Toward a Theory of Emergence: The Role of Social Influence in Emergent Self-Organisation

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Toward a Theory of Emergence:
The Role of Social Influence in Emergent Self-Organisation

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Abstract

The creation of perpetual novelty has long puzzled organisational theorists, scientists and philosophers. Over the last 100 years, numerous strands of inquiry have woven together to form a superstructure of ideas, concepts and principles known as complexity theory, to understand the spontaneous emergence or order. The study of complex systems has given rise to many empirical advances, including a deeper understanding of time, evolution, and the organisation of living systems. Despite being surrounded by complexity, the real-world application in organisational theory appears to have gained only few of its potential benefits. Furthermore, prior studies have failed to produce a theory for emergent self-organisation, its anchor-point phenomenon. After many years of direct theory to phenomena translations, this study reveals their tenuous link to root theory and numerous gaps in the existing body of knowledge to translate central ideas of complexity to applied social science.

In organisations faced with considerable uncertainty and responsibility for the control of immense resources, it is surprising to find an emergent, iterative approach is ingrained within key strategic activities. In an uncertain global climate, a better understanding of the capacity to adapt without explicit plans or centralised coordination could not be more timely or important. Human social systems and the mechanics of their organisation is one of the most pervasive topics of applied social science, leadership and management, and has relevance to almost all economic, political and social research that concerns dynamic interaction between people.

Drawing on pragmatic foundations, this study explores how complex organisations adapt through emergent self-organisation, with a focus on the role of social influence between agents. The study argues that social influence is a principal mechanism for energetic transfer in complex human social systems. The study examines two primary research questions, concerning: the *function*, and *process* of emergence in human social systems. Furthermore, the role emergence plays in adapting to new or acute pressures, and the general process for such a mechanism. An interview driven, multiple case study approach is used to observe the interactions and behaviours of agents within complex systems.

Data collection and analysis is without parallel in both cases, comprised of 47 interviews and over 3.2 million transcribed words. Case one focuses on the operation of Wivenhoe Dam during the Brisbane Floods Crisis of 2011, Case two examines the actions of seven investment firms at the epicentre of the Subprime Mortgage Crisis in late 2008.

The case study approach has yielded rich analysis and findings, applicable to similar firms in times of turbulence. Findings reveal a distinctly emergent process of decision making in structured organisations, and a surprising method of post hoc strategy labelling, where structural inertia has perverse impacts on risk intensification, irreversibility and the amplification of small change. Analysis extrapolates the mechanics of amplification associated with the use of structured investment products, collateralisation and bundling of risky assets, generating increased risk velocity and the erosion of strategic choice. Findings deliver a practical application of downward causation, and many recursive theoretical developments, with regard to autonomy, information coupling, sustainability and immunity of emergent, self-organising forms and the role of information and people in groups. Findings shed a number of new insights into the anatomy of crisis that unfolded in both cases, and areas for potential improvement in the practical application of theory and research outcomes. Over 40 unique contributions to the body of knowledge are noted.

The findings of this study have several important implications, to aid a more comprehensive understanding of the latent potential for emergent self-organisation in human social organisation. The study develops and proposes further sophistication and robustness in methods to continue research into complex phenomena within the field of applied social science research. The study explores warning signals, systemic risk factors, and their relationship to leadership, management and corporate strategy. While the findings of this study contribute to the body of knowledge, further research is proposed through a research extension agenda. Following the extensive review of literature and presentation of findings, the study concludes a theory of emergence is in a nascent state, and is not yet fully developed, refined or tested. This study makes a contribution toward a theory of emergence, in particular to better understand the function and process of influence in complex human social systems.

Statement of Originality

This work has not previously been submitted for any degree or diploma in any university. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

[signature redacted]

Omer Yezdani

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Sincere and particular thanks to Dr Louis Sanzogni, Dr Luke Houghton and Dr Arthur Poropat for their supervision and guidance throughout my candidature. Also, Dr Stephen Weller for his valued encouragement in the final stages. I would to express thanks to the Rock Center for Corporate Governance at Stanford University and the Robert Crown Law Library at Stanford Law School who have made information on the Federal Commission of Inquiry available in their library. Also, the Queensland Government in releasing general information on the Commission of Inquiry into the Brisbane Floods Crisis, and all those that invested their time and efforts in contributing evidence to both cases.

1 Introduction

In a rapidly changing, unpredictable and competitive world, the need for organisations to successfully adapt has become a core organisational attribute (Burnes, 2005; Brown & Eisenhardt, 1997; Dawson, 2003; Johnson & Scholes, 2002; Hannan et al., 2003). The challenges facing modern firms in an uncertain global economy are clear and urgent. Despite the apparent need for this essential capacity in firms, a surprisingly large number of organisations fail to effectively adapt to changes in their environment, contributing to the high level of corporate mortality and the continuation of the assumption of organisational life cycles (Levie & Lichtenstein, 2010; Brodbeck, 2002; Burnes, 2005).

Since the inception of the modern corporation, organisational theorists have proposed many strategies to prolong the lifespan of organisations or their parts and to perpetuate the creation of novelty within them. Despite being surrounded by complex adaptive systems in nature, organisations are often conceptualised as mechanical control systems of a post-World War II era (Plowman & Duchon, 2008). Rigid communication and control systems however, do not lend themselves to a continuously shifting and dynamic landscape. Moreover, the reduction of complex organisational systems to their individual component parts fails to deliver a comprehensive and holistic understanding of the complex web of interacting elements they are ultimately comprised of. The art of organisation in firms, governments, community services or social networks are the subject of countless articles and inquiries, over the course of the last century. One could be forgiven for asking how it could be possible there is any stone left unturned. A continuously developing landscape of inquiry and implementation means that practice is forever catching up with theory, and theory is always learning from practice. The world is not static. Therefore, our understanding of it is always evolving.

In response to the challenges of organisational structure and change, a range of theories have emerged, grown in popularity and reached some level of maturity, sustainability or decline. The origins of complexity theory are rich and varied and not completely inseparable from their past. From the non-reductionist, holistic and gestalt theories of the post-1900s (Wertheimer, 1900); communication, control and feedback mechanisms of Cybernetics (Weiner, 1948), Lewin's (1945) 'unfreezing' process of change; an ecosystem of interdependent actions of general systems theory (Bertalanffy, 1951); the convergence of deliberate and emergent ideas into realised strategy (Mintzberg, 1984); the punctuated equilibrium of discontinuous radical change (Tushman & Anderson, 1986); and finally, an evolutionary, continuous, complex and emergent process of self-organisation elaborated on by Brown & Eisenhardt (1997), Anderson (1999), Hayes (2002), Chiles et al. (2004) and Plowman et al., (2007). In its contemporary form, the paradigm of complexity theory is one of an ever-changing, unpredictable world in which physical and social phenomena follow divergent and non-linear paths. Despite the appeal of complexity theory as a means to understand the world around us, its practical application to everyday organisational problems is not well understood (Marion, 2008; Moldoveanu & Bauer, 2004, Brodbeck, 2002).

The concept of *emergence* proposes that: at critical points in an organisation's life cycle, thresholds can be reached where concentrations of 'energy' increase to the point where new structures spontaneously emerge, without explicit coordination, design, and as a result of the complex interplay between agents within the system (Anderson, 1999). Theory holds that the ingredients for such an outcome can be as simple as a group of heterogeneous agents, motive to connect, and a sufficient number of connections with other agents (Kauffman, 1993). However, the direct application of this theoretical construct has remained tied to a problematic theory-phenomena link, which relies on abstract interdisciplinary translations from root theory, without an accepted conceptual model developed within the social sciences.

The conceptual development and practical application of complexity theory and the emergent, self-organising capabilities of complex systems remain in nascent stages of development; as a result there are many research applications yet to be explored.

The application of complexity to organisation science continues to move through a logical cycle of theoretical development, from asking 'why' we should be interested in a science of emergent change (McKelvey, 1999; Anderson, 1999) to ‘how’ we should apply it to modern organisations and what benefits it may provide (Plowman et al., 2007; Schneider & Somers, 2006). Only a handful of studies (e.g. Plowman et al., 2007; Chiles, Meyer & Hench, 2004; Lichtenstein, 2000) have specifically examined the practical application of emergent self-organisation as a viable organisational and managerial tool. These studies however, have not completed the recursive cycle of theory building and are open to the development of an operationalised theoretical framework, practical application and continuous refinement (Lynham, 2002).

Previous researchers that have engaged in *the study of complex systems,* generally defined as ‘complexity theory’ (Goldstein, 2008), have found that a variety of systems of interdependent and interacting components do not require explicit coordination to create ‘ordered’ behaviours or lasting structure (Ablowitz, 1939; Anderson, 1999; Goldstein, 2008; Kauffman, 1993; Lichtenstein & Plowman, 2009b; Marion, 2008; McKelvey, 1999; D.A. Plowman, Solanski, et al., 2007; Turing, 1952). A number of contemporary organisational theorists, including those cited, pioneered the application of this new understanding of complexity to the organisation of human social systems. Yet, after more than fifty years, we remain without an accepted *theory of emergence* in the domain of organisation science – to frame the field’s anchor-point phenomenon and position it within a pragmatic worldview.

In an economic climate characterised by intense change and unpredictability, this novel understanding of the inherent capacity for complex organisations to create, adapt or modify themselves could not be more timely or important. At the heart of the demand for continuous change is an increased prominence on knowledge-intensive business activity, adding value to organisations and markets by diffusing innovation and development opportunities through the exchange of knowledge (Boden & Miles, 2000). An ability to measure, apply and manage emergence would mark the beginning of the application of a novel theory of emergence which has to this point not occurred (Burnes, 2005; McKelvey, 1999).

The ability to successfully adapt to a changing and uncertain environment is reasonably well accepted as a core attribute of the modern organisation (Brown & Eisenhardt, 1997; Burnes, 2005; Dawson, 2003; M. T. Hannan, Polos, & Carroll, 2003). Despite the apparent need for this capability, a surprisingly large number of organisations fail to effectively adapt to change, contributing to high levels of corporate mortality (Brodbeck, 2002; Burnes, 2005; Levie & Lichtenstein, 2010).

Over the last few decades, complexity theory has continued its pathway into the social sciences (Anderson, 1999; Goldstein, 1999; Marion and Uhl-Bien, 2001; Osborn, Hunt and Jauch, 2002; Plowman, Solanski et al., 2007; Wheatley, 1999). This relatively recent application of complexity principles has generated a deeper understanding of the non-linear, complex and adaptive behaviours within and between organisations that give rise to the emergence of form (Lichtenstein et al., 2006; Uhl-Bien, Marion and McKelvey, 2007).

Complexity theory applies an understanding of leadership and organisation as less an art of prediction, and more one of sense-making, cultivated participation, interaction and influence between individuals across all levels of the organisation where leadership itself is viewed as an emergent event, arising from relational processes between individuals (Lichtenstein et al., 2006). However, the utility value of the concept of emergence in research and practice relies on a tenuous theory-phenomena link, which this study argues, remains relatively underdeveloped despite its central importance to the robustness of theory and its real world application. The effective isomorphism of theory and structures to real-world behaviours is vital to the reliability of theory, without which there are few reasons to believe a theory of emergence for complex organisations exists (McKelvey, 1999).

1.1 Background

The study of complex systems (known as complexity theory) is a fascinating and challenging area of research that holds great significance to the advancement of human knowledge. Many of the constructs of complexity theory are conveyed in literature as counterintuitive to classical assumptions about the behaviour of organisations, nature of leadership and understanding of seemingly divergent behaviours.

The reality however, is that emergent behaviours that affect system-level outcomes exist in almost all complex organisations, observed over many years through myriads of theoretical perspectives and frames of reference.

Although many of the notions of complexity theory appear prima facia as counter-intuition, the intention of this research is not to propose a radically new or altered shift in perception, as argued by some earlier works (Marion & Uhl-Bien, 2001; McKelvey, 1999; D. A. Plowman & Duchon, 2008). The operation of organisations, governments and society, despite being planned or command-control oriented have emergent underlying qualities and it therefore could be said exist by 'default', rather than by design. The hierarchical and pyramid structures that govern economies and global firms have evolved as much as they have been invented – therefore, there are reasons why they exist in this manner. With this in mind, emergent self-organisation, the anchor-point phenomena of complexity theory is believed to be an important dimension of our understanding of the functioning of complex human social and organisational systems, and fertile ground to apply a pragmatic, sense-making approach.

1.2 Research Aims and Purpose

This research aims to contribute to the development of a theory of emergence in complex firms by exploring the role of social influence in the emergence of coherent structure in human social systems. This study explores how complex organisations adapt through emergent self-organisation, with a focus on the role of influence between agents. The study delivers a deeper understanding of the function of emergent self-organisation and its real-world application in the context of high levels of uncertainty, change and crisis, drawing on real-world case study research. This study examines how emergent self-organisation occurs in complex firms, and role of social influence as a moderating factor in the creation of coherent structure, form or behavioural patterns. Drawing on an interview-driven, multiple case study approach, there are two main research questions of this study:

1. What role does emergent self-organisation play in adapting to new or acute internal/external pressures? Can emergent self-organisation be reliably observed and predicted?

2. How do (emergent) patterns of behaviour coalesce in complex organisational systems, can a conceptual model for the theory of emergence be applied to this process?

The outcomes of this study contribute to a deeper understanding of how emergent self-organisation occurs in human social systems and the dynamics of inter-agent influence and interdependence on the capacity of firms to adapt, thereby addressing many limitations in existing literature. The output of this research contributes to the refinement, conceptual development and operationalisation of theory and the broader framework of complexity research. A multiple case study approach is used to explore the intricacies of complex phenomena at play in a real world setting. The methodology chapter provides a more detailed overview of research questions and methods.

1.2.1 Research Value and Outputs

There are two main outputs of this research. Firstly, in its contribution to the body of knowledge for the study of complex human social systems, with regard to the function and process of self-organisation and the role of social influence. Secondly, to the application, refinement, conceptual development and operationalisation of the nascent theory of emergence for complex firms, an anchor point within the broad and multidisciplinary study of complexity theory. The value of this study is measurable by its contributions to the body of knowledge, developments in methodology, practical application and suggestions for real-world application and theory development. Making sense of complex behaviours holds significant importance for industry, to enhance the ability of firms to adapt to unpredictable change, explore new organisational configurations, growth cycles and management practices, and diffuse innovation across firms or markets. Through self-reflection embedded within the research process, this study explores the extent to which it has contributed to theory and practice in these domains.

1.2.2 Justification for the Study

Generating further understanding about how emergence occurs within complex organisations has significant benefits for refining management and organisational strategies or practices and identifying new organisational configurations that are more amenable to the growing climate of change. This study makes a contribution to more adequately recognising the role of social influence as a fundamental organisational process, thereby impacting business performance, commercial value, diffusion of innovation, systemic risk and the regulation of public infrastructure and markets. The lens of complexity theory offers a pioneering way to understand the realities of what is occurring within organisations for the purpose of extending the longevity and many other possibilities of the modern firm. An operationalised and refined theory of emergence has numerous benefits including giving cause to modify counterproductive management practices, parameters for identifying opportunity in disorder, the creation of anticipative capacity, rapid adaptation, continuous innovation and efficiency.

1.3 Overview of the Thesis

The thesis is arranged in logical sequence, divided into six main Chapters: Introduction, Literature Review, Methodology, Findings, Discussion and Conclusion. Further detail on the sequence of the structure and the purpose of each section are provided below.

Chapter 1 – Introduction: provides an introduction, background, research aims, overview and delimitation of the program of research.

Chapter 2 – Literature Review: examines the rich tapestry of existing literature to help understand the groundwork of modern complexity theory, and is divided into six parts: (2.1) introduction and mapping of existing literature under review; (2.2) conceptual foundations that underpin the study of complex systems; (2.3) history and development, chronology of a theory of emergence, and key theoretical constructs that have moved the focus of theory from parts to whole systems; (2.4) root theory on influence processes in organisations and relational processes of human agent interaction; (2.5) the current state of the theory of emergence, drawing on the application of Lynham's (2002) general method for theory building research; and finally, (2.6) critique, synthesis and limitations in current and concluding remarks are discussed.

Chapter 3 – Methodology: outlines in detail the epistemological and ontological foundations for research, aims and purpose, research questions, data collection and analysis processes, techniques, research tools, case study selection, data validation procedures, issues, limitations and reflections on the research method.

Chapter 4 – Findings: provides a summary and analysis of the findings of the study, including industry dynamics, cultural factors, results of data analysis, coding, themes, patterns, correlations, triangulation, concept analysis and mapping, weightings, frequencies, concept clusters, comments on analytic generalisability and limitations.

Chapter 5 – Discussion: the implications and interpretation of findings, contributions to the body of knowledge, emerging theory, methodological advances, conceptual models, evaluation of the research process, research outputs, challenges, issues and limitations, together with suggestions for further research.

Chapters 6, 7, 8, 9 – Conclusion, Glossary and Bibliography: summary of research process and outcomes, key findings and implications, further research opportunities, and closing statements.

1.4 Delimitation

Emergent self-organisation is a natural process whereby system-level order spontaneously emerges, not to be confused with the employment relations concept of self-management, referring to self-directed individual or group work toward particular objectives, democratic workplace decision making and loosely structured companies.
Workplaces with self-management policies may provide an interesting location for a later exploration of the presence of emergent self-organising behaviour on a case study basis, but are not the exclusive focus of this study. The concept of self-organisation is applied extensively in the natural and physical sciences, where it arguably originates; this study undertakes an interdisciplinary translation to the study of human social systems within a commercial setting, extending on prior research and attending to the associated challenges of theoretical development.

Given the celebrated history of complexity theory and its diverse origins over more than a century, an extensive variety of literature is available. However, inclusion of an exhaustive list of all the influences and elements of complexity theory over the last century would not be feasible. Consequently, two main strategies to limit the selection of literature are employed in this study and outlined in further detail in Chapter 2. As a general guide, literature is chosen for its direct relevance to the concept of emergent self-organisation in the social sciences, with preference given to works that have made a significant contribution to the field and where possible those that are published in international high quality peer reviewed journals.

