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Emergent Strategy and Cascading Behavior Patterns During Crises: Evidence from Brisbane's 2011 Floods

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Abstract

In January 2011, flooding of historic proportions hit the Australian city of Brisbane causing one death. Understanding the decisions made on dam operation in response to intense rainfall is crucial for preventing such disasters or at least, minimising risk in the future. This article reports on an analysis of 345 legal transcripts conducted during the Queensland Floods Commission of Inquiry (QFCI) revealing a subjective, process of decision-making, akin to bricolage, with a distinctly complex and emergent quality to the formation of mitigation strategies during one of the city's worst natural disasters on record. The main contribution of this article is how complexity theory, uniquely connected to the concept of emergent strategy formation, can be applied to complex disaster situations. There has been limited research on how problems require a flexible and adaptable process to manage the cascading patterns of emergent crises. The article proposes future research related to understanding emergent patterns and the management of complexity in organizations.

Keywords: Emergence, Strategy, Planning, Complexity, Concept Mapping, Flood Mitigation

Introduction

This research is based on the Brisbane flood crisis of 2011 which reached catastrophic proportions, inundating a large residential area of 29,000 homes, leading to one death and more than AU $5 billion in damages. The geographic environment enveloped by the city of Brisbane is flood-prone, settled in a low lying plain surrounded by a catchment of rivers and creeks, combined with a humid subtropical climate. Brisbane experiences heavy seasonal rainfall typical of a humid subtropical climate. Lake Wivenhoe is an unnatural reservoir with a capacity of 3.132 Megalitres, constructed with a rock fill embankment, above Brisbane on the Brisbane River and onto a watercourse into the Brisbane river on which the central business district is built. Not only is Wivenhoe the city's main water supply, but it also serves as a key flood mitigation facility with storage of over 3 million Megaliters. Wivenhoe dam is operated by a state government bulk water supply authority, SEQ Water.

Dr Margaret Cook, a Brisbane historian, highlighted the core problem with the city in her work (Cook, 2019). In this book Dr Cook details how Brisbane is really a 'River with a city problem." Cook (2019) argues that the city was built around a flood-prone river that created a problem for the river as it was subjected to decades of engineered controls. The city has been inundated by several catastrophic floods but low-lying areas, for example Rocklea can experience flooding in moderate rainfall. In this study, the authors dig deeper to find out the events of the 2011 flood, and how the complexity of the situation created waves of problems, termed 'Cascading Events,' led to the tragedy seen. Cook (2019) also makes the point that the planners and city dwellers had pinned their hopes on the dam being able to prevent floods. As discussed in this paper, that was probably false hope due to the intersectional nature of complexity and the fact that such whether events themselves are not infrequent. Cook's (2019) discussion on the design of the dam correlates well with the findings presented later about how hard it is the plan for such problems given the city itself is built on a flood plain.

Although governments and communities seek to reduce the impact of crises, they are incapable of eliminating the risk of natural disaster altogether. For example, in the case under discussion, dams have finite flood storage capacity so can only mitigate floods. For this reason, understanding the contributing factors and causes for risk during crisis planning and management are of principal concern to enable society to learn from and effectively handle natural disasters in the future. This case examines the situational factors leading to the flood crisis and particularly the decision making of on-duty engineers responsible for managing this prime catchment during the city's worst flood crisis on record.

It is not unusual to observe an early tendency to assign blame during disasters (QFCI, 2012; US HoR, 2006; Boin et at., 2010). In the case of Brisbane in January 2011, questions were raised about the operation of the city's largest reservoirs, Somerset and Wivenhoe Dams, and the consequences of water releases leading to the flooding of large residential areas of downstream Brisbane. The Queensland Flood Commission Inquiry (QFCI) following Brisbane's flood events focused heavily on the use of operating manuals and the decisions of engineers immediately before and during the floods from 8 to 12 January 2011 (QFCI, 2012). An analysis of decision making during the flood crisis reflects a distinctly emergent quality to management strategies that were adopted, despite the presence of detailed operating plans, procedures, manuals and policies. To this end, this study adds a pragmatic contribution to the application of complexity in research and management, and further incorporates complexity principles into crisis and risk management thinking. The paper begins with a reflection on the conceptual foundations of the study of complex systems, followed by an overview of data collection and analysis methods, findings, discussion, limitations and concluding remarks.

It is worth noting that in the lead up to the flood crisis, the city had experienced one of its most enduring periods of drought. Decisions to release precious water from the catchment area would likely have been met with a high level of concern that losing water from the reservoir, while necessary to mitigate flood risks, would also reduce the city's future water supply. These factors create a substantially complex, unpredictable and emergent situation suitable to apply the theoretical framework of complexity theory.

Background

The study of human responses to the complexity of disasters is well established (Fussell and Elliot 2009, Neisser, 2014). The majority of work in this area has focused on the management (Forero & Rodríguez 2020) and response aspects of disaster management; essentially a post hoc event congruent with most disaster response situations. Responses to complex disasters scenarios remain somewhat of a 'black box' in that much remains unknown about them and how they emerge. The majority of current literature seems to be focused on how to create an effective responses to disaster management scenarios which is based on reacting to events as they happen. This research seeks to move the literature away from the project response mindset and led it towards an integrated management view required to predict and manage cascading patterns of complexity as they emerge. Recent studies (Norberg & Cumming 2008, Levy & Lichtenstein, 2012, Schneider, Wickert, & Marti 2017) have used complexity theory to make sense of phenomena like environmental disaster response and emergency response coordination. These studies however are disparate and lack consistent findings.

Traditional responses to disaster management involve forming and developing collaborative rapid response teams, the division of tasks, and related matters. It is well known in this literature, that an effective response to a crisis with emergent properties is required. What is not well known are the peculiarities, nuances, and characteristics of contextual emergent properties as they happen. Stacy (Stacey 2001) and Bergström & Frykmer (2016) independently identify complexity as a culprit for emergent disaster scenarios. With the field still largely conceptualizing the nature of complexity and disaster response, this paper takes a leap forward and argues that the patterns that emerge from these crises, the cascading flows of activities, and the way in which the independent learning activities (Stacey 1996) relate to form a complex response can be reliably studied and analyzed.

