illustrative of the power of stakeholder network statistics to predict the central entity's performance, here the riskiness of its common equity as estimated by public markets during a period of radical disorder. In research submitted for publication elsewhere, these metrics are connected with firm performance across a broad range of financial and nonfinancial measures, with high levels of significance. This accords with percolation theory's utility as one of the simplest, most promising means for modeling disordered mediums [28, p.3].

Managers may use graph topology statistics as leverage points to improve organizational ecosystems. Here, further research opportunities are plentiful. Applied work in mathematical epidemiology has developed rewiring algorithms, switching edges to make simulated graphs more social and less technical and, thus, more likely to facilitate epidemics [34], [35]. Such approaches could be useful, in the pandemic context, in guiding physical reopening strategies. However, additional understanding is needed to rewire real-world stakeholder systems, which are sparse, heterogeneous, weighted, and constrained by economic, legal, and other considerations. While Pareto-improving rewiring was often found possible in OEX100 stakeholder networks, raising assortativity and resilience without increasing clustering, this is by no means assured, and further research is necessary to perform tradeoffs between graph topological measures. Finally, while the causes and benefits of decreased clustering in social networks are well known, going back to long-standing concepts of brokerage, structural holes, and the strength of weak ties in sociology [4], this is not so for assortativity. One study notes the lack of research in this area and finds that increased degree correlation is driven by new entrants exhibiting antipreferential attachment, whereby newly arrived nodes with initially few connections accumulate links with less-connected, older nodes, consequently emerging as rivals to incumbent leaders, suggesting the benefits of incorporating new, diverse stakeholders [36].

However, the purpose of this article is not to argue for specific techniques from network science, and the technical details of this work have largely been passed by. Rather, it is merely to offer a stakeholder network perspective on managing in a post-COVID-19 world, and an example of the tools available for the important work ahead. This perspective argues for the need for scholars and practitioners to embrace an inclusive stakeholder orientation, to better counter the pandemic's unprecedented breadth of impact, especially its second-order network effects on unseen, hidden stakeholder populations, while being mindful of the ways in which the COVID-19 pandemic has impacted our modes of group sense-making.

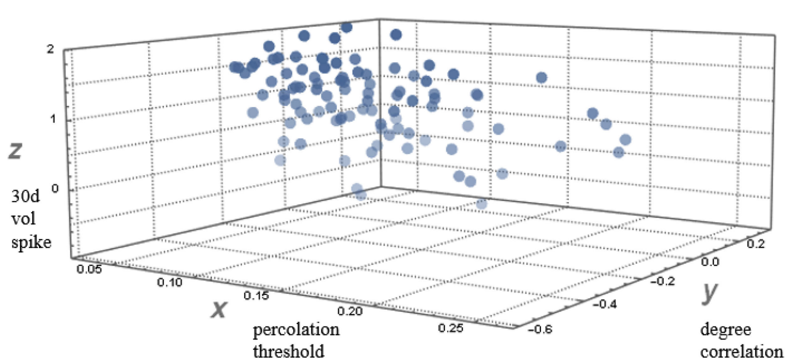

Figure 1. OEX100 Q2 2019 Firm Stakeholder Network Metrics versus Q1 2020 Volatility Spike.

Table 3. 30-Day Historical Volatility of Oex100 Stocks During Market Fall From Peak to Trough 2.19.20-3.23.20 Linear Regressions With Standardized Coefficients.

Dependent Variable (log transformed)	Percolation Threshold	Degree Correlation	Clustering	Market Cap (log transformed)	R^2	Adj. R^2
Feb 19 30-Day Historical Vol***	.259*	.172	−.117	−.385***	.353	.263
% Increase in 30- Day Hist. Vol***	−.395**	−.297**	.0129	.217*	.425	.345

*$p < .05$, **$p < .01$, ***$p < .001$. Both tests are overall significant at the .00*** level.Industry dummy variables are included (eight categorical variables, for nine sectors) in both tests.Both tests fail to reject the null hypothesis of normality (Shapiro–Wilkes test) and homoscedasticity (Breusch–Pagan test) of residuals, with no signs of multicollinearity. Market data obtained from Bloomberg. Stakeholder network statistics collected at end of Q2 2019.

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