As a point of further clarification, is may be beneficial to note this study employs the use of the term ‘complexity theory’ as opposed to ‘complexity theories’. The latter is used in some literature such as Burnes (2005) to reflect the many underlying ideas and constructs that make up the umbrella term of complexity. Although this study does not seek to develop a general theory for complexity, it uses the former, singular version for the purposes of clarity – that signify the umbrella term of complexity, including underlying elements, but not specifically relating to any one particular element. More specific terms are used where necessary, for example ‘emergent self-organisation’ or ‘complex adaptive systems’.

Terms ‘emergence’ and ‘emergent self-organisation’ are used interchangeably, and for the purpose of this study refer to the phenomena of emergent self-organisation resulting from complexity dynamics. The term ‘emergent/s’ is used to describe the physical or non-physical objects or properties that arise from emergent processes, in other words, the form or shape that an emergent pattern takes.

1.5 General Limitations

An interview-driven multiple case study approach provides many opportunities to observe the intricate details of emergent self-organisation within organisations in their natural environment. There are however, limitations on the generalisation of results to organisations in differing circumstances. It is noted that previous researchers in the field of complexity have experienced difficulty in delivering universally accepted results

(Burnes, 2005), partly due to the interdisciplinary nature of the conceptual framework in use. Consequently, the field is accompanied by a lack of empirical data that provide ‘sharp’ predictions (Moldoveanu & Bauer, 2004).

In consideration of the relevant limitations and risks, this study is concentrated on the phenomena of emergence as the most tangible and commercially relevant facet within the theoretical lens of complexity (in applied social science), mindful to avoid a too-broad view. The proposed method is sequenced and structured, commensurate with risk and in harmony with the growing methodological experience of organisational complexity research of the last decade. Careful attention is given to external validation by accurately defining the context in which findings are observed and through cross-case analysis. Multiple sources of data, triangulation, an extended period of collection, recursive cycle of validation, context rich delimitation, cross-case analysis, and supervision of the research process is used to mitigate limitations and assist in validating research outcomes.

2 Literature Review

2.1 Introduction

Since the inception of the first corporation, organisational theorists have scaled vast and radical ideas in the pursuit of perpetual novelty and organisational longevity. In the search for more comprehensive knowledge, management thinking has looked to complex systems in the natural world for answers.

The ideas of complexity theory and emergence provide a novel lens for understanding the underlying dynamics of organisation with concepts derived of a range of natural, physical and social sciences. In the context of human social systems, emergent self-organisation is a process whereby order spontaneously emerges without explicit control. Existing literature on emergence suggest this phenomenon is less an art of prediction and more one of sense-making and cultivated participation (Marion & Uhl-Bien, 2001). Complexity theory is a vast field of study, an interdisciplinary web of ideas without universal classification or structure. This study is positioned within the conceptual framework of complexity theory, with particular focus on the function and process of emergent self-organisation. Hence, a robust and logical grounding in these ideas is necessary to understand the shape of the field, and to position further research. The review of literature has been logically structured around the major thrusts of complexity, described as follows.

Complexity theory in its modern social science context is largely derived of two parallel schools of thought: General Systems Theory and Cybernetics (Anderson, 1999; Ashby, 1956; Goldstein, 2008; Skyttner, 1996; von Bertalanffy, 1951; Weiner, 1948). These two areas of study, while unique, both describe a major intellectual transition in scientific understanding – to understand whole systems, not only the functioning of the parts of which they are comprised (Goldstein, 1999). In other words, complexity is largely concerned with two main themes: firstly, *systems* – the character of complex phenomena at the level of the system or the 'what' of complexity (Anderson, 1999;

Capra, 1996; Holland, 2006; Manson, 2001), and second: *processes* – the patterns and dynamic interplay of agents within a system that generate system level order, or the 'how' of complexity (Blackler, Crump, & McDonald, 2000; Brodbeck, 2002; Drazin, 1992; Lichtenstein, 2000a; Lichtenstein et al., 2006; McKelvey, 2008; Stacey, 1995). The anchor-point phenomenon of all complex adaptive systems is the capacity for emergent self-organisation or *emergence* (Anderson, 1999; Chiles, Meyer, & Hench, 2004). The literature review is structured around this high level framework to give coherence and simplicity to what is a vast body of knowledge, as illustrated below as roadmap to the literature review.

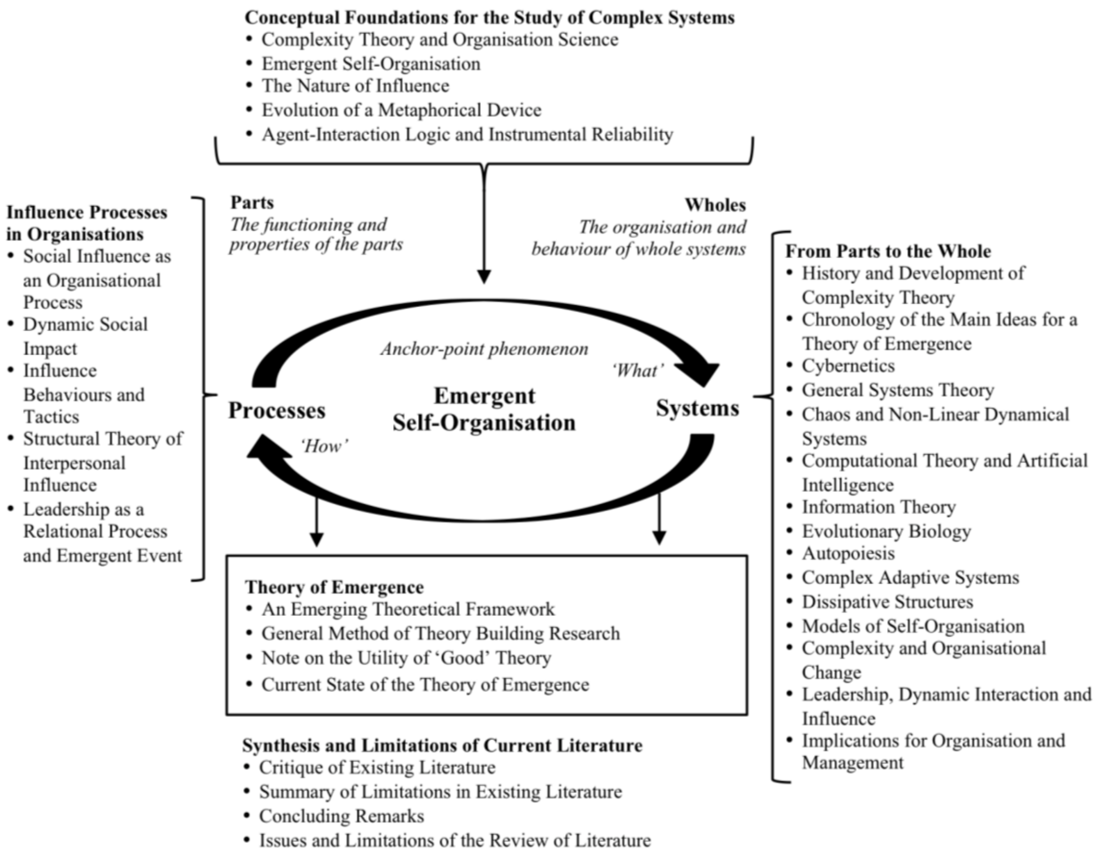


Figure 2.1 Literature Review Roadmap

In concert with the literature review map presented at Figure 2.1, this Chapter is logically structured around four elementary components of complexity literature, as they apply to this study. To that end, the Chapter is comprised of the following sections: (2.2) conceptual foundations for the study of complex systems; (2.3) a systems view of complexity – from parts to the whole; (2.4) a process view of complexity in human systems – influence processes in organisations; (2.5) exploration of the anchor point phenomenon – the theory of emergence; and, (2.6) synthesis, discussion and limitations of current research. Throughout these sections, the review summarises and evaluates current literature, identifies issues and gaps, and positions this study (Creswell, 2009). The structure of existing literature and contributions are revisited at Figure 5.19, Chapter 5.3.1 (Research Contributions).

2.2 Conceptual Foundations for the Study of Complex Systems

2.2.1 Complexity Theory and Organisation Science

The concept of self-organisation and the emergence of order is not in itself a new idea. The notion of open systems that are coordinated and interconnected across their parts and boundaries can be traced back at least to the philosophies of ancient Greece and early Eastern tradition (Goldstein, 1999). Emergence refers to 'the arising of novel and coherent structures, patterns, and properties during the process of self-organisation in complex systems' (Goldstein, 1999). Where complexity theory is concerned with the study of complex [adaptive] systems, emergence is its anchor-point phenomenon – that which makes all else worthy of attention, 'the appealing paradox' as put by Ablowitz (1939).

The journey of complexity theory traces a well-documented history from the non-reductionism of post-1900s gestalt and holistic thinking (Wertheimer, 1900); landmark workings into the mechanisms of order found in Cybernetic communication and control systems (Weiner, 1948); and the broadly diffused view of organisations as open-systems – ecosystems of interdependent actions and consequences (von Bertalanffy, 1951). Advancing from the success of General Systems Theory, parallel developments in Cybernetics and the observation of dissipative structures in chemical systems (Nicolis & Prigogine, 1977), later works posited further adaptations from the natural sciences, including a punctuated equilibrium of discontinuous radical change (Tushman & Anderson, 1986); and evolutionary, adaptive and emergent processes of self-organisation in the context of the modern firm (Anderson, 1999; Brown & Eisenhardt, 1997; Chiles et al., 2004). Each of the aforementioned theoretical developments is described in more detail in the following section.

Complexity theory, although lacking a universal definition, can generally be referred to as *the study of complex systems* (Goldstein, 1999). The emergence of order within, between, or of organisations themselves is not currently distinct from the general constructs of complexity theory, rather can be viewed as an element within a broader interdisciplinary framework. Currently, emergence is for most intents and purposes a component of complexity theory (Manson, 2001) rather than a theory in itself, contrary to such a proposition by Ablowitz (1939) around 80 years ago. Despite its principal importance to all other matters concerning the adaptive potential of complex systems, the idea of emergence holds the status only as a thing that is observable and exists – a phenomenon, or in its interdisciplinary state, an 'ontological notion' (Huttemann, 2005). One would be forgiven for asking why this key plank at the very foundation of our understanding of the mechanisms for emergent order merely *exists*. The section that follows explains the reasons behind this major limitation in complexity literature.

A worthy point to note in undertaking a review of complexity literature is to explore the meaning of complexity theory itself, its main ideas, and what subject matter it applies to. One of the continuing challenges of complexity is the question: *why* should we be interested in a science of complex systems and emergent change (Marion, 2008), and what use is it in everyday practical affairs. Collective intelligence has become a familiar and lay term to describe complex underlying phenomena and despite its increasing use, the theory that is driving our understanding of this behaviour and its application to social and human phenomena is relatively underdeveloped and not well understood as a practical management tool (Schneider & Somers, 2006).

The first observation of complex systems is that through the many complex interactions of individual agents, order can be generated without the need for explicit coordination or control (Anderson, 1999). In addition to the ability to co-evolve new structures, the dynamic nature of this interaction implies that the future is resolutely uncertain and the resulting effects of small change can have irreversible and large ramifications (D.A. Plowman, Solanski, et al., 2007). The amplification of small change has been popularised as 'the butterfly effect', from the original work of Lorenz (1963) on weather forecasting models. A second relatively less explored implication (in the social sciences) is that order is also created through the dissipation of energy, in contrast to traditional assumptions that order is generated through the accumulation of energy (Anderson, 1999; Prigogine, 1977; Marion, 2008).

Complexity theory could be informally defined as the study of complex systems (Goldstein, 1999). However, its root meaning and boundaries are far more intricate. Broadly, complexity theory describes an interrelated set of ideas about how order emerges from chaos, through multiple interacting agents that act on casual feedback without a central point of control, as further described below.

> Complexity theory is derived from a broad and well-documented intellectual movement rejecting nineteenth century assumptions and incorporating the non-reductionist tenets of early-1900s gestalt and holistic thinking, explorations into the mechanisms of feedback, communication and control in cybernetics (Weiner, 1948), and the broadly-diffused general systems theory view of organisations as ecosystems of interdependent actions and consequences (Skyttner, 2006). Drawing on the precepts of general systems theory, cybernetics and the observation of dissipative structures in chemical systems (Nicolis and Prigogine, 1977), later works have posited further adaptations from the natural, physical, chemical and mathematical sciences to human social systems, including a punctuated equilibrium of discontinuous and radical technological change (Tushman and Anderson, 1986), evolutionary and emergent processes of self-organisation in the context of the modern firm (Brown and Eisenhardt, 1997; Chiles et al., 2004) and of humans as agents with 'schemata', a malleable set of rules (Anderson, 1999). (Yezdani, Sanzogni, & Poropat, 2015).

The ideas of complexity theory have deep and varied historical roots punctuated by significant interest in Cybernetics, General Systems Theory, and more recent growth in the application of complexity principles to an increasingly wide variety of fields. Opposing viewpoints coexist in a fractured landscape of research, grappling with traditional applications of scientific and mathematical complexity. Goldberg and Markoczy (2000) and McKelvey (1999) assert that social scientists are at risk of misusing chaos and complexity theories due to not fully understanding them; conversely Anderson (1999), and Marion and Uhl-Bien (2001) argue that complexity principles are well established and social science researchers do well to extend them. Scholars may indeed do well to follow the latter advice, for the inclusion of a general treatise on all interdisciplinary matters concerning complexity may require many lifetimes' work.

With even a brief review of literature, it is immediately apparent that the boundaries of complexity theory are largely defined by what the theory is not, and less so by what it is (Marion, 2008). For example: complexity theory is focussed on non-linearity and non-reductionism, dissipation and disequilibrium in an unpredictable world without centralised coordination (Marion, 2008). The ill-equipped English lexicon inevitably turned to the exotic terminology of its origin fields, which it is now littered with – bifurcation points, Bénard cells, fractals, anisotropy, strange attractors, morphogenesis, Mandelbrot sets, and so on. The issue is not in the borrowing of language or concepts in itself; rather, it is the muddy approximation of an idea without an empirically tested bridge (Yezdani, Sanzogni, & Poropat, 2015).

It is a baseline assumption that the processes of dissipative structures work in an equivalent manner for human social systems as though it were simply a broader application of entropy and the Second Law of Thermodynamics (Gleick, 2011). There remains much zeal for critique in the rudimentary juxtaposition of electrons with employees, but few compelling solutions. As highlighted at Table 2.1, a focus on the process of interaction within a system is a mainstay feature of complexity literature, for if a system is in stasis – it is wholly unlikely to be an emergent one. The distinction between fiction and fact for complexity as it applies to human social systems is in understanding how the principles of organisation work in the process of how *interaction* transmits changed behaviour between agents in a complex system (Marion, 2008; D.A. Plowman, Solanski, et al., 2007). Interactions between agents that result in the exchange of information and knowledge, forming into ideas that become action are the foundation of emergence in human social systems – *influence* is this vehicle.

Table 2.1 Definitions of Complexity Theory in Organisation Science

Author	*Definition of Complexity Theory*
Marion (2008)	'Complexity theory is the study of the dynamic behaviours of complexly *interacting*, interdependent, and adaptive *agents* under conditions of internal and external pressure.'
Goldstein (1999)	'The study of complex systems … evolving, adaptive systems of *interacting agents*.'
Conveney (2003)	'The study of the behaviour of large collections of … simple, *interacting units*, endowed with the potential to evolve with time.'
Plowman et al. (2007)	[Complexity theory pertains to] '…a complex system is comprised of numerous *interacting agents*, each of which acts on the basis of local knowledge or rules.' In the case of organisations, people or groups adapt to feedback about the behaviour of others and act in parallel without explicit coordination or central communication.
Lichtenstein & Plowman (2009)	'Complexity … focuses on the dynamic *interactions between* all *individuals*, explaining how those interactions can, under certain conditions, produce emergent outcomes.'
Anderson (1999)	'Complex outcomes flow from simple schemata and depend on the way in which agents are interconnected … systems of *interacting* co-adapting *agents* [that] evolve.'
Manson (2001)	[Deterministic complexity] '…the interaction of two or three key variables can create largely stable systems prone to sudden discontinuities.'

Note: sources identified within the table (emphasis added).

2.2.2 Emergent Self-Organisation

In January 1939, Rueben Ablowitz published a short, albeit seminal article in *Philosophy of Science* entitled 'The Theory of Emergence'. Inspired by a range of earlier works including G.H. Lewes 'Problems of Life and Mind' (1875); J. S. Mill's 'Logic' (1843); S. Alexander's 'Space, Time and Deity' (1920); C. L. Morgan's 'The Emergence of Novelty' (1933), in addition to the writings of Thomas Henry Huxley and Aristotle. The article issues a broad description of emergence as the force that 'accounts for the transformation of quantity into quality' (Ablowitz, 1939).

Still frequently cited today, Ablowitz draws on an earlier definition of emergence, depicted by Sellars (1922) as 'The tendency of units of one kind in combination, to constitute units of a new kind, with more complex constitution and new qualities due to the new togetherness of the parts' (Sellars, 1922; in Ablowitz, 1939). The theory of emergence promulgates that 'the whole is more than the sum of the parts' (Ablowitz, 1939). Sixty years later, in the first issue of its namesake journal, Goldstein (1999) retains a consistent definition, as: ‘the arising of novel and coherent structures, patterns, and properties during the process of self-organisation in complex systems’.

Earlier notions of emergence can be found in the *Atomist* movement, where order (or substance) is created from chaos through combinations of invisible atoms, in writings of Lucretius and Democritus (Palmer, 2012); complex dynamical systems were also hypothesised by Kant (Cooper, 2017; Van de Vijver, Van Speybroeck, & Vandevyvere, 2003); Descartes’s circular motion of particles that form an ordered *Cartesian* universe (Descartes & Gaukroger, 1998; Hutchins, 2015), also Descartes’s apparent influence on Alan Turing is observed in the ‘epistemic limitations’ of necessary unpredictability that defines artificial intelligence, later to become the Turing Test (Abramson, 2011), perhaps also on *Morphogenesis* (see Section 2.3.15) (Turing, 1952).