To help understand these effects two key terms are be used. The first term ise "tipping points", defined by Lenton (2013) as a adhoc disturbance in a complex environmental system that can cause 'large' impacts. Serrao-Neumann et al (2016), defined tipping points as a threshold that a complex system passes that creates an "irreversible shift" (p.57) in dynamics of that system. Moreover, tipping points lead to "radical shifts" (p.57) in the dynamics of a system that can lead regimes to shift or collapses of the systems itself. These "tipping points" can be so catastrophic that the previous state of the system, its constituent variables and relationships, are forever changed.

In the case of the Brisbane floods, this equates to the release of water at predefined times, dictacted by an operating manual, that lead to to devastating floods and causing millions of dollars of damages. Tipping points are the point in a complex system where occurrences create network effects due to the interconnected nature of the environment. These secondary impacts are sometimes called 'cascading effects' (Kinzig et. al, 2006) that result in regime shifts (Rocha, Peterson, Bodin & Levin (2018)). These are the result of knock-on impacts in a change or a tipping point in a complex system where the effect cascades into other parts of the system creating noticeable ripple effects. For instance, in their study of overfishing Scheffer, Carpenter, & de Young, (2005) note that coral ecosystems, kelp and other marine ecosystems are impacted by cascading effects of overfishing in our oceans. The authors use both of these familiar terms in the paper to make sense of the impacts of the flood.

Accordingly, this research extends the boundary on how complexity theory and the ideas around emergent strategy conform to practical responses to situations and disasters by analyzing the 2011 Brisbane floods crisis as a secondary data case study. To support this aim, in the following section an appropriate theoretical framework around complexity theory using emergent strategy is introduced.

Theoretical Framework

The development of complexity theory is documented as early as the mid 1970's (Prigogine & Nicolis, 1977) with considerable work in the 2000s (Chiles et at., 2004), through to present time (Baker & Turner 2019, Rosenhead, Franco, Grint, Friedland, B. 2019)

In this section the history of Complexity Theory is briefly introduced to set the context for the paper.

Complexity theory came into being as a response to the study of non-linear dynamics and causality, e.g. weather patterns (Palmer, 1993) in the 1970s. It was also seen as a way to comprehend dissipative structures in thermal dynamics (Prigogine & Nicolis, 1977). From the study of these complex patterns, terms like Chaos Theory and The Butterfly effect emerged (see Thietart, & Forgues, B, 1995). Many different disciplines and fields have used these ideas to make sense of situations that are complex, non-linear, dynamic and densely interrelated in the pursuit of understanding the complex (Stacey, 2001). This has emerged as field of study from about the 1990s. (see for example, Murphy, 1996, Koehler, Kress, & Miller, 2014, Purworini, Purnamasari, & Hartuti 2019).

Scholars in this field have understood complexity theory to be the study of the dynamics of response to emergent crisis situations (Murphy, 1996, Koehler, Kress, & Miller, 2014). In short, complexity theory has been applied as a theoretical lens to understand, from a holistic perspective, what the non-linear dynamics of certain phenomena (e.g. a disaster) might be. Another example might be the study of how in complex organisational systems, collaboration or interdependent learning relationships are of critical importance to a successful company (Stacey, 2001). One of the major tenants driving complexity theory is the idea that complex phenomena cannot be reduced down to a singular explanation (Anderson, 1999). Manson (2001) further argues that complexity theory is not a single theoretical framework but a loosely coupled set of concepts with multidisciplinary applications.

Complexity theory is a multidisciplinary field of inquiry that has emerged through a confluence of a diverse collection of ideas (Anderson, 1999; Goldstein, 2008, Stacey 2016; Larsen-Freeman, Ortega, L & Han 2017). One of the foremost tenants of complexity theory is its tenuous link to systems theory (Stacey, 2001). From this came the term 'complex systems' (Rihani & De Soto, 2002). Complex systems are argued to be comprised of independent agents that act on local knowledge; simple rules or what is occasionally referred to as 'schemata'(Anderson, 1999). In organizations, individuals and groups (agents) adapt to local feedback, a mechanism that informs learning in a complex systems, and a new form or order emerges (called emergence) from the aggregation of individual adaptations (Anderson, 1999; McMillan, 2004, van de Wetering, Mikalef, & Helms, R. 2017). These notions of self-organization have been applied across the natural sciences through chemical and mathematical modeling, complex adaptive systems in ecology, physics, and more recently in the social sciences (McMillan, 2004, Hoogeboom & Wilderom 2020). Although the capacity for emergent self-organization exists in numerous organizations, firms often employ a more traditional form of structuration with emergent behavior as a latent feature (MacIntosh & MacLean, 1999). 'Perpetual novelty' across nature (Prigogine & Nicolis, 1977; Stacey, 1985, Dougherty, Ambler, Triantis, 2017) and emergent self-organization are key components of complex adaptive systems (Anderson, 1999; Chiles et al. 2004, Wang, Zhao, & Liu, 2020). In organizations, surprising future states emerge as a result of the aggregation of individual action and the exercise of free choice (Stacey, 1985:2016). Complexity theory is a reasonably new addition to the social sciences; as a result, there are many research applications yet to be properly explored (Marion, 2008; McKelvey, 1999, Gear, Eppel & Koziol-Mclain, 2018, Turner & Baker 2019). As suggested by Stacey (1995), this study examines self-organized learning processes, feedback mechanisms and local knowledge that lead to macro-level behaviors and changed strategic direction.

Despite the capacity to adapt to unpredictable change being seen by many as a core organizational competency, there remains a high rate of failure to successfully manage change, especially in the highly pressurized circumstances of natural disaster (Burnes, 2005; Brown & Eisenhardt, 1997; Hannan, & Carroll, 2003, Macintosh & Wilkinson, 2016). A contributing factor to the difficulty of implementing change is the existence of structural inertia (Hannan & Freeman, 1984). This may include physical infrastructure, equipment, personnel, culture (Schwarz, Yang, Chou & Chiu, 2020), internal politics (Safavi, Omidvar & Glaser 2020) and the tendency to normalize behaviors (Hannan & Freeman, 1984, Shi, Lu, Zhang & Zhang, 2020). Major challenges to be addressed for complex organizations in a crisis (Tasic, Tantri, & Amir, 2019). include: the detection and understanding of an emerging crisis to a degree that justifies the necessary mobilization of counteracting resources (Rzevski (2017)): the management of weak communication networks in multicomponent systems (Mutebi, Muhwezi, Ntayi & Munene 2020); and effectively dealing with uncertainty at numerous levels (Lagadec, 1997). The 'crisis' provides an opportunity for different styles of leadership to emerge (Pillai & Meindl, 1998, Rosenhead et. Al 2019). It follows that the effectiveness of leadership is contingent on the degree to which leader behaviors complement prevailing environmental conditions and contribute to the performance of individuals under the duress of those circumstances (House, 1996). In this case, rather than focusing solely on the actions of supervisors or leaders, the study takes the view that system-level outcomes may emerge from the actions of all organizational members regardless of their designated authority (Plowman & Duchon, 2008). Practical implications in relation to the management and organization of emergent behaviors are discussed, in addition to opportunities for further research.

Complexity theory is chosen to analyze this particular study from the perspective of complex feedback mechanisms, the emergent properties of the problems, self-organization that took place during the flood, and finally to gain specific insights into the inquiry to see what can be learned about how to manage such situations in the future. In particular, complexity theory offers a theoretical lens that helps to understand people's actions leading to a more coherent model to explain this phenomenon. While it's obvious from the QFCI that many different parties' actions can be understood, what is not clear is what kind of management approach works in these situations. What kind of decisive actions might an actor take considering this evolving complex problem and how would they adopt a better approach to the emergent reality they find themselves entangled in? Complexity theory offers a window to explore these concepts and a more adequate understanding of how to navigate such situations in the future.

Methods

This study explores how organizations adapt to change through emergent patterns of behavior, as a process of self-organization. The study was conducted using a case study analysis of the management of Wivenhoe Dam during the January 2011 floods of South East Queensland (SEQ), and in particular Brisbane City. The following sections provide a detailed overview of the aims, tools and methods used in this study. Extending from the theoretical propositions of Lichtenstein and Plowman (2009), and , Anderson (1999), , this study generates a deeper understanding of how the emergence of strategy occurs in a socio-organizational context and the effect of emergent behaviors on the capacity of firms to adapt in crisis.

Data collection

Transcripts from the Queensland Flood Commission of Inquiry (QFCI) 2011 were used in this study. The focus of the analysis is on the critical decisions that took place in relation to the management of Brisbane's major reservoir, Wivenhoe Dam between 8 and 12 January 2011. Transcripts from the inquiry produced 6133 transcribed pages of evidence which stemmed from cross-examinations, testimony and legal testimony. Of note was testimony from four flood engineers on Days 59 and 60 of the inquiry. While transcripts from the entire proceeding were analyzed, the transcripts from these two key days have been given particular consideration. This testimony from engineers are used as the basis for the concept analysis and mapping visualizations presented as part of the research.

Broader testimony that was collected as part of the flood inquiry provides contextual information on the case, but does not reveal any additional information about the nature of decision making, as these actors were not 'in the room' with the engineers.

Data analysis

The flood crisis provided an ideal example test case study given the high level of complexity inherent to the situation, environment and the organization. Research aims were achieved by applying a conceptual lens to the analysis of data as themes and clusters emerged, with visual aids constructed through the use of a concept analysis and mapping (CAAM) technique after Trochim, Cook and Setze (1994), Kane and Trochim (2007) and Rice and Martin (2011). Originally referred to as structured conceptualization (Kane and Trochim, 2007), the CAAM technique involves focusing on a construct of interest, gathering input from several participants, sorting data, interpretation, and the visualization of results as a map of interrelated ideas and constructs (Trochim, 1989). Concept mapping is considered a type of mixed method research as qualitative and quantitative elements are combined to generate quantitatively derived concept maps (Kane & Trochim, 2007).

The concept analysis and mapping tool is constructed by identifying words that occur frequently together throughout the text which combined form a concept. Each word is weighted based on how frequently it occurs in sections of text which contain concepts. Each sentence is tagged. In addition to identifying the existence of concepts, the mapping tool identifies co-occurrence of concepts. In turn, these co-occurrences are what is used to form a concept map, showing the relative strength and frequency of concepts and their interrelationships. Themes can be identified by identifying concepts which are interconnected. In this case, legal transcripts are analyzed to identify the presence and frequency of concepts, which may be words or phrases, or more compound text structures such as collections of words relating to by proximity with the concepts. The visualization of concept mapping is achieved using Leximancer software which assigns frequency and weighting, measuring frequency of occurrence in relation to concepts and displaying these calculations as nodes, connecting lines and spheres, Other software such as NVivo can also be used for similar purposes. At the time of this research, NVivo software was available to import, organize, catalogue and analyze frequency counts, however, was not capable of producing multi-dimensional conceptual mapping based on a combination of frequency, weighting and proximity with concepts and concept clusters.

The CAAM technique is applicable to a range of research pursuits, as elaborated on by Rice and Martin (2011). Concept mapping enables measurement of the presence and frequency of concepts within a chosen text, and a relational analysis of concepts and clusters of concepts that co-occur in proximity. Concept analysis and mapping is suited to exploratory areas of study and is particularly useful for a large quantum of data given its convenience and reliability (Jackson & Trochim, 2002). The practical limitations of manually sorting a large quantum of data, experienced by Jackson and Trochim (2002), are significantly reduced with the use of a computer-aided sorting and analysis tool, while increasing consistency and reliability. The Leximancer software was used in the analysis of data to automate the generation of frequency distributions, preliminary clustering of concept themes and measurement of the strength and dynamics of association between concepts and concept clusters. The software offers an efficient and manageable way to handle the large quantum of data analyzed in this study–including around 3 million transcribed words acquired over 68 days of legal testimony during the QFCI outlined in further detail shortly. A growing body of literature is available demonstrating the use of Leximancer and examples of its application in several areas, including social science, computational linguistics, management systems and cybercrime (Smith & Humphreys, 2006; Gapp, Fisher & Kobayashi, 2008; Chen & Bouvain, 2009; Rice & Martin 2011). As a generic research technique, concept mapping can be applied to almost any field of research that involves the organization of dialogue toward an area of interest (Kane & Trochim, 2007). This paper offers a logical extension of this technique to the field of complexity theory.

This analysis is based on testimony obtained from the QFCI report on the catastrophic flood event, and as with most case studies lacks the generalizable quality normally associated with large-scale studies of this nature. Fit for this reason, the case study is used to explore the patterns that emerged in the thinking and in the actions as they are related through the QFCI.

In this matter Leximancer was used to review the patterns and to collate the researchers' interpretations through a concept map, leading to the determination of the events perceptions and how they lead to the cascading patterns and actions that were noticed in the complex response to the disaster. As observed in prior research, such as Smith & Humphreys, (2006); Gapp, Fisher & Kobayashi, (2008); Chen & Bouvain, (2009); Rice & Martin (2011), such a tool can reveal valuable insights that are out of reach using manual processes and no computer-aided technology. In summary, the 2011 Queensland flood crisis is the case under study. Leximancer software is used to assist with analysis of legal transcripts, and the concept map provides a visual display and further understanding of the strength of the relationships between concepts and themes arising from the testimony.