The idea of emergent order can be found in classical economics, the ‘invisible hand’ that guides the free market economy (A. Smith, 1776), the *Law of Requisite Variety* (explored further under Section 2.3.3), and the principles of self-organisation are explored within Cybernetics by Ashby (1962). Importantly, according to Ashby, self-organisation is primarily a metaphysical concept; therein ‘organisation’ is itself in the eye of the beholder. Ashby suggests that with mathematical extrapolation, no system could properly be said to be self-organising – Ashby’s inquiries of emergence within artificial and natural systems remind his audience to conduct interpretations of self-organisation with careful reasoning and examination (Ashby, 1962). To paraphrase, emergence requires the field to hold ontological adequacy to avoid existence only in a metaphysical state – where self-organisation is a construct of mind, not necessarily reality. Together with this, one of the key issues surrounding complexity is its accurate interpretation for *human* social systems (Manson, 2001). While a complete appraisal of logic and reason within classical philosophy is unnecessary, a detailed chronology of complexity science and emergence will be explored shortly at Section 2.3.1. Self-organisation in large-scale social systems is one such example of emergence in social systems, which was introduced and has remained a part of classical sociology.
Durkheim (1997) used the notion of structural emergence as the basis of his ideas on the division of labour and methodological individualism, ‘the more complex an organisation is, the more the necessity for extensive regulation is felt. In the normal state, these rules emerge automatically from the division of labour’, Durkheim wrestled

with a grave concern for the decay of society caused by individualism, and henceforth removed himself from the *laissez-faire* thinking of the 19th century. Many other examples exist, the self-generation of process from the ‘interfunctioning of parts’ of Follett (1998), and the ‘sociogenesis and social dynamics’ of Elias (1978). These two examples demonstrate the gradual development of empirical support, with sustained attention to self-generating order from complex processes.

Despite the decades that have passed since its first appearance in print, Ablowitz (1939) expresses what could be a very similar dilemma to that which is faced today:

> A scientific appraisal of the theory of emergence is not easy. The introduction of the concept in biological evolution is illuminating, and it has service to give at least partial answers to many a philosophical dilemma. However, like alcohol, it is a stimulant only in proper doses: many who have used it have gotten drunk in the attempt to apply it to everything. Sociology, however, is one field in which it has as yet not been applied to full advantage. ‘Felix quis potuit rerum cognoscere causas’, said Vergil; and if we cannot always know the causes of things, let us at least know how and why we do not know. (Ablowitz, 1939).

The very idea of emergent order without a central point of control is a difficult concept to grasp if it were not for the use of metaphorical device, such as the seamlessly moving flock of Starlings or Slime Mould crawling across the forest floor (Burnes, 2005; S. Johnson, 2001). While these examples may be empirically supported behaviours of complex adaptive systems in their respective fields, they have also served to stigmatise complexity by the translation of seemingly fantastic ideas to unfamiliar territory (complex adaptive systems referred to in detail at Section 2.3.10). This problem is exemplified by Burnes (2005) ‘there is a world of difference between restructuring an organisation because science has discovered that this action is necessary, and doing the same thing because that is what a computer simulation has shown that a flock of birds would do if faced with wind turbulence.’ This stream of criticism over complexity theory demonstrates the success of its application as a metaphorical device has exceeded its use as a practical tool for organisations and management. Real-world testing, refinement and empirical support are vital for the further development of theory.

As discussed up to this point, *emergence* is complexity theory's 'anchor-point phenomenon' (Chiles et al., 2004). Emergence refers to the process whereby system level order emerges as a result of the interplay between agents within a complex system (Anderson, 1999), additional definitions are provided at Table 2.2. Notably, in both human social systems and physical or chemical systems, the emergence of self-organisation occurs without a central point of control (Chiles et al., 2004). The foci of studies of complexity (and emergence) are on both process and systems, whereby understanding derived of reduction and holism must intertwine to explain the resulting order – an attention to 'process rather than state' (Gleick, 2011). Emergent self-organisation is a product of dynamic interaction between individual agents with local knowledge, casual feedback, and no central point of control (Chiles et al., 2004; Anderson, 1999). Hence, order is most often surprising as it is an unintended consequence of repeated interaction of lower system components acting without intervention or central coordination.

Table 2.2 Descriptions of Emergent Self-Organisation

Author	*Descriptions of Emergent Self-Organisation*
Nicolis & Prigogine (1981, p. 659)	'Self-organisation phenomena, leading to ordered behaviour, can arise in an initially uniform and time-independent system far from equilibrium.'
Lichtenstein et al., (2006, p. 620)	'At a critical threshold, when the system has reached the limit of its capacity, it can either collapse or re-organise.' '… agents/resources in the system re-combine in new patterns of interaction that tend to improve system functioning.'
Manson (2001, p. 410)	'The capacities of a complex system are greater than the sum of its constituent parts. A system can have emergent qualities that are not analytically tractable from the attributes of internal components.'
Goldstein (1999, p. 49)	'…the arising of novel and coherent structures, patterns, and properties during the process of self-organisation in complex systems'

Sources as referenced within the table.

The actual process of emergent self-organisation was dramatically demonstrated by Nicolis and Prigogine (1977) in their observations of 'dissipative structures'. Nicolis and Prigogine observed the actual processes that take place in a chemical system that organises itself in a far from equilibrium state. Further discussion is devoted to unpacking each of these four processes at Section 2.3.11, and how or if they can reasonably translate to the world of human social systems.

The phenomenon of emergence is not unique to the internal workings of organisations or between individual people, and may also be observed across organisations (Chiles et al., 2004), through the emergence of entirely new ventures (Lichtenstein, 2000), or in the materialisation of our perception, explanation or understanding (Drazin, 1992). Moreover, emergent self-organisation is a concept that extends to the origins and definition of life itself (Maturana & Varela, 1987). Extending further on the philosophical and mathematical concern of self-organisation across all living and cognitive systems, Maturana & Varela (1987) define a circular method of organisation common to all living things – autopoiesis. Maturana & Varela (1987) outline their focus on the nature of organisation, of which various forms of structure are a product, not necessarily a catalyst, thus – systems may arrive at organisation through countless variations of structure. Through participation among diverse agents, transfer of information and transformation of components, the phenomenon of self-organisation is a process of 'self-making', whereby boundaries are defined and structures are created (Maturana & Varela, 1987).

As an ontological notion, knowledge itself is continuously emerging and re-emerging, evolving and changing, with our understanding of the world influenced by perceptions, interactions and history (Proulx, 2008). Then, there exists an indirect causal relationship between the physical world and our arising understanding of it. The distinction is explained by Proulx (2008), 'It is not because I perceive something that I physically change it, but by perceiving or making sense of something, my own actions are modified and influenced by these (new) perceptions and understandings.' In other words, as we acquire knowledge or change our behaviours, this effects on some level the physical texture of the world around us (Proulx, 2008).

The ontological question of emergence is as pertinent in mathematics and physics as it is in the social sciences. For instance, the self-organising processes that link parts to wholes require empirical explanation at successive levels and a reasonably developed meso-model for multiple level analysis. Regarding emergence and explanation, 'if it is (in principle) impossible to explain the behaviour of a compound in terms of the behaviour of its parts, the behaviour in question is said to be emergent', therefore with additional assumptions a progression is made from impossibility of explanation to ontological argument (Huttemann, 2005). Such a boundless leap in quantum mechanics, is suggested as unproblematic, despite the idea of emergence in this sense being merely an 'ontological notion' (Huttemann, 2005). However, relying only on an observation of arising forms with no explanation of underlying processes is utterly dissatisfying. This study suggests methodological preparedness to understand the underlying functions and processes that give rise to emergent forms, by employing conceptions that are adequate to applied social science research (Lawson, 2016; B. Smith & Searle, 2003). The ontological adequacy of direct theory-phenomena applications is discussed in detail in the literature review and discussion chapters. The following section moves to focus on the processes of self-organisation as they occur in human social systems, as a result of dynamic interaction – the nature of influence.

2.2.3 The Nature of Influence

Social influence is not a conceptual foundation within the study of complex systems, at least not *per se.* However, the link to this field of study is easily explained. In self-organising human systems, order comes from the actions and interactions of interdependent agents, who exchange information, take actions, and continuously adapt to feedback from others' and the impact of their own behaviour, all this is with or without the impost of an overall plan by a central authority (Chiles et al., 2004). More than simply an exchange of information, to have potency the interaction between agents must result in some form of *influence,* 'exerted by one person over other people to guide, structure and facilitate activities and relationship in a group or organisation' (Yukl, 2006).

Complex systems are characterised as non-linear because the components that comprise them are constantly interacting with each other through a dynamic web of feedback loops (Anderson, 1999; Stacey, 1995). The non-linear and distributed nature of interaction and influence within, across, and around an organisation, gives rise to emergent, unknowable futures, despite the presence of formal leadership and management roles. Non-linearity in social systems denotes the potential for disproportionality in output relative to input, characterised by unpredictability, and dynamic behaviour. Humans are complex agents with the potential for a multitude of response choices, irrationality, amplification and ploy.

The principal argument in this thesis is not however, to say leaders and managers do not play an integral role in an organisation. Rather, the aim is to understand the nature and extent of emergent self-organisation that occurs within organisations, whether acknowledged or not, and in particular to understand the character of emergent processes and systems in real world setting. Importantly, despite influence being a primary attribute within the definition of leadership (Yukl, 2006), the majority of interactions in a large and complex organisation will usually be between peers and among distributed systems of informal leadership (Yukl & Tracey, 2003), where influence is 'raw' (Lichtenstein & Plowman, 2009b) and not always within the sphere of deliberate plans (Mintzberg, 1994).

The complexity viewpoint suggests that influence, if a self-organising principle, occurs continuously, throughout the system, in multiple directions and with varying degrees of effect, and at a system level follow an emergent *pattern* (Hazy, 2008b). When an agent within the system adjusts their behaviour in response to influence stimuli, they give rise to a cascade of interactions and repertoires that expand and alter the behaviour of the system itself (Mary Uhl-Bien, 2006). It is at this point the conditions and 'sequences' of emergent self-organisation are hypothesised to occur, extending the idea of emergence beyond the application of metaphorical device, and outside the chemistry lab.

2.2.4 Evolution of a Metaphorical Device

Complexity has long been a feature in the chronicles of organisation science, from classical economics (A. Smith, 1776) to new methods for building a self-managing organisation (Bernstein, Bunch, & Lee, 2016). The shift from understanding phenomena based on a reduction to their component parts – to understanding the nature of whole systems is a remarkable yet gradual transition in sociological and scientific worldview. The modern conceptualisation of organisations as fluid, boundaryless, self-directed, and unpredictable entities is dramatically different from the early notions of management, such as Frederick Taylor's *Scientific Management* (esp. Taylorism), predominant during the 1910s to 1930s to apply principles of design and control to engineer processes and management in the pursuit of productivity and efficiency (Beissinger, 1988). Despite their differences, control-oriented and complexity schools of thought emerged in popular organisation science thanks to inter-disciplinary borrowing. The act of importing concepts is a common feature of criticism on the application of modern complexity theory in social science – allegedly ill-fit, in contrast to its origins in biology, physics, chemistry and mathematics (Burnes, 2005).

The study of emergence in organisation science does not mark the discovery of previously unobserved phenomena, but rather a new lens with which a deeper understanding of complex systems may be derived (Marion, 2008). Therefore, it offers a changed perspective on how to interact with a deeper knowledge of the mechanisms of order within a complex organisational system.

Emergent self-organisation is a matter of great importance to the field of organisation science (McKelvey, 1999). It also matters that practice-informed theory and theory-informed practice keep some kind of pace with one another, for empirical results to deliver a measured link to everyday practical affairs (Lynham, 2002). It is highly likely the potential for rapid diffusion and use of complexity terms or principles greatly exceeds the pace for empirical results to be delivered. Organisational actors would however, be mistaken in thinking the theorems of disequilibrium, entropy, or dissipative structures unilaterally apply in both chemical *and* human systems – and must question the added ethical dimension of orchestrating the conditions of chaos in order to bring about new change.

Over the course of the last decade, the application of complexity theory to fields beyond the natural sciences has dramatically widened, including simulations to model traffic flows, population growth, criminal activity, emergent leadership, stocks, supply chains, multi-agent networks, and social theories (Burnes, 2005; Hazy, 2008b; Lichtenstein, 2000b; Tyler, Wilkinson, & Huberman, 2003, 2005). The commercial application of complexity principles, similar to that of systems thinking, has been accompanied by a thirst for discourse. Many may recall the 'circles of causality' or 'mental models' brought about by the popularised practice of systems thinking (Senge, 1990). Practical application of theory may include discussion on whether or not the practice of 'managing' intra-organisational emergence benefits from a similar discourse of complexity via metaphorical device.

As proposed by Goldstein (1999) the study of emergent phenomena has been ‘ripe’ for exploration, particularly in the areas of informal (emergent) leadership and emergent networks. In conceiving a prospective research agenda, Goldstein (1999) located major research opportunities within a grid identifying the type and source of structure in which emergent phenomena may occur. Published in the first issue of *Emergence: Complexity and Organisation,* Goldstein’s grid is reproduced here (see Figure 2.2).

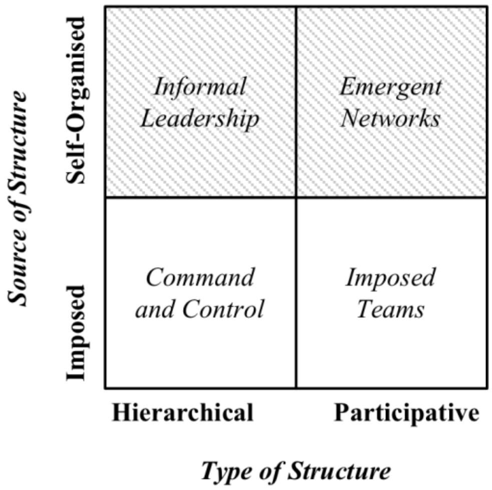


Figure 2.2 Emergence and Organisational Dynamics

Following the research agenda set out by Goldstein (1999), the swinging pendulum has not come to rest within the bounds of a single epistemological framework, nor should it. Various scholars have argued that if the findings of complexity are not driven by computational or mathematical (post-positivist) models it has little chance of being adequate (McKelvey, 1999). Other viewpoints posit two clear but ultimately limiting alternatives for the theory: a) only for use as a metaphorical device, or: b) a method of mathematical discovery (Burnes, 2005). Alternatively, complexity has use within a symbolic, interpretive *and* practical approach (Marion, 2008).

On review of eleven frequently cited articles expanding the knowledge base on emergent leadership and emergent networks within social and organisation sciences, it is clear that non-simulated empirical research (using real world phenomena rather than computer-generated or artificial models) has been a prominent feature of studies over the course of the last decade. To illustrate, a hybrid ‘McKelvey/Goldstein’ grid juxtaposing the former (McKelvey) proposed research agenda and latter (Goldstein) methodological ideals is presented (see Figure 2.3). An increasing number of empirical works deployed over recent years have applied complexity principles to a variety of real-world examples.

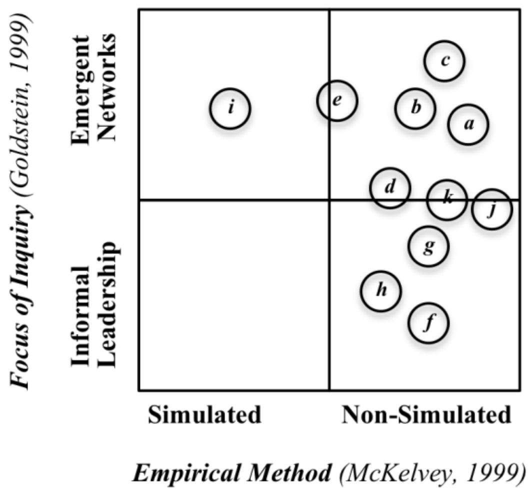


Figure 2.3 **McKelvey/Goldstein Grid of Selected Studies of Emergence and Organisational Dynamics**

Table 2.3 **Selected Studies of Emergence and Organisational Dynamics**

Ref.	*Author*	*Description*
a	Chiles et al. (2004)	In-depth case study into organisational emergence / recombination of a collective across musical theatres
b	D.A. Plowman, Baker, et al. (2007)	In-depth single case study on the emergence and amplification of change within mission church
c	Lichtenstein (2000b)	Multiple case studies on emergence in several high-potential tech-enabled new venture firms
d	Blackler et al. (2000)	Comparative case study of three strategy teams within a single high-tech firm, processes of organisation via networks of activity
e	McKendrick, Jaffee, Carroll, and Khessina (2003)	Emergence of organisational form using archival data on the global disk array market
f	Pescosolido (2002)	Observation of how emergent leaders influence interacting groups, multiple case analysis of jazz music and rowing groups
g	Kickul and Neuman (2000)	Survey of 320 university students on the behaviours of emergent leaders and their relationship to team processes and outcomes

h	Carte, Chidambaram, and Becker (2006)	Emergent leadership across 22 self-managed virtual project teams of university students
i	Zott (2003)	Simulation study on the emergence of intra-industry differential firm performance, the link between capabilities, resources and performance
j	Corley and Gioia (2004)	Inductive case study on organisational identity change in a Fortune 100 company spin-off
k	Huygens, Baden-Fuller, Van Den Bosch, and Volberda (2001)	Coevolution of firm capability using multiple case study of firms within the music industry

It is noted that Figure 2.3 represents a limited exposition of selected articles (n=11) applying thin search parameters relating to emergent networks and emergent leadership that contribute to the research agenda proposed by McKelvey and Goldstein. While a small sample, the grid demonstrates that simulation methods are only part of the overall picture when it comes to research on emergence and organisational dynamics. Further expansion of the proposed McKelvey/Goldstein Grid is suggested, but is unnecessary for the purposes of this study.

2.2.5 Agent-Interaction Logic and Instrumental Reliability

The symbolic and interpretive nature of interaction has a unique and special importance on the construction of aggregate social outcomes and inference of meaning in human social systems (Marion, 2008; Goldstein, 1999; Conveney, 2003; Plowman et al., 2007; Anderson, 1999). From a social science perspective, a theory of emergent self-organisation is concerned with the study of patterns of dynamic human interaction in a complex human social system.