Data analysis was undertaken in stages to enable within case analysis which allows themes, concepts and patterns to emerge from the data (Lichtenstein, 2000; Yin, 1981). Following individual analysis of testimony, a synthesis between different accounts was used to generate a robust outcome and identify consistencies and differences across statements from engineers and the broader report (Eisenhardt, 1991). Analysis and coding were conducted in five stages using the following techniques.

1. Raw data was organized and prepared, sorted and extraneous information was removed (document names, pages, process matters). Testimony from key people were marked in chronological order relevant to key decisions and events. Cleansing of data is a basic process of removing extraneous information such as page numbers, file names and any other document features which are not content related. This process enables the software tools and further coding to be more efficient and accurate. No research data is removed during this process, it links with the next step as the basic organization and preparation of data is required in order to progress to the open coding step.

2. An open coding process was used to further organize the data into segments (Creswell, 2009). The open coding draws on prepared data referred to at step 1. Grounded by relevant literature, data were organized into provisional categories then final codes as themes, interrelationships and concepts emerged through successive stages of analysis and review (Lichtenstein, 2000; Corbin & Strauss, 2008). Data were processed using the Leximancer software tool. Three types of codes emerged during analysis and were applied in a recursive process: context codes, strategy codes and activity codes (Creswell, 2009).

3. Critical moments in the decision-making process were identified with similarities and differences across each of the transcripts explored in detail. Differences in perception and

the pressures of the inquiry process were considered and reflected upon in terms of the limitations in accuracy of the transcripts. Inconsistencies or ambiguous statements were noted in the coding process.

4. A timeline was constructed of the key decisions that occurred during the flood and externally validated using a range of objective measures, including flood release graphs, dam operating manual flowcharts, flood release timing data and flood scenario hydrographs.
5. Context building, triangulation of data sources, data displays/matrixes in the form of a concept map assisted in the interpretation of data to identify patterns, themes, interrelationships and irregularities in the data (Pratt, Rockmann & Kaufmann, 2006, Creswell, 2009). Coding and analysis of data were placed within relevant contextual factors as defined by Yin (2009) as analytic generalizability.

The testimony driven case study method derived from the inquiry, provided many opportunities to observe the intricate details of decision-making and strategy formation within organizations in their natural environment. There are however, limitations on the generalization of results to organizations in differing circumstances (Corbin & Strauss, 2008).

Findings

The results of qualitative analysis and cluster analysis are discussed in the following three sections. Decisive mechanisms of engineers and the implications for future research are outlined first, using testimony with engineers during days 59 and 60 of the flood inquiry. These results are considered in light of findings from concept cluster network analysis that identifies distinct cluster networks. This is followed by discussion on the development and analysis of a cluster analysis and concept map.

Decisive mechanisms of engineers

Findings of this research reveal that at 9:00 am on Wednesday, 12 January Wivenhoe Dam peaked at 188.5 per cent, testing the limits of flood mitigation capacity. Engineers' statements (QFCI, 2012, p. 451). indicated that if earlier releases had been made from Wivenhoe, this would have substantially reduced the inundation of low-lying areas of Brisbane, such as those in proximity to the Brisbane River. Therefore, decisions whether or not to spill water from Wivenhoe reservoir, and the volume of releases, were instrumental factors in the magnitude and prolonged impact of the floods. For this reason, it is emphasized that the decisions of engineers on duty during the flood held significant ramifications for the city and its residents.

In an environment where it may be natural to assume a methodical and control oriented system of management is in place, it is surprising to find that strategies employed during the crisis had a distinctly emergent quality: 'there is no bright line between when you have ceased to be in one strategy and you are in the next' (QFCI, 2012, p. 459). A range of situational factors clouded the operation of the dam, including unpredictable weather patterns, decision making based on local information, poor communication between radio operators and engineers (p.399) and a rapidly changing environment of massive reservoir inflows. These factors constitute a basic frame for emergence, as outlined in the seminal works by Kauffman (1993).

A basic chronology of four strategy changes at Wivenhoe Dam has been assembled using calculations of releases, each strategy (e.g. 'W1') symbolizing a regime of release rates, road closures (W3), and the eventual inundation and evacuation (W4) of downstream residential areas (QFCI, 2012, p. 439):

a. Strategy 'W1' from the start of the flood event on 6 January to 8.00 am on 8 January
b. Strategy 'W3' from 8.00 am on 8 January to 8.00 am on 11 January
c. Strategy 'W4' from 8.00 am to 9.00 pm on 11 January
d. Draw down of the lake from 9.00 pm on 11 January to 19 January.

It is noted that according to legal transcripts and catchment release logs, Strategy W2 was bypassed. Engineers claim this strategic choice became unavailable due to the prevailing circumstances and inflows exceeding predictions (QFCI, 2012, 456). Although the chronology indicates only four strategy phases, at least 56 release decisions were made during the flood period each reflecting a rate based on the calculated risk of inundation and further rainfall (QFCI, 2012). Far more strategic choices were made during the crisis than those that are reflected in the chronology of official strategy changes. The pattern of small decisions leading to aggregate system-level behavior connects strongly with the theoretical frame for this research, also noted by Lichtenstein (2000). Through successive analysis of this testimony, three central themes emerged in relation to the decision-making mechanisms employed by engineers in their operation of Wivenhoe Dam:

(1) emergent patterns of behavior,

(2) subjective judgment in decision making, and

(3) transient primary objectives.

The actions/behaviors of these actions observed through transcripts and their implications for future research are outlined in detail at Table 1.

[INSERT TABLE 1 HERE]

An emergent process of strategy formation characterized much of the activities and decisions that governed the operation of Wivenhoe Dam throughout the flood period. Earlier interpretations of the operation manual, by members of the Minister for Planning's Office and engineers at the time, for Wivenhoe assumed that strategy could be chosen and applied in a cause-and-effect manner. The report states that there was no real way to predict a flood based on the earlier predictions due to the lack of an existing comprehensive flood plan (QFCI, 2012, p. 143). However, as discussion unfolded, this interpretation proved incorrect, as outlined by engineers during legal testimony.