The application of complexity to the social sciences requires an abstraction from its original form and consequently has been the source of much of its criticism (Burnes, 2005; Moldoveanu & Bauer, 2004). Complexity is an intrinsically non-reductionist field of inquiry and thus presents unique methodological challenges in deriving qualitative meaning from individual agent interactions. As Wheatley (1999) has proposed, the initial stage in applying complexity to organisation science may begin with an 'act of faith' to assume theories derived of the natural sciences can in fact be transferred to the social sciences (Burnes, 2005), or vice versa [e.g. statistical methods] (Plowman et al. 2007). To preface the application of the conceptual framework using the example of agent interaction, the implications of interdisciplinary logic to derive qualitative vs. quantitative meaning are hypothetically illustrated at Figure 2.4.

Figure 2.4 putatively demonstrates that as the accumulation of agent interactions [x] increase [n] in a human social system; the likelihood of reliably obtaining quantitative meaning from these interactions also increases [x + n]. Conversely, the likelihood of obtaining qualitative meaning from an increase in traditional [e.g. chemical system] interactions also increases (Prigogine, 1977; Plowman et al. 2007).

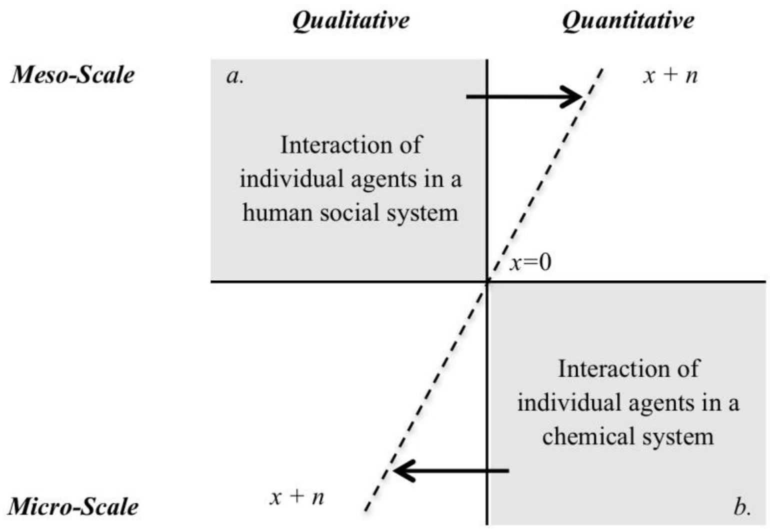


Figure 2.4 Agent Interaction Logic and Instrumental Reliability

Note: For illustrative purposes, the diagram has been constructed from in text references to cross-disciplinary applications of Marion (2008), Anderson (1999), Plowman et al. (2007) and McKelvey (1999). Arrows indicate the increased probability of deriving quantitative/qualitative meaning from observations of increasing agent interactions denoted 'x' [in respective quadrants 'a' and 'b'] and increasing by a given amount 'n'. It is noted that the diagram is provided for illustrative purposes, with hypothetical values.

The traditional understanding of interacting chemical agents in a complex system, such as Hydrogen and Oxygen in convection exhibit quantitatively observable behaviours, and when under micro-scale analysis exhibit relatively predictable patterns of behaviour (Prigogine, 1977; Knox, et al. 1994). The abstraction of the same theory to social sciences demands a different understanding of agent interaction, in consideration of the qualitative nature of interaction and the co-construction and disparate interpretations of its use, meaning and output (Blumer 1969; Corbin & Strauss, 2008; Anderson, 1999).

The purpose of the diagram at Figure 2.4 is to demonstrate the critical differences in deriving meaning of phenomena identified using similar terms, but with contrasting measurement instruments and epistemological foundations. Quantitatively observable phenomena in one field may be qualitatively observable in another. The diagram also signifies [direction of arrows] the potential for mutual contributions between disciplines as methodological applications and aggregate meanings are derived of the data (Plowman et al. 2007). The importance of recognising the implications, risks and opportunities of an operationalised theoretical framework constructed for the purposes of human social interaction are further elaborated upon at Section 2.5.

2.3 From Parts to the Whole

2.3.1 History and Development of Complexity Theory

The study of complex systems is a diverse field of inquiry that has arisen through the confluence of a variety of ideas and constructs, generally referred to as complexity theory (Goldstein, 2008). The idea of systems comprised of interacting components that are coordinated across their parts and boundaries can be traced back to a range of classical and ancient philosophies (Goldstein, 2008). More recent study of complex systems is punctuated by three distinct waves: (a) pre & post WWI Holism and Gestalt Theories, (b) post WWII Cybernetics and General Systems Theories, and (c) the gradual emergence of complexity constructs from the late 1960s (see Table 2.4).

Table 2.4 The Evolution of Modern Complexity Theory

Chronology [circa]	*Major Theoretical Developments*	*Key Propositions*
Scientific Revolution (16-17C)	Major developments in physics, astronomy, biology, medicine and chemistry	The 'scientific method' of empirical analysis and hypothesis testing
a. 1910s – 1940s (pre & post WWI)	Holism and Gestalt Theories	Natural systems viewed as wholes, more than the sum of their parts, totality, non-reductionism, non-structuralism, interpretation, form

		generating, especially in reference to the theory of mind and brain.
b. 1940s – 1960s (post WWII)	Cybernetics General Systems Theory	Communication and control, open systems, feedback loops, interconnectedness, coordination, complex systems, requisite variety, systems thinking
c. Late 1960s +	Non-Linear Dynamics Chaos Theory Catastrophe Theory Swarm Theory Dissipative Structures Emergent Self-Organisation	Self-organisation, autopoiesis, dynamic interactionism, far from equilibrium states, evolving adapting systems of interacting agents, stabilising feedback, collective intelligence, coevolution
2010s and beyond	Modern Complexity Theory Developing Theories	Operationalisation of theoretical frameworks and application in social and organisational systems

Source: Adapted from Goldstein (1999), Anderson (1999), Lichtenstein & Plowman (2008), Dreyfus (1978), Capra (1996).

It is relevant to note in its historical context, a move toward holistic thinking was a remarkable yet gradual transformation on scientific and sociological worldviews. The main thrust of each of the key theories contributing to the current understanding of emergent self-organisation are elaborated on at the following section. The Aristotelian philosophy that dominated sixteenth and seventeenth centuries was radically changed with the arrival of the scientific revolution of Descartes, Galileo, Bacon, and Newton laying the foundations for modern science (Capra, 1996). In addition to placing the Earth at the 'centre of the universe' [now defunct], defining the laws of gravity, and the existence of atoms, the core of the scientific movement was a revolution in the advancement of the scientific method. During this period, Cartesian methodology largely consisted of understanding complex systems through the analysis of their component parts (Capra, 1996).

2.3.1.1 First wave of inquiry

The first wave of inquiry came in the years following WWI as interest grew in gestalt and holism theories, encouraging a greater tendency to view natural systems as wholes, more than the sum of their parts, and that cannot be comprehensively understood through reduction and analysis of individual component parts. Gestalt is from the German language, meaning ‘form’ or ‘shape’ [especially organic] and is used to refer to wholeness. In reference to Gestalt psychology, and its later development into a form of psychoanalysis and therapy, gestalt is a non-structuralist, existential and holistic theory of mind and brain (Henle, 1975). An excerpt from one of the pioneers of Gestalt psychology, Wertheimer (1900) may shed further light:

> Gestalt theory will not be satisfied with … a simple dichotomy of science and life … of breaking up complexes into their component elements … to reduce to pieces and piecewise relations. The fundamental ‘formula’ of Gestalt theory might be expressed this way: there are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole. It is the hope of Gestalt theory to determine the nature of such wholes. (Wertheimer, 1900).

Many developments in later theory can be inferred from early thinking in gestalt, including references to self-organisation. However, the concept of emergence as an observable behaviour in natural or chemical systems did not reach maturity until over fifty years later, and do not appear to have been methodologically aided by gestalt theories. The mathematical and scientific groundwork for understanding the intricacy of self-organisation had not yet been developed. The ideas of gestalt may have served as catalyst for further research and popularised challenges to scientific assumptions of reductionism that gradually progressed in the years following the First World War.

2.3.1.2 Second wave of inquiry

A second wave of major developments in science and technology occurred shortly after WWII, fuelled by the success of war-time inspired feedback and control devices, such as electrical networks, mechanical systems, and the hastening development of computers (Anderson, 1999). Both Cybernetics and General Systems Theory influenced an intellectual revolution that generated a new understanding of organisations in the 1960s. Cybernetics and General Systems Theory emerged in close

chronology and it could be said may have mutually influenced one another's development (Skyttner, 1996). The ideas of Cybernetics were firmly established as a discipline by mathematician Norbert Weiner [1894-1964] in parallel to the notions of General Systems Theory by biologist Karl Ludwig von Bertalanffy [1901-1972] (Skyttner, 1996; Anderson, 1999; Goldstein, 2008).
Classical Cybernetics and General Systems Theory share similar territory yet differ considerably in that the former is concerned with feedback and communication for the purposes of control (Plowman & Duchon, 2008), whereas systems theory has a more 'ecological' tenor, focused on interdependency of behaviours and relationships among individuals in a fundamentally unpredictable environment, in which it is highly improbable to achieve absolute control (Goldstein, 2008; Skyttner, 1996). Systems thinking is still in wide use in social and organisational sciences, such as ecology, education and management, helped through popular press articles such as The Fifth Discipline by Peter Senge (1990), albeit with continuing refinement (Flood, 1999). A common feature for both Cybernetic and General Systems Theory viewpoints is that they pose enormously valuable principles of practical application that are still in use today, such as the principles of feedback and control in automated mechanical systems, or the broad application of systems thinking in education and management.

2.3.1.3 Third wave of inquiry

The third wave of inquiry arrived in the late 1960s, as a new understanding of far from equilibrium dynamics emerged (Simon, 1996; Anderson, 1999). Catastrophe theory demonstrated how a small initial change can send a system to different equilibriums; non-linear dynamical systems theory (and later chaos theory) illustrated the curvilinearity of functions and equations when graphed, in addition to core mathematical constructs of complexity, employing the use of attractors, phase space, bifurcation and fractals to model complex behaviour (Goldstein, 2008).

While rich and varied, the superstructure of complexity research across its many disciplines has not reached a universal synthesis (Moldoveanu & Bauer, 2004; Goldstein, 2008). There is no complete history of complexity theory, as the concepts cut across so many interdisciplinary lines and assorted fields, it would be beyond a lifetime's work to compile. However, the underlying principles of various methods and theories have formed part of the synthesis known as complex adaptive systems (Schneider & Somers, 2006; Goldstein, 2008). A complex adaptive system is a system of complexly interacting, interdependent parts that though the processes of individual agent interaction, patterns of behaviour emerge (Anderson, 1999; Marion, 2008; Schneider & Somers, 2004). The shared emphasis of Non-Linear Dynamical Systems Theory, Cybernetics and General Systems Theory is a set of equations to model the movement of 'deterministic dynamical systems' (Anderson, 1999). Complex adaptive systems however, provide a view of complex phenomena characterised by order generating behaviours at successive levels of aggregation in a complex system (Anderson, 1999; Plowman et al., 2007). The term complex adaptive system is often used interchangeably with complexity theory, particularly to refer to the boundaries of the system under study.

Ilya Prigogine, a Belgian physical chemist delivered a definitive insight into the tendency for self-made order to emerge and be sustained at far from equilibrium states. Prigogine argued this process explains the creation of perpetual novelty across nature (Prigogine, 1997). Dissipation in its traditional sense refers to the release of energy and consequent entropy (Marion, 2008). Despite the common association between entropy and the deterioration of order, Prigogine uncovered the mechanisms by which order emerges through the dissipation of energy, rather than its accumulation – non-equilibrium thermodynamics. Prigogine referred to these new chemical forms as dissipative structures, found at far from equilibrium states. Common examples of dissipative structure can be seen with the naked eye, for instance the heating of oil in a frypan causes an arising formation of cells.

Prigogine's landmark theorem, on the concept of emergent self-organisation is still held as the anchor-point phenomenon of complex systems, the antecedent conditions (or sequences) of which are of significant and cross-disciplinary research interest (Anderson, 1999; Chiles et al. 2004; Plowman & Duchon, 2008). Following its rich and varied origins, the idea for a theory of emergence ties together a range of related ideas and system principles. The following section provides a detailed chronology of the development of these ideas, and explanation of how they relate to self-organisation in human social systems.

2.3.2 Chronology of the Main Ideas for a Theory of Emergence

Emergence can be described as ‘the arising of novel and coherent structures, patterns, and properties during the process of self-organisation in complex systems’ (Goldstein, 1999). Order emerges as a result of the interplay between agents within a complex system, with those agents and the system itself taking on a range of meanings depending on the field in which they apply. Potentially for this reason, the idea of emergence has an unclear status in the complexity sciences. This section briefly outlines the history and development of emergence to better understand how and why this remains the case.

As explained at Section 2.2, complexity theory is a diverse area of research, bringing together a range of ideas and constructs to understand and study complex systems. While there is no single unifying ‘theory’ of complexity or definitive parameters, there are certain components that are shared, the most notable of which is the concept of emergent self-organisation (Chiles et al., 2004).

The origins of emergence traverse a variety of fields, a number of which are outside the physical and natural sciences. This includes philosophical and scientific theories and beliefs related to systems, boundaries and interconnectedness, and uncertainty. The origins of the *idea* of emergence refer to coherent patterns and structure coming about as a result of the dynamics of large and complex system dynamics – such as labour markets, market economies and the social rules that govern society (Durkheim, 1997; A. Smith, 1776). The gestation of these ideas into concrete process has continued for more than 100 years. Despite Ablowitz (1939) compelling article declaring existence of a theory of emergence, the necessary groundwork to support such a claim remains underdeveloped even today.

The age of understanding for the nascent theory of emergence occurred post-WWII in the exploration of a range of related ideas most remarkably in the work of General Systems Theory and Cybernetics, in particular through the work of Ashby (1956); von Bertalanffy (1951); Weiner (1948). Many of the underlying principles for emergence are derived of the interrelatedness of general systems, feedback, uncertainty and requisite variety laws of Cybernetics which have been combined within their broader umbrella of complexity theory (Capra, 1996). The ecological basis of the ideas of

General Systems Theory are linked to the evolution of plants and animals, with reference to the adaptive nature in which natural systems rebalance or change over time in accord with environmental conditions, constraints or challenges (Capra, 1996).
By the 1960s and 1970s, a set of general principles and common ideas were beginning to appear consistently across most research regarding emergence within complex systems. With many of the concepts originating in Cybernetics and General Systems Theory, the combination of these principles in a new science of complexity effectively linked the idea of feedback loops, communication networks, uncertainty and novelty in an ecosystem of agents that generate order without a central controller. These new ideas gave way to a reconceptualisation of organisational theory, drawing on concepts of uncertainty, self-organisation, open systems, chaos, feedback loops and humans as agents within a complex adaptive system (Anderson, 1999; Marion, 1999; D. A. Plowman & Duchon, 2008), elaborated on as follows.

Sensitivity to initial conditions – made famous by the flap of the butterfly wings, Lorenz (1963) work on non-deterministic patterns and effects of small initial changes in conditions in weather pattern modelling continues to be an essential characteristic of complex systems. The concept is related to a non-deterministic universe, in which it is impossible to completely predict future states in complex systems due to sensitivity to initial conditions, amplification of small change and reinforcing feedback (D. A. Plowman & Duchon, 2008). In a social science context, of particular interest is not only the sensitivity to the external environment but the function of unpredictability that is a product of the dynamic interactions between agents *within* the system (organisation). In this sense, a complex organisation is both the generator and the mechanism by which new order emerges, adapting to its own internal conditions, not only those of the outside world (D. A. Plowman & Duchon, 2008).

Darkness principle – shared by Cybernetics and General Systems Theory, the darkness principle suggests that no complex system can be known completely and is therefore imbued with the potential for uncertain outcomes (Clemson, 1984). The Darkness Principle is also related to the Law of Requisite Variety from Cybernetics, in which the variety of the controller must be at least as great as the system which is being controlled (Weiner, 1948).

Self-organisation – the term existed long before its practical application in complexity theory and management, however its meaning has evolved from simply describing the existence of emergent systems (Durkheim, 1997; Wertheimer, 1900) or self-regulation (A. Smith, 1776). The meaning of the term deepened to apply an understanding of spontaneous self-generated order which may also extend to the making of a system and our observations of it (Capra, 1996; Nicolis & Prigogine, 1977).

Far from equilibrium – while General Systems Theory provided the notion that a system tends toward homeostasis or equilibrium, it is the far from equilibrium or edge of chaos conditions that cultivate dynamics for emergent self-organisation. The far from equilibrium idea is the basis for Chaos Theory, conceptually related to the Second Law of Thermodynamics and is otherwise not inconsistent with the notions of General Systems Theory (Gleick, 1988; Skyttner, 1996).

Reinforcing feedback – following the success of post-WWII electronic and mechanical systems, the concept of feedback in Cybernetic Theory is one of its most enduring foundations (Weiner, 1954). It is the presence of feedback loops that provide the recursive interaction, amplification of small change, and stabilising mechanisms that enable coherent structure to emerge. Agents within a system are connected via feedback loops, the absence of which is most likely a system incapable of adaptive behaviour (Kauffman, 1993).

Non-linear dynamics – in addition to the feedback loops that transmit self-reinforcing feedback, complex systems are characterised as non-linear because agents within the system are constantly interacting through a dynamic web of feedback which can occur in a far from stable environment (Stacey, 1995). 'As complex adaptive systems, the disequilibrium-learning-feedback cycle in organisations at the local level creates a kind of perpetual novelty' (D. A. Plowman & Duchon, 2008). As individuals and groups interact, exchange knowledge and information, new thinking becomes changed action, creating further interactions and adaptations, altering the organisation in unexpected ways and calling into question traditional views of management and structure (D. A. Plowman & Duchon, 2008).