> 'The volume of the flood upstream, the release rate that you adopt once you've hit gate trigger will determine the resultant dam level. So, there is a dependence between the magnitude of the event you're managing and the release rate you adopt and that will itself determine whether you stay the W1 range or transition to another strategy.' (QFCI, 2011, p. 5216).

All engineers indicated that there was no clear separation between strategy choice and its execution; rather they are intertwined as an emergent behavioral pattern formation process. In this case, the determination of strategy choice was governed by actions already taken, reflected through a set of chosen releases rates. Engineers were required to choose between dam release options that involved road closures, urban inundation and infrastructure damage – the presence of early risk factors means the discretion exercised in subjective judgment had significant ramifications, signaling the probable existence of substantial levels of inertia.

> 'As a general proposition, had releases been increased at an earlier stage during the January event flood damage overall might have been reduced but, of course, by doing that,

by ramping up releases earlier, urban inundation would certainly have occurred.' (QFCI, 2011, p. 5214).

Although the dam operational manual and flood mitigation plan was provided to engineers to 'govern the exercise of the discretion involved in that judgment call', engineers claimed they were often not explicitly aware of their strategic choice and instead used ad hoc tools to calculate risk and weigh-up alternatives (QFCI, 2011, p. 5214). The choice of strategy would then be labeled after the fact in one of the applicable risk categories – dependent on earlier release decisions. The question remains – how and why were lake release choices made? In terms of emergent patterns of behavior and choice, there was some level of discrepancy between engineers' recollection of events as highlighted during legal testimony. One engineer felt their choices were 'unconscious' and imposed by adherence to the operating manual: 'I don't choose strategy; it is imposed upon you' (QFCI, 2011, p. 5217); whereas three others indicated their strategy choices were 'implicit' in the sense that they had general knowledge of the operating manual and their strategy choice was obvious by the release rates they adopted: 'strategy labels are generally only attributed after the event as part of the reporting process' (QFCI, 2011, p. 5190). Despite the differences in language used during testimony and varying levels of ownership over decision-making, indications for the existence of emergent pattern formation persist.

Subjective decision-making added further complications to the operation of Wivenhoe in advance of and during the flood. Events prior to the decision to choose higher release rates for Wivenhoe involved a significant element of surprise and unpredictability. Precise weather patterns are inherently unpredictable and while engineers take into account measured rainfall and the likelihood of additional inflows, they are unable to conclusively determine the magnitude of risk until after the inflows have occurred. With the lack of a mandated calculation tool to assist in making decisions, engineers used their own ad hoc spreadsheets to predict the impact of rainfall on dam levels and the consequent need to adopt early release strategies. Consequently, the failure to engage a higher level of release rates at an earlier stage in the crisis resulted in the magnification of urban inundation in low-lying areas of residential Brisbane.

Transient primary objectives that informed strategies adopted during the flood events of January 2011 were very much dependent on a calculated assessment of risk to the inundation of urban areas. In this way, rules that governed the operation of discretion are likened to Anderson's (1999) conception of schemata, rules that allow flexibility depending on the circumstances. In their choice of strategy, engineers grappled with factors that were outside their control.

> 'There are conditions in the system that don't - that you have no control over. So the volume of the flood and the magnitude of the downstream tributaries you have got no control over. You have to react to take them into account.' (QFCI, 2011, p. 5217).

In an attempt to 'react' to changing situational factors, engineers adopted strategies, as stipulated in the manual, that minimized the risk of local urban inundation, including seven low bridges and roads near the spillway. In retrospect, although it is clear that earlier dam releases might have spared many areas of Brisbane, an early release strategy that would have voluntarily inundated even minor residential areas or roads would have been seen as an 'adventurous, risk-taking approach' (QFCI, 2012, p. 512), which may have not yet been seen as entirely necessary given the lack of reliability in rainfall predictions.

The general approach to avoiding risk rather than acquiring it, and post hoc mitigation strategies reflects the presence of significant structural inertia and a reactive rather than responsive approach: 'This event is now getting bigger, and so you will need to start making releases with other objectives in mind' (QFCI, 2011, p. 5218). Engineers reacted to changing conditions but were reluctant to adopt early risk acquiring strategies that would have increased short-term risks, but may have mitigated more severe longer-term risks.

Concept analysis and mapping

Results of the analysis reveal seven key concept clusters that emerge through legal transcripts: *flood, information, water, people, strategy, evidence and property*. The relationship between each of these concepts, their frequency and themes are illustratedin the concept map at Figure 1. The map is comprised of concepts, networks and higher-level themes. Concepts that exhibit a strong attraction in the text appear in close proximity in the map space and constitute a concept network. Concept networks appear as grey lines, indicating concept pathways or storylines. Clusters of related concepts are also visible as themes, illustrated as circles on the concept map, with major themes identified in bold text. The relative frequency of cluster topics is highlighted by the size of each respective circle. The CAAM technique provides a visualization of the strength and relative frequency of connections between several related concept clusters. The use of computer-aided mapping enables the creation of a multidimensional concept and cluster network, with pathways overlaid by clusters and cluster relationships. Quantitative results of the concept-mapping algorithm are provided at Table 2.

Concept analysis and mapping reveals a weak underlying relationship between two concept networks – strategy and flood information. The limited connection between these two cluster networks, represented by the underlying grey pathways, is suggestive of a relatively separate treatment of the flood and information related concepts and strategy concepts. The implications of this finding are as follows. Firstly, the greater separation of strategy from information suggests that the emergence of strategy is considered a significant risk in the mitigation of flood impacts. Flood engineers will be unable to enact a forward-looking strategy without adequate feedback loops and accurate forecast data. Secondly, and as an alternative, it is possible that the discussion of strategy and causes for the flood were given unique treatment due to perceived ramifications of this part of the inquiry. Testimony by engineers highlighted the pervasive element of uncertainty in the entire process of decision-making, an element that is impossible to completely remove. Further preparation was needed in crisis management planning to cater for emergent outcomes in an environment characterized by unpredictable and rapid change, and further compounded by unreliable feedback data. Despite the underlying disconnect between cluster networks highlighted previously, the concept map demonstrates numerous concerns that occur in close proximity with a relatively strong level of connection and frequency. Individual weights and frequencies are provided at Table 2.