Agents with schemata – a complex system consists of heterogeneous agents that operate according to a set of simple rules (Kauffman, 1993). While the schemata (or malleable rules) may emerge and change, they are a building block for the stabilisation and holding shape of a new structure (Anderson, 1999).

While agents within the system by no means need to be prisoners of certain schemata, total abstraction at every level on every interaction is not likely to be a system with observable patterns of order. Complexity theory itself does not imply that every system at the edge of chaos will reform in a new coherent structure, rather it may eventuate that the system disintegrates itself entirely and the building blocks are jettisoned into a new system, reconfigured, damaged or destroyed. Not all systems have the capacity to evolve (Levie & Lichtenstein, 2010; Schneider & Somers, 2006), noting however that such studies on the disintegration or emergent dysfunction of complex organisational systems remains limited despite being earmarked by A. Y. Lewin and Volberda (1999) as an important focal point for future research.

Perpetual novelty – perhaps one of the most fascinating ideas of emergence, and in light of all other principles, is the enduring capacity for the spontaneous generation of new patterns, structure, order or form as a result of dynamic interplay at lower levels within a complex system (Prigogine & Stengers, 1984).

The use of the term emergence is to an extent a construct to describe phenomena that display a certain kind of behaviour in which macro-level patterns of order are observed from interactions at a lower level in the system (Anderson, 1999). The existence of macro-level patterns of behaviour is not a reason in itself not to unpack the mechanisms by which that order has been created. Without a concrete theory of emergence, the idea itself operates merely as a provisional construct or descriptive term, shorthand that points to the patterns and emergent structures that come about as a result of certain environmental conditions. Conversely, if we understand complex organisations to be non-linear and unpredictable systems with the potential to self-generate order in states of near chaos – a solely reductionist approach to researching them is likely to produce incomplete results (Stacey, 1995).

Computational complexity is considered a feature in the development of complexity and emergence in part due to the link with Information Theory and early forms of artificial intelligence, cellular automata and complex networks (Abramson, 2011; Capra, 1996; Gleick, 2011). Turing's work on extending computational capabilities and early forms of artificial intelligence further prompted questions about what the limitations are of computers in society (Hopcroft, Motwani, & Ullman, 2007). A frequently cited application of computational theory is the mathematical model of *cellular automata* used to examine self-organisation in statistical mechanics (Wolfram, 1983). Each of the automata (a simply programmed mathematical and computer simulation), tend to generate 'self-similar patterns with fractal dimensions', also exhibiting novelty in structure, irreversibility and in essence a mathematical extrapolation self-organising phenomena (Wolfram, 1983).

While the mathematical model of self-organisation demonstrates the emergence of novel structures in computer simulations, (Nicolis & Prigogine, 1977) effectively described the major processes of emergence, as observed in a naturally occurring chemical system. The Prigogine theorem of dissipative structures sparked a new and empirically sound movement in complexity and emergence, by uncovering the fundamental processes of organisation as observed within a chemical system (Prigogine & Stengers, 1984). The model refers to emergence as a dissipative structure, found to occur at the edge of chaos, as a result of four key mechanisms – disequilibrium state, amplification of small change, self-organisation / recombination and stabilising / positive feedback (Prigogine, 1997). The dissipative structures theory considers these four processes to be the baseline mechanisms by which emergent order is generated in complex systems, consequently the theory is directly applied to all manner of disciplines and sciences, including social science and management (Lichtenstein & Plowman, 2009b), albeit without a conceptual bridge or recursively validated empirical translation (Yezdani et al., 2015).

The 1990s and beyond has marked a broad expansion in the application of complexity theory and emergence to the world of organisation science, in several key topics as illustrated at Figure 2.5, Table 2.5 and Figure 2.6. Sustaining its reference to Cybernetics and General Systems Theories, the modern application of complexity principles to organisations, social systems, and management has taken many forms. For some, this 'new' science marks the beginning of a new era in leadership and management were traditional notions of hierarchical organisational structure and control are recast through the complexity lens (Marion, 2008). A significant movement in the social sciences has been the establishment of Complexity Leadership Theory, proposing a new style of leadership and organisation based on the principles of complexity and self-organisation.

The empirical research that underpins Complexity Leadership Theory is referred to in several parts of this study, as it often provides a contemporary application of complexity principles with reference to fundamental processes of emergence in human social systems, albeit with a focus on the agents of leadership. If leadership is to be understood as a relational process (Lichtenstein et al., 2006), with the carriage of influence between agents within a system is at its core, then the process of leadership, regardless of who is enacting it, is of relevance to both the study of emergence in complex organisations and the pursuit or understanding of leadership as a function within those environments.

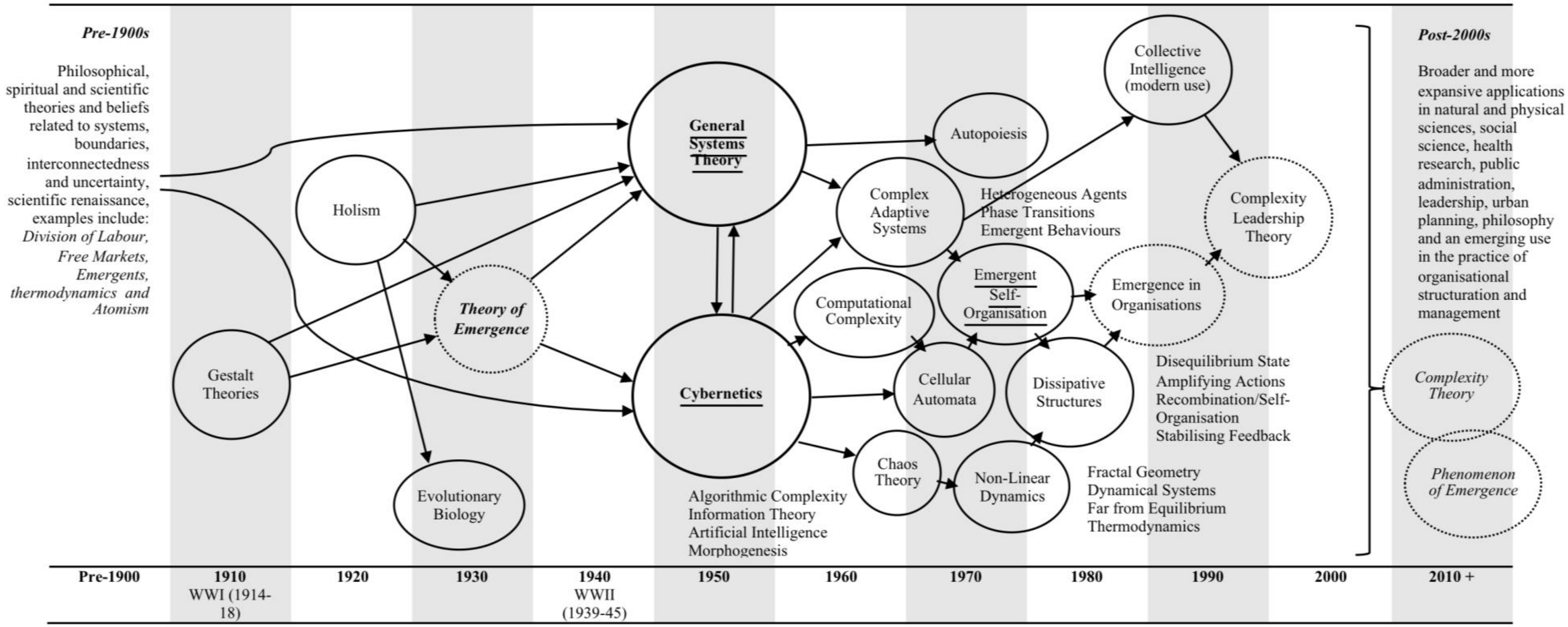


Figure 2.5 **Chronology of the Study of Emergent Self-Organisation – Literature Map**

Source: constructed from a review of references cited in Table 2.5.

Table 2.5 Chronology of the Study of Emergent Self-Organisation – Reference Table

Pre-1900	1910 WWI (1914-18)	1920	1930	1940 WWII (1939-45)	1950	1960	1970	1980	1990	2000	2010 +
Cooper (2017); Descartes, Gaukroger, and ebrary (1998); Durkheim (1997); Hutchins (2015); Palmer (2012); Smith (1776); Van de Vijver, Van Speybroeck, and Vandevyvere (2003)	Henle (1975); Wertheimer (1900)	Dreyfus (1980); Goldstein (1999)	R. Ablowitz (1939); J. Goldstein (1999)	Gleick (2011); Weiner (1948, 1954)	Ashby (1956); Beer (1972); Boulding (1956); J. Goldstein (1999); Jeffrey Goldstein (2004); Kast (1972); Plowman and Duchon (2008); Rowe (2010); Skyttner (1996); Turing (1952); Von Bertalanffy (1951)	Ashby (1962); Choi, Dooley, and Rungtusanatham (2001); Holland (2006); Levy (1994); Lichtenstein (2000); Lorenz (1996); Polacek, Gianetto, Khashanah, and Verma (2012); Prietula and Carley (1994); Prigogine (1997); Prigogine and Stengers (1984); Stacey (1995)	Kabamba, Owens, and Ulsoy (2011); MacIntosh (1999); Maturana and Varela (1980); Nicolis and Prigogine (1977); Podgórski (2010); Van de Vijver et al. (2003)	MacIntosh (1999); Nicolis and Prigogine (1977); Reynolds (1987)	Anderson (1999); Anderson, Meyer, Eisenhardt, Carley, and Pettigrew (1999); Antonelli (1999); Bedau (1997); Brown and Eisenhardt (1997); Capra (1996); Drazin (1992); Kauffman (1993); Levy (1994); Lewin (1999); Lorenz (1996); MacIntosh (1999); Maguire and McKelvey (1999); Marion (1999); McKelvey (1999); Mintzberg (1994); Prigogine (1997); Senge (1990); Skyttner (1996); Stacey (1995); Thietart and Forgues (1995)	Conveney (2003); Hazy (2008); Lichtenstein et al. (2006); Marion (2008); Marion and Uhl-Bien (2009); McKelvey (2008); Plowman and Duchon (2008); Reynolds (1987); Schneider and Somers (2006); Uhl-Bien, Marion, and McKelvey (2007)	Reuben Ablowitz and Goldstein (2010); Alberti, Sugden, and Tsutsui (2012); Bernstein, Bunch, and Lee (2016); Bruce, Vlatka, and Chris (2010); Daft (2010); Espinosa, Cardoso, Arcaute, and Christensen (2011); Fagerberg and Sapprasert (2011); Garud (2011); Ghobadi and D'Ambra (2012); Gleick (2011); Greenwood, Raynard, Kodeih, Micelotta, and Lounsbury (2011); Houglum (2012); Keller, Desouza, and Lin (2010); Lewis (2015); Podgórski (2010); Polacek et al. (2012); Rowe (2010); Swanson and Zhang (2011); Yezdani, Poropat, and Sanzogni (2013)

Source: constructed from a review of references listed in the Table.

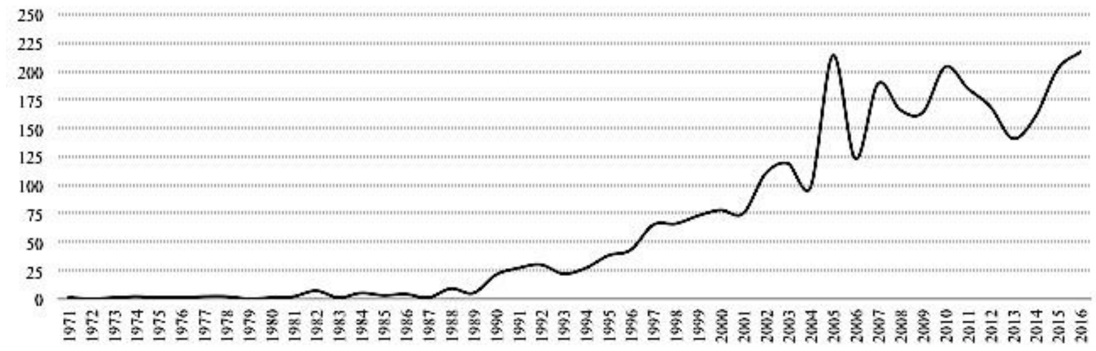


Figure 2.6 Bibliometric Data on 'Complexity Theory' Publications

Source: Thompson Routers *Web of Science* Database

2.3.3 Cybernetics

Following the end of WWII, a new intellectual movement combined physics, engineering, mathematics, and psychology to form the transdisciplinary field of Cybernetics (Capra, 1996). In parallel with another major scientific movement, General Systems Theory, Cybernetics aimed to provide a unified treatment on the mechanisms of communication and control in complex systems. Attributing his work primarily to Gibbs (1902) elementary principles in statistical mechanics, Weiner described the field of Cybernetics as 'the scientific study of control and communication in the animal and the machine' (Weiner, 1948). The theory concerns communication, as a means of exercising control over machinery and society.

> As entropy increases, the universe, and all closed systems in the universe tend naturally to deteriorate and lose their distinctiveness, to move from the least to the most probable state, from a state of organisation and differentiation in which distinctions and forms exist, to a state of chaos and sameness. In Gibbs' universe order is least probable, chaos most probable. But while the universe as a whole, if indeed there is a whole universe, tends to run down, there are local enclaves whose direction seems opposed to that of the universe at large and in which there is a limited and temporary tendency for organisation to increase. Life finds its home in some of these enclaves. It is with this point of view at its core that the new science of Cybernetics began its development. (Weiner, 1954).

Without a word to describe such a theory, Weiner invented one – derived of the Greek word *kubernetes* (meaning 'steersman'), known today as Cybernetics (Weiner, 1954). Following from his earlier and incomplete work on the ramifications of the *theory of messages,* Weiner refers frequently to the governing principles within thermodynamics and entropy. Weiner fused the laws of physics, mathematical models, engineering, and psychology to form a new set of principles that have made great and longstanding contributions to the design and control of mechanical systems and a foundation for the study of complex systems (Capra, 1996; Goldstein, 1999).

While not entirely addressing the issue, Weiner navigates extremely close to a solution on the idea of energy transfer between humans, 'The transfer of information cannot take place without a certain expenditure of energy, so that there is no sharp boundary between energetic coupling and informational coupling.' (Weiner, 1954). It could be assumed the necessary coupling of information and energy is sufficient to transmit the idea of dissipative structures throughout all other systems, however, the generalisation of this result to human social systems requires empirical validation.

Cybernetic systems in their classical sense are component systems controlled by a central point of reference through circular and causal feedback loops (Capra, 1996). The application of a Cybernetic viewpoint to living systems employs the use of analogies with physical systems, such as machines, focusing on the specification, design, coordination, authority and decision making structures that serve to achieve intended goals (Plowman & Duchon, 2008). Early versions of self-organisation are found in Cybernetics to describe an artificially created, goal oriented, self-regulating system (Ashby, 1956; Goldstein, 2008; Skyttner, 2008).

The operation of Cybernetic systems can generally be described as the achievement of predetermined goals, through the use of feedback about current and desired states and the enacting of a finite set of alternatives in response to remedy the 'gap' between states (Goldstein, 2008). Despite its military and mechanistic origin, Cybernetics provided a range of fundamental principles that continue to inform mathematics, engineering, and complexity sciences, including the principle of uncertainty (darkness), requisite variety and the important causal role of stabilising feedback in the emergence of pattern and form (Clemson, 1984).

Cybernetic principles are widely used in mechanical, electronic and artificial systems, a simple example of which is the thermostat or basic feedback amplifier. Figure 2.7 illustrates an idealised simple feedback system that gains positive and/or negative feedback on the state (e.g. temperature) of an environment and responds accordingly with a set of predetermined rules, such as switching cooling or heating devices on or off; the desired effect of which is homeostasis, within shifting conditions of the external environment. Feedback and amplification models are far more complex in the practice of contemporary device modelling, requiring expertise in the field to interpret – a simple model is sufficient to demonstrate the underlying principles (Palumbo, Pennisi, & Ebooks, 2002).

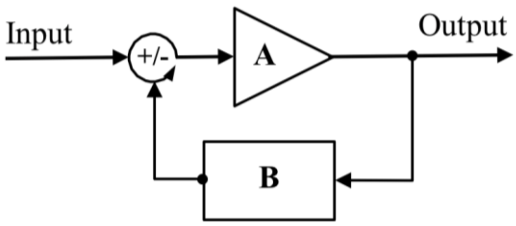


Figure 2.7 Idealised Simple Feedback System

Notes: where '+/-' is the feedback type/direction, A = Amplification, B = Feedback.
Source: Palumbo et al. (2002).

Plowman & Duchon (2008) argue that due to the oversimplification of the feedback-control metaphor, Cybernetic views of management are based on an unfounded assumption of certainty and artificial control. Further criticism toward Cybernetics points to the misuse of the analogy of physical systems, such as machines or electrical networks, to describe the functioning of a variety of natural systems such as the human brain, society, governments and organisations (Skyttner, 1996; Goldstein, 2008; Plowman & Duchon, 2008). The metaphor of the organisation as the machine-like control structure was a pervasive concept during the pre and post-WWII era, of process engineering, and remains a cornerstone of modern corporate structure. Cybernetic views have not been eliminated from organisational theory and pervade much of the discussion on the role and function of management and leadership in its various forms – to plan, lead, organise and control (Plowman & Duchon, 2008).

Traditional forms of management or leadership are arguably Cybernetic in origin. However, remain tied to metaphorical devices that present limitations when applied to the non-mechanical world of social behaviour (Plowman & Duchon, 2008). Key criticisms mounted against Cybernetic or 'traditional' forms of management argue that notions of certainty, communication and control are insufficient to comprehensively understand the unpredictable and complex nature of organisational behaviour and that of the surrounding environment (Plowman & Duchon, 2008; Goldstein, 2008). Nonetheless, many organisations appear to have remained in the Cybernetic era, such as command-control structures of many public and military organisations (Plowman & Duchon, 2008). The colloquial term 'just another cog in the wheel' may well reflect this sentiment within a bureaucratic structural context. However, such structures are a human projection and may not represent the underlying behaviour of individuals and groups within and around the system, such as emergent patterns that occur despite a rigid organisational form (Marion, 2008).

A key element of Cybernetics that remains a core principle of complexity and General Systems Theory, also known as the First Law of Cybernetics – is the *Law of Requisite Variety*, formulated by Ashby (1958). Requisite variety proposes that the control of systems can only be achieved 'if the variety of the controller is as least as great as the variety of the situation to be controlled'. The idea is enmeshed with the concept of information – the mechanism for exerting and responding, and thereby exercising control (Ashby, 1958). In an increasingly complex and rapidly changing world, it is improbable that any single organisational actor can either predict or directly control all elements at play in an open system (Richardson, 2004). Therefore, understanding the implications of collective behaviour is a critical factor in 21st century business and management practice (Goldstein, 2008; Plowman & Duchon, 2008).

2.3.4 General Systems Theory

The essence of General Systems Theory can be summarised as an approach that seeks to understand individuals as interacting parts of a whole system (Skyttner, 1996). Systems theory adopts the important concept of feedback loops and communication among agents, but does not place any single agent at a central point of control

(Goldstein, 2008). The modern application of General Systems Theory principles is known as 'systems thinking', made widely known in popular management literature through the work of Senge (1990). The origin constructs of gestalts and holism are carried into systems thinking, synonymous with an ecological worldview, which is unsurprising given its origins in botany (von Bertalanffy, 1951). Systems thinking emphasises the idea 'of living organisms as integrated wholes' (Capra, 1996).

Systems thinking provides a view of the essential properties of an organism or living system as being the properties of the whole, arising from interactions between the parts – but from which the system is inseparable (Skyttner, 1996). The emergence of a systems view marked a profound revolution in scientific thought and method. However, this is not solely attributed to the work of von Bertalanffy (1951) and his attempts to form a new unity of science. Despite the earlier works of Ablowitz (1939) with its many predecessors, the groundwork of a revolution in thought existed – but the conceptual foundations, method and instruments of that empirical work remained under development.

In this way, the ideas of systems thinking made known by von Bertalanffy (1951) were profound in proposing a fundamental shortcoming of the Cartesian paradigm of reductionist scientific analysis (Capra, 1996). Systems thinking applies meaning to phenomena by placing them within their contextual setting of a larger system, in this way the importance of the relationship between the parts and the whole is reversed.

> In the systems approach, the properties of the parts can be understood only form the organisation of the whole. Accordingly, systems thinking does not concentrate on basic building blocks but rather on the basic principles of organisation. (Capra, 1996).

At the height of its early development as an interdisciplinary framework, some general systems theorists proposed that its devices were '…of almost universal significance for all disciplines' (Boulding, 1956). In a period where the open systems view of organisations was gaining prominence, Boulding (1956)proposed a hierarchy of nine levels of systems – based on their relative complexity, recreated and adapted at Table 2.6.

Table 2.6 Boulding's Scale of System Complexity

Level	*System*	*Definition*
1	Frameworks	Static structures
2	Clockworks	Simple dynamic systems with predetermined, necessary motions
3	Control systems	Cybernetic systems which maintain given equilibrium within limits
4	Open systems	Self-maintaining structures in which life differentiates itself from non-life
5	Blueprinted growth systems	Systems with a division of labour among cells
6	Differentiated systems	Internal image systems with detailed awareness of the environment
7	Symbol processing systems	Systems of individuals acting in concert
8	Social organisations	Collections of individuals
9	Transcendental systems	Complex systems not yet imagined

Source: Adapted from Boulding (1956) In Goldstein (2008).

Using Boulding's scale of system complexity (Boulding, 1956), the incongruence between the application of Cybernetic viewpoints (level 3) and the complexity of social organisation (level 8) is clearly depicted. The open systems movement of General Systems Theory adopted a focus on relationships, structure, differentiation, cyclicality and interdependence (Schneider & Somers, 2006). General Systems Theory adopted a principle of totality (similar to Gestalt Theory) in which the whole system could not be described only by a summation of its parts (Schneider & Somers, 2006). Gestalt psychologists, including Wertheimer considered irreducible wholes as a product of and inseparable phenomenon of perception (Wertheimer, 1900). The idea of pattern and emergence are present in Gestalt thinking, integrating parts into irreducible whole systems with new qualities and meaning and as a protest against scientific fragmentation and mechanistic schools of thought (Capra, 1996). Gestalt thinking however, did not deliver a modern and comprehensive understanding of emergence; rather it progressed as an ontological notion to explain larger wholes, without being overly concerned with an empirical connection to lower level system behaviours (Capra, 1996; Wertheimer, 1900).

Originally published in 1950, von Bertalanffy (2008) attempted to enjoin the principles of General Systems Theory to a new and complete unity of sciences, as a moderating and governing device across all its disciplines. Methodologically, von Bertalanffy acknowledged the lack of, and need for a means by which principles can be transferred from one field to another, at the same time formulating exact ‘criteria’ to protect the field from superficial analogies (von Bertalanffy, 2008).

> The central position of the concept of wholeness in biology, psychology, sociology and other sciences is generally acknowledged. What is meant by this concept is indicated by expressions such as 'system,' 'gestalt,' 'organism,' 'interaction,' 'the whole is more than the sum of its parts' and the like. However, these concepts have often been misused, and they are of a vague and somewhat mystical character. The exact scientist therefore is inclined to look at these conceptions with justified mistrust. Thus it seems necessary to formulate these conceptions in an exact language. General System Theory is a new scientific doctrine of 'wholeness' – a notion that has been hitherto considered vague, muddled and metaphysical. (von Bertalanffy, 2008).

General Systems Theory had a sweeping impact on management and organisational thinking from the 1950s onward. However, the ecologically driven origins of General Systems Theory later received criticism in relation to troublesome analogy of organisations to organisms (Katz & Kahn, 1978). Numerous principles which are prominent in General Systems Theory continue to inform complexity theory, including the principles of hierarchy, darkness, flowing balance, and complementarity (Adams, Hester, Bradley, Meyers, & Keating, 2014), briefly explained as follows.

Hierarchy Principle – a further feature in complex systems is the tendency for systems to self-organise into hierarchies (Richardson, 2004). The hierarchy principle is described by Skyttner (1996) as follows: ‘Complex natural phenomena are organised in hierarchies wherein each level is made up of several integrated systems.’ Hence, complex systems are often ‘nested’ (systems within systems), the levels of which co-evolve and are inseparable as a complete whole – but require understanding at successive level of analysis (Lichtenstein & Plowman, 2009b). While systems thinking focuses on the relationship between components of a system and across successive layers, it is also taken that a nested hierarchy of successively greater macro levels can give rise to multiple levels of emergence (Crutchfield, 2008). General Systems Theory added this idea to complexity theory, however the specific relationship between levels in a complete hierarchy of systems is an existential problem for a theory of emergence (Crutchfield, 2008).

The *Darkness Principle* applied within General Systems Theory states that no system can be known in its entirety; therefore there is no hope of absolute predictability (Skyttner, 1996). The darkness principle has arrived at complexity from a range of angles, among them is the understanding that unpredictability changes our assumption that any one individual can predict or determine future states and that complex systems are comprised of co-evolving agents that are mutually responsible for the creation of new organisational forms, either consciously or not (Goldstein, 2008). Further, networks of individuals such as social networks are potentially capable of arriving at [undetermined] future states of their own accord, through the interactions of individuals pursuing their own agenda (Marion & Uhl-Bien, 2001). A more complete understanding of whether self-organised social systems are beneficial from an organisational point of view is yet to be determined (Burnes, 2005).

Fliessgleichgewicht – given certain conditions, and despite constant and continuous change, inflow and outflow of materials, open systems may attain a steady state (von Bertalanffy, 2008). Since there was no equivalent expression for this in German, the term *Fliessgleichgewicht* was introduced, meaning ‘flowing balance’ (Capra, 1996). von Bertalanffy used this term to address the problem of describing open systems in a steady state far from equilibrium (Capra, 1996). Radically, von Bertalanffy hypothesised the Second Law of Thermodynamics (of ever increasing entropy or disorder) may not apply to open systems and entropy may in fact decrease (von Bertalanffy, 2008). Unfortunately for von Bertalanffy, it wasn’t for another 30 years that mathematical techniques to extrapolate this finding in the thermodynamics of open systems would be achieved (Capra, 1996). Nicolis and Prigogine (1977) used new techniques to re-evaluate the Second Law in their dissipative structures theorem, recasting traditional views of order, and demonstrating a novel emergence of order (via recombination) at far from equilibrium states and the stabilisation of those systems through continuous feedback.

Finally, the *Complementarity Law* asserts that two or more points of view on a given scenario may coexist and provide observations that are neither entirely independent nor entirely compatible (Skyttner, 1996). Goldstein (2008) argues that rather than appearing to be a derivative of postmodern thinking, the law of complementarity is based on the assertion that system outcomes can be reached via different pathways and multiple internal configurations.

While von Bertalanffy to a large extent did not realise his own vision of a general and transdisciplinary science of wholeness, new conceptions of emergent order, systems thinking and the earlier principles which have been carried into modern complexity theory owe much to his pioneering literature. While the work of von Bertalanffy was extraordinary in itself, it required further evidence from mathematics to elicit meaning from the characteristic unpredictability of complex systems and non-linear dynamics. Drawing on the mathematical principles developed the century prior, chaos theory and non-linear dynamics answered this call.

2.3.5 Chaos and Non-Linear Dynamical Systems

The origins of Chaos Theory stem from the study of deterministic non-linear dynamical systems (Thietart & Forgues, 1995), largely derived of the mathematical treatments by Poincare during his work on the three-body problem in the late 1800s (positions, masses, velocities) (Poincare, 1892; Simon, 2008). Chaos Theory is a mathematical study of the non-linear dynamics of complex systems (Capra, 1996). Originally considered an intractable mathematical problem, chaotic systems have been of interest for more than a century. Poincare's methods formed the basis of topological concepts (visual models) to analyse the qualitative features of complex dynamical systems (Capra, 1996). What Poincare referred to as a problem that needed to be overcome, a 'fortuitous phenomenon' would later be referred to as sensitivity to initial conditions, where infinitesimally disturbances may give rise to radically altered trajectories (Peterson, 1993; Poincare, 1892).

While chaotic systems are deterministic (non-random), they are inherently unpredictable (Simon, 2008). Their behaviour is unpredictable due to a number of factors that characterise and describe chaotic systems: *non-linearity*, *sensitivity to* *initial conditions*, *determinism*, *instability*, and from a topological point of view – *attractors* (Adewumi, Kagamba, & Alochukwu, 2016). Non-linear dynamical methods flourished with work of Lorenz (1963) study of turbulent flows in liquids, and weather forecasting – using the analogy of the flap of a butterfly wing in Brazil to set off a tornado in Texas (Lorenz, 1972). The mathematics of non-linear dynamics made it possible to observe order in what was otherwise seen as noise, randomness – and chaos (Thietart & Forgues, 1995).

There are a range of examples to demonstrate the topological concepts of non-linear mathematics – for example, the swinging pendulum with friction. Using Cartesian coordinates, the movement of the pendulum can be plotted in a model of two dimensional phase space with its each axis labelled x = velocity, and y = angle (Capra, 1996). The topology of a *point attractor* is illustrated at Figure 2.8 – a system that tends to a fixed point, such as a pendulum with friction (Adewumi et al., 2016). As Lorenz observed more than 50 years ago, despite knowing the precise location at which the pendulum originates, and its speed and direction, its path remains unpredictable (Lorenz, 1996). Small variations in the oscillation of the object are magnified by each swing, thereby giving rise to cascading divergences and 'chaotic' behaviour, with a tendency toward a point of rest – known as an 'attractor' (Levy, 1994).

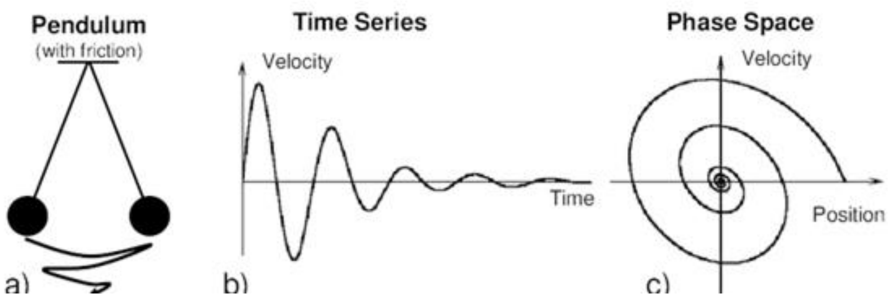


Figure 2.8 Topology of a Point Attractor

Source: open source from Hasse and Bekker (2016).

Notes: The topology of a point attractor in the form of a pendulum with friction showing: a) trajectory, b) time domain of behaviour and velocity, and c) trajectory of the pendulum in phase space.

Similarly, no coin or dice can be thrown (by a human) in precisely the same manner, each iteration is subject to slightly different conditions and increasing unpredictability, producing a more or less random outcome (Ford, 1983).

Detailed mathematical models to describe the patterns of self-organisation and order within chaotic and complex systems has been essential in validating many of the fundamental assumptions of how order emerges from non-linear and dynamic behaviours. Poincare pioneered the use of topological concepts to visualise and understand the qualitative properties of complex dynamical problems (Capra, 1996). Using mathematical techniques to craft a topological interpretation of chaotic behaviour, Poincare imagined a range of interesting topological qualities that he described as 'homoclinic tangles' in the three-body problem, or now better known as *strange attractors* (Stewart, 1990). In his original grid (reproduced below at Figure 2.9), Poincare observed the 'footprints of chaos' (Stewart, 1990).

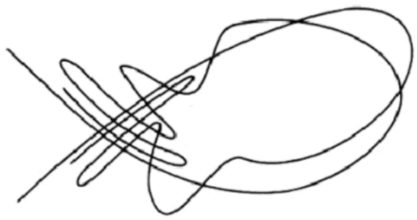


Figure 2.9 Homoclinic Tangles
Source: Stewart (1990)

Mathematical techniques to make sense of complex behaviours have enabled researchers to find order in what would otherwise appear to be noise and chaos. The earlier work of Poincare was further advanced with developments in high-speed computer processing, making possible the visualisation and execution of equations for large complex systems that were out of reach a century ago. This has also given rise to a range of attractor models, illustrated using points in phase space. Three frequent examples of attractors in chaotic systems are *point attractors* – a system that tends to a fixed point (e.g. hypothetical pendulum); *limit cycle attractor* – cyclical motion (e.g. planets); *limit torus attractor* – similar to a limit cycle, but bounded within a region (e.g. rings of Jupiter) both of which are *periodic*; and *strange attractor* – which take an irregular shape which despite its erratic motion does not display random distribution of points in phase space (e.g. weather systems, turbulent liquid flows) (Adewumi et al., 2016; Capra, 1996; Stewart, 1990). Each of these topological concepts is illustrated at Figure 2.10.

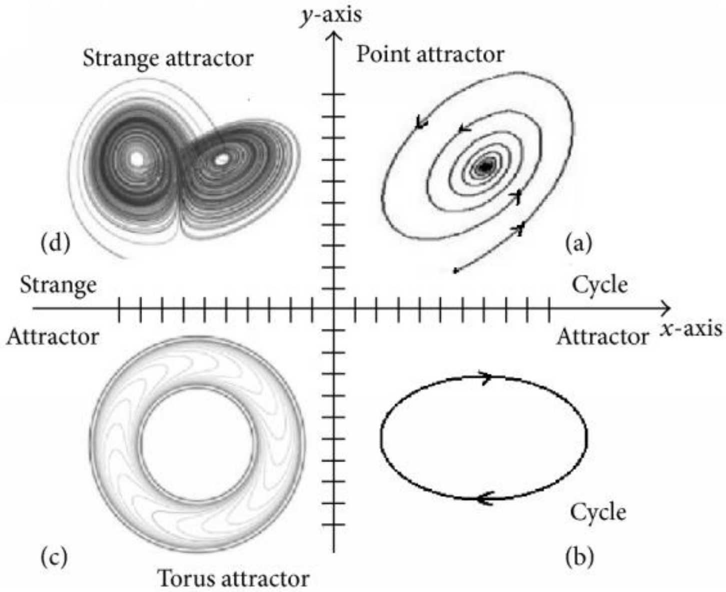


Figure 2.10 Four Attractors in Two-Dimensional Phase Space

Notes: (a) point attractor, (b) limit cycle, (c) limit torus, and (d) Lorenz strange attractor.
Source: Adewumi et al. (2016); (Lorenz, 1963).

The mathematics of non-linear dynamics provided Chaos Theory with a demonstration of how simple relationships produce surprising but patterned results (Feigenbaum, 1983). These methods are demonstrated in the parallel work during the 1960s and 70s on *Fractal Geometry* – describing the multi-scale structure of chaotic attractors in geometry and nature, mainly developed through the work of Mandelbrot (1982). Mandelbrot created topological methods to analyse the complexity of irregular shapes in the natural environment, through this work finding self-organised patterns in descending scales (Mandelbrot, 1982). In other words, self-similarity is noticeable at multiple scales in a cauliflower, snowflake or the leaf of a fern – mathematical principles can be used to decipher this pattern.

The prospect of finding order, or universal behaviours in non-linear systems may help explain the broad adoption and popular interest in Chaos Theory (Levy, 1994). However, despite its appeal, the application of Chaos Theory to social sciences requires the observer to determine if the system under study is exhibiting chaotic behaviour or is merely subject to random perturbation. It is also possible for a system of this kind to readily transition between random and non-random states (Levy, 1994). With respect to human social systems, Chaos Theory can be considered a key dimension within the broader complexity sciences, or even as an extension of General Systems Theory rather than completely new paradigm (Katz & Kahn, 1978). Despite their elegance and ingenuity, the non-linear mathematics behind Chaos do not bend their rules to cater for the social relationships among variables in a human system. The unpredictable behaviour of humans is a major factor in itself, potentially altering the parameters and structure of a social system. Hence, symbolic interaction and perspective-laden behaviour is largely absent from even a non-linear dynamical mathematical model (Levy, 1994).