Concept analysis clearly shows that strategy deployed during the flood crisis was a principal focal point during the discussion. There is a reasonably strong level of reactiveness between the rainfall flowing into the dam and the strategy that was deployed. Stemming from this are the areas that were potentially impacted and eventually the evaluation of local areas and communities. The results indicate that the people cluster is considered separate from property yet is strongly connected to strategy. Human impact, such as death or injury, is clearly given priority as a concept in the data available. It is troubling that most of the sources of this data come from reports about property and its location instead of reports about possible human impact in the event of a catastrophic flood.

Concept analysis differs between flood engineers and the general public in that decision criteria and considerations made on the operation of the dam were unknown to the general public. Engineers referred to the reservoir operating manual as a decision-making framework, which did not require broad consultation or a high chain of command to undertake local decision making.

[INSERT FIGURE 1 HERE]

[INSERT TABLE 2 HERE]

Discussion

The QFCI concluded that engineers at Wivenhoe Dam breached the operating "Urban Drainage" manual from 8.00 am on 8 January 2011 until the evening of 9 January 2011 (QFCI, 2012), and as noted in the findings instead used a process of post-hoc strategy labelling and emergent decision making rather than a rigid control framework. It may provide additional context to reflect on other major disasters, such as the American examples of 9/11 and Hurricane Katrina where 'the most important failure was one of imagination' and the 'bureaucratic inertia that caused death' during Hurricane Katrina that conversely 'salute the exceptions to the rule' (U*S House of Representatives Report on Hurricane Katrina,* 2006, p. 1). The events of Brisbane were neither on the scale nor the ferociousness of Katrina or 9/11. These findings share a similar focus: indecision and uncertainty in how to decide, poor disaster planning, lack of appropriate technical and managerial controls, lack of communication amongst key technical and non-technical staff, poor information sharing amongst key personnel, no effective stakeholder planning and coordination and no forward thinking or planning, are all factors in the successful/unsuccessful management of each crisis.

Despite claims of a failure of planning, communication or control, mitigation strategies to protect Brisbane from further flooding would have required an adventurous, risk-acquiring approach that engineers were unwilling or not compelled to adopt. This correlates with Stacey's (2001) conceptualising of complex adaptive systems that require dense interconnections to operate effectively. Without these connections, or at least an understanding of them, the emergent properties of complex adaptive systems can't effectively be observed. Findings reference several direct statements and concepts which indicate that while risk management is top of mind, aggregated impacts are considered less. Although engineers performed a kind of bricolage in their strategy formation, the existence of prescriptive plans did not sufficiently reduce levels of structural inertia toward risk acquisition. The paradox of choice in this case was the need to acquire further risk in the early stages of the crisis to avoid more significant consequences and risks caused by a cascade of small, conservative choices and a lack of awareness of the interconnections between the complex parts of the system. However, a complete knowledge of alternate future states that result from a cascade of choice, for instance through a ripple analysis or the interdependencies (Stacey, 2006),was not a discernible part of the operating procedure. Among the major strategic weakness this research identifies is the absence of a reinforcing feedback loop on decision making processes; a frame of reference for the calculation of risk; and a reactive, gradual decision-making process where small incremental decisions were favored without foresight of their collective impact on irreversible, catastrophic flooding outcomes. This pattern of decision making based on simple rules and localized feedback is an establishment partof the theoretical framework of complexity theory (Anderson, 1999). It also extends partially the idea that a complex adaptive system creates the rules as it builds towards the tipping point. This research adds a real-world dimension to understanding therisk mindset which is often overlooked because the aggregating of small decisions can have catastrophic 'cascading' impacts. This is in addition to the frequently discussed positive and constructive patterns of emergence referenced in the complexity literatureas a whole (Marion, 2008). Practical limitations of decision making, inconsistent and ad hoc information analysis tools, and hindered dynamic interaction between engineers, planning and policy makers suggest the positive outcomes of an emergent pattern of behavior may have been stifled.

The importance of feedback to the rate of effective resolutions or choices agrees with Rudolph and Repenning's (2002) quantitative 'stock and flow' model of disaster dynamics. Using two case studies and a myriad of interruptions that occurred during the 1977 Tenerife airport disaster, Rudolph and Repenning (2002) identify oscillations in problem resolution rates caused by a delay in the perception of system changes. As pressure on the system increases towards the tipping point, , negative feedback is argued to increase a at a much faster rate eventually leading to system collapse (Rudolph & Repenning, 2002). In human systems, perspective, judgment and choice play a role in the triggering of cascading event that result from positive (reinforcing, amplifying) or negative (dampening, homeostatic) feedback. System-level behaviors and interrelatedness of individual actions triggerascading events (Marion, 2008). Such events are not required for the emergence of complex problems. Intelligent behaviors exhibited at the system-level can result from relatively unenlightened behaviors at the level of individual agents (Marion, 2008) who are unaware of how their actions can cause cascading events. As the findings demonstrate, there is a lack of understanding, for example, of how 'Urban Drainage' planning could be related to the cascading events of the flood.

The dynamics of intuitive judgment, for example: that which comes 'automatically and rapidly' in relation to risk acquiring or diminishing behaviors, are explored in detail by

Kahneman (2003) and are evident in the findings of this paper. Although a thorough account of the underlying psychological basis for intuitive judgment are beyond the levels of analysis in this study, the complementary idea of natural boundaries on rationality in decision-making are noted. The rational model of choice in strategic decision-making operates on the assumption that human choices and behaviors have some rational purpose (Eisenhardt & Zbaracki, 1992). In their review of literature on strategic decision making, Eisenhardt and Zbaracki identify a decision-making process that is inherently political, due to the existence of conflicting objectives between actors and the bounded rationality of organizational members. In defining the term 'bounded rationality', Simon Herbert (1955) proposed a human condition of rational behavior as bounded by access to information and cognitive (or computational) capacities, applied to the environment in which organisms exist. Grounded by Simon's (1955) ideas, authors have explored the nature of heuristics of judgment, risky choice and cognitive bias or 'framing effects' (Kahneman, 2003); with particular reference to decisions made under the duress of risk and uncertainty in economic systems (Mousavi & Gigerenzer, 2014).