The ideas of Chaos do however have a role in organisations and management. One of the most compelling claims into the world of organisation science is the notion that human social organisations exhibit unpredictable and non-linear behaviours (Goldstein, 2008). This change from a mechanistic, linear function of organisations and their actors to an ecosystem of feedback loops and dynamic interaction has brought the techniques of Chaos closer to the intricacies of organisations and social science, and thus contributed a great deal (Thietart & Forgues, 1995). While the development of Chaos Theory has not retained the excitement it once had during the 1960s, 70s and 80s, it has established essential conceptual and mathematical tools that enable the detailed study of certain complex systems and which have application in the real world (Simon, 2008).

2.3.6 Computational Theory and Artificial Intelligence

The application of complex non-linear mathematics used in areas such as Chaos Theory, requires the use of high-speed computing, in order to process the quantum of mathematical equations, and to generate detailed trajectories and future states. Before the arrival of high-speed computing, deriving qualitative pattern for analysing complex behaviours was limited to specific and local analyses and to a large extent invisible (Simon, 2008). Processing power and advanced mathematics to describe non-linear dynamics has enabled ‘qualitative’ analysis of the topological features of nonlinear systems (Capra, 1996). Perhaps this was the distant vision of Ablowitz (1939) ‘transformation of quantity into quality’, or it is a product of a nascent theory of emergence. While the confluence of scientific methods is a methodological breakthrough, it has also given rise to fractured ontology – for the explanations of underlying phenomena do not yet concur entirely with sense-making at the level of the system.

In complexity science, the use and role of computer processing power is not however limited to solving mathematical equations. This question has inevitably turned to the fundamental capability and limitation of computers and their ability to perform cognitive processes (Sipser, 2013). With this view, the cognitive process of the human brain and its intelligence can be described as an information processing centre – which a synthetic processing system may be able to replicate given a long term view of its further development. The idea of advanced, human brain-replicating computer processing power was established as a result of this idea, laying the foundations for the study of artificial intelligence. Early ramifications were the Logic Theory Machine and the General Problem Solver – computer programs developed primarily by Allen Newell and Herbert Simon to test the theorems of Whitehead and Russell's *Principia Mathematica* (Crevier, 1993).

The idea of the human brain as a computer and vice-versa is linked in a number of ways to the theory of emergence. The complex mathematics used for complexity science have provided the bedrock for both understanding the arising of pattern within the complex systems of the human brain, and also the recreation of these emergent patterns in an artificial environment (Crevier, 1993). Beyond the sheer processing power of a computer system, it is the capacity for organic emergent order that is the foundation for artificial 'intelligence', to replicate the capacity for human cognition and to potentially blur the lines of consciousness between that of a human and its synthetic counterpart.

In addition to developing a test to establish the cognitive capability of computers, Turing developed a range of concepts and processing applications which have contributed to the development of the modern computer (Hodges, 2000). By applying the concept of emergence in a chemical setting, Turing used a mathematical model to explain the self-organising generation of new forms in embryonic development (Goldstein, 2008). Turing used non-linear dynamics to develop a mathematical formulation representing a mixture, diffusion and reaction of chemicals whereby the emergence of new order arises – known as *morphogenesis* (Turing, 1952). The non-linear and unstable characteristics, and bifurcation evidence in morphogenesis is a central idea of complexity theory (Goldstein, 2008). Furthermore, it is conceivable that Turing imagined the cohesion of his findings in chemical morphogenesis in a new form of robotics or artificial life, driven by the ability to self-replicate and self-organise, and therefore applied his mind to a test to make this distinction clear in future generations, between the 'mind' of the computer and that of a human. Alternatives to these concepts are the limitations of 'incomputability', as no such machine has been created (Boschetti & Gray, 2007); nonetheless, morphogenetic robotics is an emerging field in developmental robotics (Jin & Meng, 2011).

The processes of organisation in a human social system, similar to physical and chemical systems, is largely a study of the interactions of agents within the system, and consequential system level behaviours (Marion & Uhl-Bien, 2001). If indeed the patterns of organisation and influence in human systems can be conceptualised, modelled and examined, computational modelling could be a useful approach to comprehensively explore variables and interaction (Hazy, 2008b). Moreover, once dynamical processes at successive levels of the system are gathered and understood with real world data to populate the model, it may be (theoretically) possible to 'predict' various aspects of behaviour and performance within a probabilistic range, within the parameters of alternative choices and with recursive validation from real cases (Macy & Willer, 2002). Such a model points to the fundamental importance of information transfer.

2.3.7 Information Theory

An essential element of Weiner's earlier work on Cybernetics was reference to the role of 'messages' in communication, for the purpose of control and self-referencing behaviours of a system (Weiner, 1954). The theory of information is derived of the foundation work of Shannon (1948) and Weiner (1948) in the late 1940s (Capra, 1996). Information Theory is concerned with messages or 'signals', rather than the technology or nature of information in itself – a cause for much confusion with this body of work (Weiner, 1948). During this work at Bell Telephone Laboratories, Shannon (1948) aimed to measure the amount of information that could be transmitted through telephone lines to test their efficiency (Capra, 1996).

In the seminal work, *A Mathematical Theory of Communication*, Shannon introduces and conceptualises *entropy* (in information theory) as the expected value of information contained in a message (Shannon, 1948). More technical reasoning is provided by Shannon to describe the limits of lossless encoding and transmission of information. However, the problem of transmitting an encoded message through a noisy channel has limited resemblance to the transmission of *meaning* (Capra, 1996). Entropy can also be described in a cognitive sense, although is still a developing area, as the basis to manage uncertain ontological concepts (Borrego-Díaz & Chávez-González), and to model cause and effect chains with complex relationships and uncertainty (Manso & Moffat, 2011). The two latter concepts are grounded by the tenets of information theory, and have been applied to the capability of decision-making synchronisation in command and control 'C2' organisations. Enabling and inhibiting factors that lead to decision outcomes – or self-synchronisation are quantifiably examined (Zhigang, Fuxian, Bo, & Xiang, 2013).

Prior authors have argued that the 'tacitness' of knowledge can be assessed through entropy (Sigov & Tsvetkov, 2015). This approach reflects the uncertainty of information loss and impact on cognitive process, caused by an imperfection in its cognitive mechanism (Manso & Moffat, 2011). Therefore, there are multiple states that can arise from cognition, resulting from information transmission asymmetry and cognitive entropy. Despite its mathematical application in a military setting, the conceptual link from entropy as an abstract concept – to cognitive process – and back to the complexity dynamics and environmental conditions present in human social systems, requires some thought-work to translate.

The lack of a mathematical basis to define agent interaction and behaviour at the level of the component within a complex system has not been a serious barrier for the concept of emergence and the science of complexity to make its way into the social sciences. An exact science to precisely describe the result and entropy value of an interaction of two human agents is presently unavailable. There is no known equation that accounts for *meaning* in a qualitative sense. Despite this, the effectual transmission of information, which gives rise to changed ideas that become actions, could be considered a derivation of Information Theory's cognitive entropy – to describe the extent to which the source of that influence has *potency*. Such a use of the abstract concept of entropy is not so different from its application in engineering, to appreciate its use in commonly encountered systems and processes (Çengel & Boles, 2015). The use of the concept of entropy is not limited only to the study of thermodynamics. Furthermore, in laying the foundations for a theory of information, Weiner (1948) emphasised the notion that a coded message is in itself a pattern of organisation.

Very limited research has been located which makes an explicit correlation between the concept of *influence increment as a mechanism for information transfer* and *cognitive entropy*, both leading to information transmission decay, and as mechanisms of self-organisation in human social systems. Each field lacks in the domain where the other flourishes. The limitations of mathematical algorithms in human systems are equalled by the limitations of subjective interpretation among agents in a mathematical model. Hence, it is unsurprising that the main attributes of 'enablers' in the study of cognitive entropy are: widely shared information resources; unconstrained patterns of interaction; and distributed allocation of decision rights (Manso & Moffat, 2011). While such determinations in cognitive entropy by Manso and Moffat (2011); Sigov and Tsvetkov (2015) are hardly surprising from an emergent strategy and complexity leadership perspective (McKelvey, 2008; Mintzberg & Waters, 1985), they provide concrete mathematical models to support their assertions, which is a deficiency of many qualitative models of complexity in human systems – to assume behaviours mirror those in the chemical world (Hazy, 2008b; McKelvey, 1999). For this reason, it is believed a cumulative conceptual model which draws on the mathematical principles of cognitive entropy and supplies further variables necessary for non-C2 settings would be a feasible and necessary contribution to a theory of emergence in complex firms.

A further link between information transfer, Cybernetics, systems theory and later, the idea of a circular organisation of living systems is explained best in the words of Ashby (1956), as follows.

> Cybernetics started by being closely associated in many ways with physics, but it depends in no essential way on the laws of physics or on the properties of matter. Cybernetics deals with all forms of behaviour in so far as they are regular, or determinate, or reproducible. The materiality is irrelevant, and so is the holding or not

> of the ordinary laws of physics. The truths of Cybernetics are not conditional on their being derived from some other branch of science. (Ashby, 1956).

Ashby claims a level of conceptual openness for the ideas of Cybernetics, paving the way for its wide application, and what has later become known as Second Order Cybernetics (Scott, 2004). Cybernetic principles claim to depend in no essential way on physical properties alone; therefore, Cybernetics has both a sociological and physical status (Ramage & Shipp, 2009). Ashby draws reference to the ontological application of energy transfer, system openness, immateriality, and therefore the irrelevance of designating Cybernetic systems only by their mechanistic properties (Ashby, 1956). It is noted that the coupling of information and energy does not remove the fact that information transmission still requires physical objects. Ashby's (1956) ideas echo earlier sentiments by Weiner (1948) on 'information, not matter or energy', and were planted as base concepts to form portions of what would later become the known as *autopoiesis* (Varela & Maturana, 1972).

> Alternatively, one can say that what specifies a machine is the set of component's interrelations, regardless of the components themselves. We call this the structure (or theory) of the machine. We are thus saying that what is definitory of a machine structure are relations and, hence, that the structure of a machine has no connection with materiality, that is, with the properties of the components that define them as physical entities. In the structure of a machine, materiality is implied but does not enter per se. (Varela & Maturana, 1972).

Finally, to complete the cycle of Information Theory back to its fundamental building blocks – we revisit Weiner's assertion many years prior in the 1940s, wherein it was emphasised that information is essentially a pattern of organisation in itself. An analogy can be drawn between the patterns of information, communication, organisation and living systems – that all exhibit and are in some way connected by distinctive pattern (Capra, 1996). Therein, information itself is a source of influence over the patterns *within* the message and potentially the house in which the message is carried. Mukherjee describes this concept in an intimate study of the human genome, as follows.

> The discontinuous nature of information would have carried an added benefit; a mutation could affect one gene, and only one gene, leaving the other genes unaffected. Mutations could now act on discrete modules of information rather than disrupting the function of the organism as a whole – thereby accelerating evolution. But that benefit came with a concomitant liability; too much mutation, and the information would be damaged or lost. What was needed, perhaps, was a backup copy – a mirror image to protect the original or to restore the prototype if damaged. Perhaps this was the ultimate impetus to create a *double-stranded* nucleic acid. The data in one strand would be perfectly reflected in the other and could be used to restore anything damaged; the yin would protect the yang. Life thus invented its own hard drive. (Mukherjee, 2016).

Humans, cells and genes are all messengers, carrying information and instructions for future adaptation, examined further in the following section on Evolutionary Biology. It is known the message itself is a pattern of information, instructing a further pattern of organisation (Weiner, 1948). Hence, information theory is a concept that is tightly linked with many areas of complexity science, and emergence – in understanding the mechanisms for self-organisation, and the 'sum' of the parts. Particularly in human systems, the act of encoding and deciphering information between agents can be just as strong an influencing factor as the message itself.

2.3.8 Evolutionary Biology

Beadle and Tatum were awarded a Nobel Prize in 1958 for their 'missing ingredient' experiments that led to a new understanding of genes (Mukherjee, 2016), following a comprehensive search to decompose the activity of genes and proteins to understand *heredity* – the passing of physical characteristics from one generation to another. Within the broader story of the gene, the theory of information is a silent witness. To decipher the actions of the gene, a code that generations of biologists had been trying to understand, 'a gene "acts" by encoding information to build a protein, and the protein actualises the form or function of the organism' (Mukherjee, 2016). The actions of the gene are described in terms of *information flow*, as illustrated below.

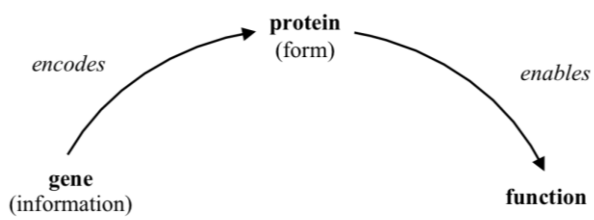


Figure 2.11 Gene Encoded Proteins
Source: (Mukherjee, 2016)

However, the concept did not answer the question of how genes ‘encoded’ information as messenger molecules, nor did it explain how organisms possessed a specific set of genes, yet remained capable of acute adaptation to changes in the environment (Gann, 2010). In 1959, Arthur Pardee, François Jacob, and Jacques Monod published the results of their study at the Pasteur Institute in France, on how genes control the production of enzymes in bacteria (Pardee, Jacob, & Monod, 1959). The study was later referred to as the PaJaMa experiments, an amalgam of the researchers last names.

The PaJaMa paper was crucial to moving past the core questions of *embryogenesis*, and how variations arise from an embryo that are derived of the same set of genes.
The activation and deactivation of genes in a certain sequence would be sufficient to ‘interpose a crucial layer of complexity on the unblinking nature of biological information’ (Mukherjee, 2016). Gene regulation and the encoding, decoding and transmission of information were the key to unfurling the unique function of self-regulation, replication and recombination from a single cell.

> According to the strictly structural concept, the genome is considered as a mosaic of independent molecular blueprints for the building of individual cellular constituents. In the execution of these plans, however, co-ordination is evidently of absolute survival value. The discovery of regulator and operator genes, and of repressive regulation of the activity of structural genes, reveals that the genome contains not only a series of blueprints, but a co-ordinated program of protein synthesis and the means of controlling its execution. (Jacob & Monod, 1961).

The mechanisms for genetics demonstrated how organisms transmit likeness to one another; but also how genes make proteins that *regulate* genes, how genes make proteins that *replicate* genes, and finally, *recombination* – the emergence of new combinations of genes as a product of those mechanisms of information transfer at a cellular level (Mukherjee, 2016). A systems view and information theory are evident in the recursive conceptualisation of genetic function, as illustrated below.

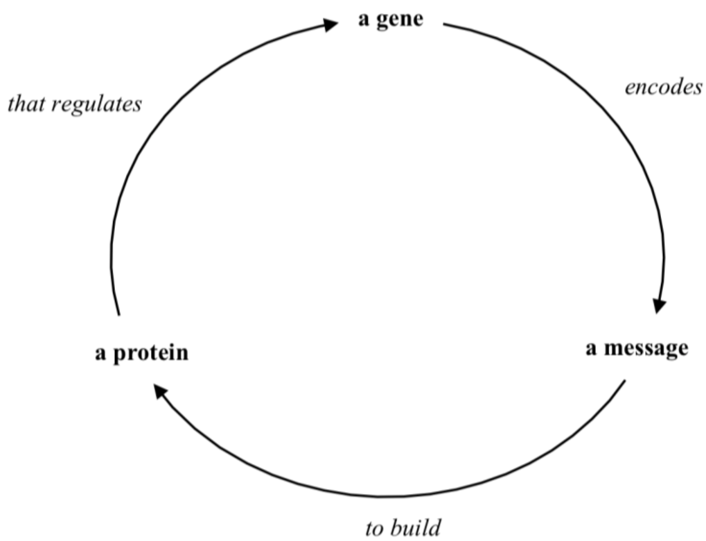


Figure 2.12 PaJaMa Gene Regulation
Source: (Mukherjee, 2016)

The ideas of emergence have contributed several key concepts to evolution, including Neo-Darwinist theory – evolutionary population dynamics; mechanisms and mathematical principles for molecular evolution; and the self-organising processes at a chemical level through morphogenesis (Kauffman, 1993).
Concepts designed for appropriation into theories of natural selection, fitness landscapes, and the adaptation of complex systems have drawn the household definition of *evolution* into the modern corporation (Brown & Eisenhardt, 1997). Equally, some that are at the edges of their origin fields – such as punctuated equilibrium (Dawkins, 2007) and assemblages of pattern across successive levels of multiple complex systems all of which are intrinsically 'connected' (Capra, 1996).

Emergence has been part of the rise of a structured view of self-organisation and accounts for many of the advanced developments at a qualitative and quantitative level, which are now applied to a variety of neighbouring fields (McLaughlin, 2008). The classical Daisyworld simulation model of Watson and Lovelock (1983) assumes a population of non-interacting organisms (daisies) that modify their local behaviours, thus self-regulating the temperature of the earth and demonstrating a recursive species-environment interaction. In this simulation, species-environment interaction is the basis of the model, specifying a dynamic fitness landscape and a self-regulating ecosystem of adaptive agents that achieve global regulation (survival) via feedback loops. However, the model does not take into account dynamic interaction between the species itself (Nuño, de Vicente, Olarrea, López, & Lahoz-Beltrá, 2010).

The survival analogy has been extended to economic, social and psychological matters, such as in the formation and distribution of collective opinion (Nuño et al., 2010). The application of precepts of evolutionary biology to social dynamics was given well known treatment by Dawkins (2006) 'the selfish gene', Eigen's relation between societies and macromolecules reviewed by Thompson and McBride (1974), and statistical physics applied to the behaviours of crowds and 'social spreading' (Castellano, Fortunato, & Loreto, 2009). A useful instance for the quantitative modelling of public opinion is the spread and exercise of democratic voting systems (Alves, Oliveira Neto, & Martins, 2002).