An interesting side note to consider for the theory of complex adaptive systems is the idea of multiple feedback loops between human and nature (Yang, 2017) and their emergent interactions, especially in disasters have not been studied as much as they could. This research highlights the nature of disaster tipping points and how human decision making is influenced by the dual feedback loops of nature of management (Yang, 2017). Feedback loops can be negative, complex and dense (Stacey, 2006). The nature of how complexity bifurcates in disaster situations. Testimony from engineers show that the kind of strategy used was not a planned, design-based approach, traditional or cybernetic organizational theory (Plowman & Duchon, 2008). Strong relationships in overarching concept clusters indicate that the development of strategy, in this case, is inseparable from execution. Strategy is taken as an ongoing cycle of: *environmental assessment; calculation of response; decision-making; execution of strategy; strategy labeling;* back to *environmental assessment*; etc. Such a conceptualization fits strongly with a systems theory view of positive feedback loops (Skyttner, 1996). However, the problem of such an approach is that each small decision creates less space for adaptation and an increasing level of irreversibility that over a short time has magnifying and potentially catastrophic results. The nature of this construct is closely aligned with earlier propositions of a range of complexity theorists, including Anderson (1999), Chiles et al., (2004), and Brown and Eisenhardt (1997). An example in this case is the avoidance of relatively minor risks (e.g. deliberately flooding low-lying bridges and roads) in favor of additional information, which in turn results in reinforcement of risk avoidance – or inertia.

Although the flood mitigation manual requires a ‘conscious adoption of, and operation within’ its strategies (QFCI, 2012, p.457) – the reality of strategy by practice, rather than by design is not necessarily a new idea. The presence of emergent strategy is considered a parallel feature of the strategy design process by strategic planning thinkers such as Mintzberg (1994). Mintzberg (1994) suggests that while intended and deliberate efforts progress towards realized strategy, emergent strategies occur simultaneously in a self-constructing community of practice, a concept developed in much more detail by Wenger (1998). Findings of this paper support Mintzberg and Water’s (1985) idea that the distinction between deliberate and emergent strategy is not necessarily a sharp dichotomy. Rather, emergent strategy formation involves interplay at several organizational levels, nested personal choices, judgment and heuristics, but with results that are complementary, albeit unbounded (MacIntosh & MacLean, 1999). Results in this study suggest that a convergence takes place between emergent and intended strategies – the nature of which is complex and emergent.

This research demonstrates the cascade of actions and choice that unfolded into an irreversible pattern of emergent behaviors despite the existence of plans, perception of risk and predefined operational practices. In this case, flood impacts were not solely the consequence of natural weather events but were magnified by the aggregation of choice and action. The realization of system-level strategic weakness during the event would have been required to avert the course of action that resulted during the Brisbane floods, in this case calling for less risk aversion and more intuitive judgement.
Flood mitigation decision failure has the potential to recur if the inherent weakness of emergent patterns of behavior, required in a time of crisis, are not incorporated into intuitive management practices. Further research is required to develop and refine a theory of emergent self-organization if the approach is to properly enter the world of management practice, necessarily drawing from an application and refinement of theory through real-world empirical data.

A further research agenda will benefit from comprehensively exploring the following propositions / research questions that have arisen through the emergent process of patterned behavior identified in this paper, as follows.

a. *The existence of plans does not eliminate the possibility for emergent behavioral patterns to arise:*

   This study demonstrates the potential for emergent patterns of behavior to occur despite the existence of plans. This is evident in localized decision making which is based on nonaggregate impacts of decisions. Further research is required to more comprehensively understand the relationship between the existence of different types of plans and the character of emergent behaviors.

b. *Small decisions early on in crisis can have magnifying ramifications and irreversibility:* Seemingly insignificant or less significant decisions early in the anatomy of crises have magnifying ramifications and eventual irreversibility. As referenced in the findings, once the reservoir levels passed a certain level, the situation was at a point of no return. Decisions leading up to this situation did not appear demonstrate the same cascading effects as noticed later. . Our research demonstrates that some awareness of this would have assisted. Further understanding of the point at which these small decisions cross over the 'tipping point' into irreversibility and how to rapidly identify this as an approaching juncture would be of use in future crisis management and training, and computer-aided prediction tools.

c. *New rules emerge in the absence of explicit instruction:* The level of ambiguity or incompleteness of plans is inversely related to the capacity for emergent rules. The existence of a flood manual for use by engineers did not inhibit localized decision making based on emergent simple rules. The ..benefits of ambiguity, or a wider range of scenarios, should be explored by reviewing a sample of plans.

d. *The presence of feedback improves the functioning of emergent behavioral patterns:* Emergent patterns of behavior are possible in the absence of feedback, however this diminishes the probability of emergent outcomes having positive results. A lack of comprehensive and broad-based feedback loops contributed to localized decision making based on the narrow criteria such as localised patterns of decision making. These patterns include the details of what is happening but not the subtle connections between larger events that are being impacted by smaller decision-making patterns.. The lack of feedback can trigger a cascading chain of events where a series of small decisions have amplifying results.

e. *Emergent patterns of behavior may be risk averse andstructural inertia intensifies risk:* This study identifies the potential for structural inertia to intensify and create additional risk. Decision making was perceived to be risk-minimizing in nature, it was not realized until later that these apparently risk minimizing local decisions were leading to higher levels of systemic risk, as they were not considered holistically. As stated earlier, it is not the existence of plans that are the problem, rather it's the fact that scenarios and latent factors, hidden from the planning process that can lead to structural inertia.

f. *The escalation of crisis may be rapid, non-linear and exponential:* Escalation of risk and impacts may be increasingly rapid, non-linear and exponential as a result of endogenous factors, such as the amount of rainfall and the existing plans for urban drainage, despite these factors being seen as beyond internal influence. Situations such as this which is driven by unpredictability in weather patterns can escalate quickly and without notice. It is essential that frameworks and models operating in such environments consider levels of uncertainty that have the potential to impact on management objectives.
g. *More research is required to understand the impacts of hindsight bias and memory loss during a review of a crisis*

During times of crisis the impacts and trauma might possibly cause memory loss and hindsight bias to occur when trying to recall actions Sensemaking of events argues that a map is placed over the past to fill in elements of cognitive dissonance (Weick, 1995). While not explored here it is clearly something that needs to be taken into consideration for future research as it will impact post-crisis reporting. At least, actors should be taking notes of every action and decision during the crisis.

Further research on crisis scenarios may also include the possibility for failure of the very mechanisms it uses to mitigate crisis impacts.From this point of view, a future crisis plan must include contingency for failure of the very plan it seeks to enact. Consequently, we are once again faced with an emergent pattern formation process, of many small decisions, characteristic of the unpredictability of crisis and with transient guiding principles that may be loosely coupled by emergent, simple rules or schemata. It should also be noted that this is a highly litigious affair. The ability for organizations to understand and manage cascading patterns of behavior and decision making need to be taken into consideration for the effective management of emergent disaster scenarios.

Limitations

There are limitations on the collection and analysis of data in this study. Due to the large quantum of data produced through 68 full days of transcripts from legal testimony, a concept analysis and mapping tool has been used. While the concept analysis and mapping tool is potentially less intuitive than manual human concept analysis, it offers a robust and efficient means by which to collate results, which would otherwise be impractical. A selection of targeted material was chosen to focus on the actions of engineers with the highest level of involvement in the crisis – those responsible for the operation of Wivenhoe dam immediately before and during the crisis. The inquiry process itself was conducted in a pressurized setting where participants would have been conscious of public impressions and legal ramifications in relation to their conduct as employees. Prevarication and caution in witness testimony is a potential cause for limitation in the accuracy of data, as is retrospective bias to recall past events with a new frame of reference. Also, written submissions do not undergo the same legal process of cross-examination and as such do not have the same veracity of comments made by engineers in this context. It is important to note the pressure to answer was due to lawyers who are prosecuting a case and examining witnesses to assess the validity of their testimony.

Analysis of data identifies a degree of divergence in one of the engineer's testimony highlighted in Findings and Discussion sections of this paper. The divergent theme relates to the definition of strategy choice – as implicit through action in compliance with predefined procedure, in contrast to conscious and deliberate choice. The culpability of these differing levels of 'consciousness' is less relevant to this study and does not alter the underlying pattern of actions and decision-making. There may also have been different interpretations among engineers on questions and experiences that went unnoticed during the inquiry and are not apparent in transcripts. Situational factors preceding the flood, such as the prolonged period of drought, are also the potential cause of perceptions of engineers and the forces of inertia. The underlying factors that drive "regime shifts" (Rocha et al (2018)) will not really be known without further research and it would only be possible to speculate about these factors.

Due to the dynamic interaction and interdependencies between components within and around complex systems, precisely calculating behaviors for the purpose of practical application in real-world systems is a challenging task, especially given the multitude of variables that effect behavior in open systems (Anderson, 1999; Marion, 2008). Burnes (2005) points to this issue by suggesting that computer simulations are not enough to generate reliable predictions of macro-level behavior in complex systems. While simulations provide valuable data, the study of real-world phenomena are also a necessary step in theory building research and its application to management practice. It is suggested that the inclusion of simulated and real-world empirical data is necessary to the incremental development of theory building research in the field of emergent self-organization and complexity.

Various limitations exist in the dataset. Data may contain bias, inaccuracies and inconsistencies inherent to the written submission and legal process surrounding the inquiry. The testimony used as the basis for analysis were conducted a few months after the crisis in the pressurized environment of the post-flood inquiry, at which time engineers were required to draw on their recollection of past events, a process that is exposed to retrospective bias and memory loss. Despite these limitations, the dataset remains a comprehensive account available and has been subject to several internal validity tests shown above.

Conclusion

Preliminary findings of the QFCI reveal that a range of situational factors promoted the formation of emergent patterns of behavior, despite the presence of control parameters. The emergence of an aggregate pattern arising from many localized and smaller decisions fits well within the theoretical framework of complexity theory. It is argued that understanding the process of emergent behavioral patterns are essential to applying a robust understanding of emergent strategy formation. Further, understanding emergent behaviors is essential to crisis scenarios, particularly in making sense of strategies and processes that emerge without deliberate or preconceived plans. Many areas of further research currently exist, a number of strands of which have been identified in this paper. This study outlines in detail a viable research method that may be expanded and adapted to suit a larger study, including multiple cases and the collection of primary or secondary qualitative data, grounded by pragmatic epistemological traditions. It is worth noting that the QFCI (2012) provided more than 175 recommendations, of which 32 were explicitly about dams, to resolve the outstanding issues the flood brought to light. The general character of these recommendations is however, concerned with crisis and floodplain management planning. For this reason, the results and conclusions of this research add an additional dimension and research-based viewpoint on the strategy by design versus emergent strategy perspectives, ideally a novel combination of both.

This research has contributed to the identification and development of several decisive techniques employed by individuals involved in the crisis scenario. The existence of explicit plans and strategies does not eliminate the potential for emergent strategy to occur, although this is likely, these artifacts and their integration into the organization influence response behaviors exhibited by management and co-workers. Emergent behaviors have the potential of being considered as counterproductive or out of line with organizational norms, depending on the level of preparedness for emergence. Sensitivity to initial conditions and the irreversibility of change arising from small decisions is particularly evident in this research. The concept of irreversibility, from complexity and resilience literature, in this case suggests that after a period of time, a particular sequence of small decisions becomes an irretrievable course of action, as other avenues to handle the situation are eliminated over time due to practical constraints and additional impacts. The underlying problem in this case is the perception of lesser risk in small, incremental decisions that on aggregate have the impact of eliminating higher risk. Conversely, strategies which are perceived to be higher risk, such as releasing a greater volume of water from the reservoir early in the crisis, as inflows naturally increase and deliberately flooding low density areas are seen as adventurous, risk acquiring behaviors, but, which would have otherwise avoided a worse inundation of high-density areas and adjoining waterways. The availability of strategic choices gradually diminishes over time as additional pressure continues to be injected into the system, which is a potential risk signal in future scenarios.

In executing this research, the novel application of concept analysis and mapping tool has been used and demonstrated its effectiveness to manage and quantify extensive data. Further techniques to visualize data in support of its interpretation would be of value in further research, in addition to the exploration of computer-aided tools that support the formation of emergent strategy schemata. An inherent challenge to this research is connecting the principles of complex adaptive systems with levels of analysis required to interpret the dynamics of a human social system operating within the confines of a structured organization, for the extrapolation of management techniques and practice. As earlier research in complexity and emergence theory revealed, some sort of organization emerges in the absence of a central point of coordination and with a lack of direct control. During the flood, the preexisting plans, the resulting structural inertia and eventually the releases of water made this a very difficult event to control. A complex adaptive system has interdependencies that only become obvious during periods of emergence. It is this emergence that makes events like the Brisbane flood so difficult to manage with conventional thinking. Making sense of complex behaviors and situational factors that occurred during the crisis would assist in reducing the likelihood of misdirected management action. Given its relevant constructs, this study provided a suitable framework to further explore the complex dynamics of emergent self-organizing behavior in complex organizations, in particular emergent strategy. Further research in this area is novel and would be a logical extension from existing studies that will support studies that contribute to organization science and management and shed further light on managing crisis and effectively handling risk.

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