The use of a cellular automata simulation to model the diffusion of public opinion demonstrates the mechanism of self-regulation, but relies on an assumption that societies are universally governed by 'micro-rules' which form the basis of action and interaction with neighbours, thereby collectively changing landscapes (Alves et al., 2002; Bagnoli, Franci, & Rechtman, 2005; J. H. Miller & Page, 2007).
Micro-rules are a prerequisite for the construction of a mathematical model for cellular automata (Nuño et al., 2010). However, this model assumes much in the construction of rules, which as described on the same occasion by Anderson (1999), complex adaptive systems in the human arena are far more complicated than the micro-scale of their founding biological and chemical counterparts. The schemata (rules) themselves may be able to adapt more readily than agents can.

> Different agents may or may not have different schemata (depending on one's theory), and schemata may or may not evolve over time. Often, agents' schemata are modelled as a set of rules, but schemata may be characterised in very flexible ways. For example, an agent may select one rule from a suite of possible rules, or it may invoke fuzzy rules, or its cognitive structure may be represented by a neural network. (Anderson, 1999).

In general terms, the schemata that govern complex human social systems are less a set of definitive 'rules', and more a malleable framework of goals and plans that frame decisions. Some of these decisions are more likely than others, but the schemata themselves are emergent, unpredictable and characterised by the invention of both the agent and the landscape within the system. This additional layer of self-making realities gives human social systems a special quality, which brings us to its underlying theoretical framework – the idea of self-producing systems, autopoiesis.

2.3.9 Autopoiesis

The concept of autopoiesis was originally developed through the work of Humberto Maturana in the 1970s, and extended collaborations with Francisco Varela in the years following (Capra, 1996). Autopoiesis refers to the autonomy of self-organising systems, which self-reproduce and evolve – wherein the making, remaking and therefore constitution of its existence are inseparable.

> Autopoiesis, or 'self-making', is a network of patterns in which the function of each component is to participate in the production or transformation of other components in the network. In this way, the network continually makes itself. It is produced by its components and in turn produces those components. (Capra, 1996).

Therein, definition is given to the mechanisms of self-production that are a key to understanding diversity and distinctiveness of living from non-living systems (Mingers, 1991). A simple example is a plant cell, which through metabolic processes has boundaries and is able to reproduce and re-make itself. Plants cells however, are not the only molecular system capable of self-organising, self-reproducing and evolving – what then, is the definition of a system that is 'alive'? Maturana and Varela were not only interested in the self-making ability for biological and non-biological systems, the fundamental questions they sought to resolve was to clearly distinguish living *vs.* non-living systems – to define life itself by its pattern of organisation (Maturana & Varela, 1980). The two authors differentiated their theory as 'mechanistic', as distinct from a *vitalist* approach to nature, in their identification of a circular organisation that pervades all living systems, and in their view an apt tool for universal application.

Vitalism has a common thread with systems thinking in that it supposes irreducibility in analyses, the sum being more than the parts, but seeks to import an answer as to the distinction of system properties as formed of by a nonphysical entity, force, field, higher or other dimension that, added to the laws of physics and chemistry, completes the human understanding of life itself. Arising from the time of the ancient Egyptians, the term declined throughout the latter parts of the 20th century, as scientific explanation sufficiently resolved its hypotheses without requiring further abstraction, or worse, obfuscation (Buchanan, 2010). One of the most prominent references to Vitalism is that of Henri Bergson, which purports to clarify the gap between mechanistic explanations of existence and the origins of life that scientific theory of the day were unable to completely explain.

> Bergson's philosophy accentuated the process of becoming at the expense of the unfinished product; at the same time it insisted that physical matter was infused with a vital force that brought the matter to life. (Gillies, 1996).

Or, as put in an article of well-known *fiction*, during the era of Vitalism.

> It was on a dreary night of November that I beheld the accomplishment of my toils. With an anxiety that almost amounted to agony, I collected the instruments of life around me, that I might infuse a spark of being into the lifeless thing that lay at my feet. (Shelley, 1818).

Vitalism is not pursued in contemporary science due to non-viability with physical and natural laws. Nonetheless, Bergson was a key influence on a range of important authors, among which include Marcel Proust, Paul Valéry, Charles Péguy, psychologists William James, Pierre Janet and Jean Piaget, and classmates Jean Jaurès and Émile Durkheim (G. W. Barnard, 2011). Following the rise of *existentialism* in France in the late 19th century, Bergson's operations on consciousness were revived by Gilles

Delouze's reviews on Vitalism which were taken as a sign Delouze was indeed himself a vitalist (Buchanan, 2010). However, the interpretations of the later work of Deleuze and Guattari (1988) require deep extrapolation and are infrequently made with universal interpretation.

Autopoiesis is a remedy to the mystique of Vitalism, in its natural application remaining within the parameters of biological, chemical and physical explanation. The idea in itself can be used to define living systems and therefore is considered by its architects a pattern for the organisation of life (Maturana & Varela, 1980). The implication of the idea is that where there is life, there is always a discernible *pattern*. The logic in theoretical terms is simple, if: a) autopoiesis is the *pattern* of organisation in living systems; then, b) self-organisation is the *process* occurring within the underlying relationships that give rise to autopoiesis. Therefore, if those processes are both a product of the system and its constitution, the system is 'alive' (Maturana & Varela, 1980). One may use this logic to attempt to define human social systems as 'living' systems, an idea that has been tested with variable success Mingers (2002). It was perhaps significant forethought that Ashby (1956) and Weiner (1954) aired their hypothesis on the 'immateriality' of Cybernetic systems – in abstract terms, a 'logic' of mind for any system with the necessary mechanisms for emergent order, with physical or non-physical constitution.

'Yet, our problem is the living organisation and therefore our interest will not be in properties of components, but in processes and relations realised through components' (Maturana & Varela, 1980). Despite the machine-like analogy in their depiction of self-organising systems, Maturana and Varela sought to develop a theoretical framework that would distinguish the properties of living and non-living systems, based on an understanding of the principles that underlie the *organisation of the living*, expressed in their own words as follows.

> *An autopoietic machine is a machine organised (defined as a unity) as a network of process of production (transformation and destruction) of components that produces the components which: (i) through their interactions and transformations continuously regenerate and realise the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in the space in which they (the*

> *components) exist by specifying the topological domain of its realisation as such a network.* It follows that an autopoietic machine continuously generates and specifies its own organisation through its operation as a system of production of its own components, and does this in an endless turnover of components under conditions of continuous perturbations and compensation of perturbations. (Maturana & Varela, 1980).

Autopoiesis was influenced by the earlier work of Cybernetics and General Systems Theory, with reference to the principles of system interdependency, communication and circular organisation. In 1974, Maturana and Varela succeeded in constructing a grid-based computer simulation which would emulate both the behaviour of self-organisation and autopoietic networks, using concepts developed by von Neumann on cellular automata to design self-constructing machines (Maturana & Varela, 1987). However, these base theories of systems and communication did not satisfy Maturana and Varela in their search to understand cognition as a biological phenomenon and a universal distinction for living systems. For Maturana, it was an investigation into colour perception that led to a realisation that the nervous system functions as a closed network, in which the interactions between components result in a change in the relationship between those and other components (Maturana & Varela, 1980). The working definition of Maturana and Varela (1987) is as follows.

> A composite unity whose organisation can be described as a closed network of productions of components that through their interactions constitute the network of productions that produce them, and specify its extension by constituting its boundaries in their domain of existence, is an autopoietic system. (Maturana & Varela, 1987).

Consistent with General Systems Theory, Maturana and Varela define their ideas of autopoiesis as structures that are constituted principally by the relations among components, rather than the physicality of the components themselves (Maturana & Varela, 1987). With a distinction between the properties of organisation and the properties of their components, the idea lends to a wide variety of phenomena. The functioning of each component participates in the transformation of neighbouring components, and in this manner the system is *making* itself. ‘It is produced by its components and in turn produces those components’ (Capra, 1996). In such an autopoietic system, the product of its operation is its own organisation' (Maturana & Varela, 1980).

Varela identified several criteria that forms part of their explanation that must be considered to determine if a complex system is autopoietic, paraphrased as follows: a) the system has boundaries and can be distinguished from its environment; b) the components belong to the system and can be identified as such due to self-referencing behaviours; c) system behaviour is dynamic; d) the system has form, and is stable enough to observe; e) the system produces its own components; f) the components are produced by the system and necessary and sufficient to produce the system itself (Hall, 2005). Maturana and Varela refer to three types of multicellular living systems: organisms, ecosystems and societies – each vastly different by degrees of autonomy and complexity (Maturana & Varela, 1980).

> Social systems use communication as their particular mode of autopoietic reproduction. Their elements are communications which are recursively produced and reproduced by a network of communications and which cannot exist outside of such a network. (Luhmann, 1986).

Maturana and Varela however, remain silent on this question, suggesting that current knowledge is insufficient to detail the pattern in such an abstraction of autopoiesis.

> What we can say is that multicellular systems and operational closure in their organisation: their identity is specified by a network of dynamic processes whose effects do not leave the network. But regarding the explicit for that of organisation, we shall not speak further. (Maturana & Varela, 1987).

Organisms and societies however, are two very different types of 'living' systems. The theories of autopoiesis have nonetheless been enlarged to encompass social systems, cognition and language, which has led to the reinvigoration of root theory in what is known as Second-Order Cybernetics (Hall, 2005; Mingers, 2002). At an abstract and conceptual level, philosophical, sociological and political arguments have been formed to define social systems as autopoietic, (Capra, 1996; Fuchs, 2003; Luhmann, 1986; Mingers, 2002). The application of autopoiesis to the web of life as a whole, encompassing multi-layered systems nested within systems, and networks within networks is however, significantly problematic. As Maturana and Varela realised, organisms are living systems containing closely coupled cells with definitive boundaries (Maturana & Varela, 1987). However, populations of organisms and species within the patterned web of organisation known as an ecosystem or society are very different from the nested molecular systems of which they are comprised. At this level, systems exhibit loose coupling, porous boundaries, and abstract notions of production. Hence, it would be speculative to apply an autopoietic classification to such larger entities without a complete understanding of the operation of self-making processes at successive levels within the system, and its nested hierarchy of associated systems.

To claim that a social system is in itself 'alive' due only to autopoietic function is difficult to substantiate. For example, if we understand that humans within a social system are the components, they are clearly not being 'made' by the system (at the level of system process), nor do they exist solely for the purposes of the system (assuming individual autonomy). Therefore, another definition for each of the componentry would be required (Mingers, 2002). A more generalised application of the notion of autopoiesis may lend to social systems by referring to non-physical properties of the system, such as rules, concepts, meaning and perceptions, which are made, self-referenced and constitute the operation of system-level behaviours.

Put simply, 'autopoiesis is the recursive production of the elements by the elements of the system' (Luhmann, 1986). However, with this explanation alone, and with its conceptual application to social systems; a new understanding for the definition of 'life' would be required at the level of social systems, one which does not depend on physical matter, natural laws or rights of existence. Fortunately, from a global perspective, there are no known social or ecological systems without autopoietic systems nested within them – therefore, there is currently latent risk in overlooking the existence of 'life' arising from a large-scale philosophical reconceptualisation. That risk could materialise if a macro system is classed as having 'life' but is comprised of components that are devoid of life are artificially crafted. In this case, autopoiesis does not provide an immediate answer on the definition of 'life' if applied to a 'conscious' entity of artificial intelligence. Furthermore, if one were to successfully apply autopoiesis to social systems, what then would be its purpose and implication? It is argued, a social system is a self-referencing pattern of organisation among living organisms. The social pattern itself does not denote the system as being ‘alive’, rather that it is constituted by living things, which are all autopoietic systems.

The concept of autopoiesis has contributed much to the body of knowledge for emergent self-organisation. While the characterisation of human social systems as ‘living’ was avoided by Maturana and Varela (1980), and remains a subject of discussion, their primary aim to define living systems with circular causality provided an important observation of the extent to the capabilities of self-making systems. It could be argued all human social systems, while not necessarily ‘alive’ are autopoietic – in that they create and are in turn constituted by components which define the system (such as rules, social norms, networks and leadership), depending how component parts and their conditions are defined. This characterisation is an important development in understanding the formation and behavioural character of social organisation, as outlined earlier in accord with the principles that define autopoietic systems.

It is in the observable pattern of organisation that a definition can be applied to autopoietic systems, and the emergence of order. Pattern is an essential component of the theory of emergence and the science of complexity. While *pattern* is an observation of the system to which is attaches, emergent self-organisation is the *process* that brings forth its form. The unique character of complex systems, and their capacity to continuously adapt, separates the complex from the complicated.

The elements of complex adaptive systems are broadly of a material nature, which are revisited in the following section in order to reconcile any further division in the nature of the complexity dynamics within which an emergent phenomenon may be observed or a party to the formation of.

2.3.10 Complex Adaptive Systems

Despite the substantial work of Maturana and Varela (1980) in attempting a universal definition for ‘life’, based on autopoiesis, it is still claimed there are no sharp definitions of any such terms: ‘life’, ‘emergence’, ‘complexity’ which also constitute the study of Complex Adaptive Systems (CAS) (Holland, 2006). Should Holland prove correct in this assertion that the field is characterised by opaque definitions, rigorous models are nonetheless required to progress with a study of any one of these matters of interest. The study of complex adaptive systems is not so much concerned with the definition of ‘life’, rather, the properties and characteristics of the system itself, which enable adaptation to changing environments and ‘survival’ in altered conditions (Holland, 2006)

Regarding *survival*, it is noted that a core focus of CAS is on modelling survival probabilities, exemplified in evolutionary biology in the computer simulation models of Daisyworld and Quasispecies (Nuño et al., 2010; Watson & Lovelock, 1983). Counterintuitively, the format for ‘survival’ does not necessarily imply existence of ‘life’ in all applications. While much of the origin fields of biology are deeply concerned with the organisation and construct of life, drawing out models of evolution, adaptation and survival to a human social and organisational context often omits the requirement for this definition: what is ‘survival’ in the context of a human social system? In particular, when using biological terms, and given the lack of agreement with reference to living systems, as discussed earlier. For this purpose, survival can simply be considered as *sustained existence*, rather than any further biological explanation of emergent life within an autopoietic system.

It is not uncommon for CAS literature to omit discussion on the definition of ‘life’, understandably earmarking a general assumption that organisations and human social systems are not considered to be living things unto themselves (Choi, Dooley, & Rungtusanatham, 2001; Holland, 2006; Holland & Miller, 1991; J. J. Johnson, Tolk, & Sousa-Poza, 2013; Lichtenstein et al., 2006; McKelvey, 1997).

A complex adaptive system can be thought of as the systems under study via complexity theory – descriptions of each of the elements of this working definition are elaborated on at Table 2.7, as referenced within. The two terms are often interchanged, – complexity theory *is* the study of complex [adaptive] systems, albeit they will not always be adaptive or adaptive at all times (Choi et al., 2001; Holland, 2006; Lichtenstein et al., 2006; Schneider & Somers, 2006; Simon, 2008). The theory of complexity provides many insights about the behaviour and capabilities of natural, social and organisational systems. A number of these insights have already been explored through a review of complexity's conceptual foundations in their historical context, including: the foundations of post-WWII Cybernetics and general systems theories, dissipative structures, non-linear dynamics, uncertainty, agent interaction and interdependency, mathematical and computational models of complexity and implications for change management and leadership.

Table 2.7 Working Elements for a Definition of Complex Adaptive Systems

Element	*Description*
Complex	An observable phenomena comprised of numerous interacting agents that act on the basis of simple rules or schemata (Anderson, 1999; Kauffman, 1993; Stacey, 1995)
Adaptive	Behaviours are dynamic, unpredictable, non-linear, self-referencing and responsive to changes in the internal or external environment (Lichtenstein & Plowman, 2009a; Prigogine & Stengers, 1984; Schneider & Somers, 2006)
System	The phenomena has identifiable boundaries, feedback loops within and outside an open system, and within which its constitution is made primarily of interacting agents (Ashby, 1962; Boulding, 1956; Skyttner, 1996)

Source: constructed with paraphrasing from various authors identified above.

A complex adaptive system contains numerous interdependent agents that interact on the basis of local rules or schemata, and through feedback loops and amplification give rise to emergent and unpredictable outcomes that are a result of the interactions within and across the system. Such systems are adaptive in that they are capable of altering their behaviours or composition to enhance the probability of survival, usually, as a response to changing environmental conditions, but also as a result of new internal challenges.

Table 2.8 provides a brief description for each of the essential elements of complex adaptive systems, adapted from Katz and Kahn (1978). A complex system is simply a system in which many independent elements or agents interact, leading to emergent outcomes that are often difficult (or impossible) to predict simply by looking at the individual interactions. Complex adaptive systems also rely on a number of essential elements, such as the importation of energy, throughput, output, non-equilibrium, and agents with schemata (Katz & Kahn, 1978). The combination of these elements defines the characteristic behaviour of adaptive systems, and the potential for emergent self-organisation.

Table 2.8 Elementary Properties of Complex Adaptive Systems

Element	*Description*
Importation of energy	Energy is imported and dissipated throughout the system
Throughput	Inputs are converted through the use of energy
Output	Produced output of emergent structures may be exported to the external environment
Non-equilibrium	Complex adaptive systems are poised systems that function at the edge of chaos for optimal buffering and adaptability
Many interdependent agents	Numerous interdependent, interacting agents that respond to one another's behaviour through continuous feedback
Emergence	Some activity occurs that is not induced by the environment, but instead, results from the interdependence and interaction of system components
Agents with schemata	The interactions agents are guided by unique and independent schemata or rules or elements with one another are need-based, bottom-up, and emergent, and are associated with the presence of catalysts and feedback mechanisms (Anderson, 1999)
Self-organising networks	The stability of systems is achieved through recursively applied rules that emerge from the system without the need for centralised coordination (Drazin & Sandelands, 1992)
Adaptation	The basic principles are preservation and adaptation of the character of the system
Path dependence	Unique final states may be reached due to sensitivity to initial conditions

Source: adapted from Katz and Kahn (1978).

Complex adaptive systems are known as such for their namesake feature – the ability to adapt (Plowman & Duchon, 2008; Anderson, 1999). Complex adaptive systems are comprised of numerous interdependent and agents, that through the pursuit of individual plans and with only local knowledge or rules and feedback on the behaviour of others, system level behaviours are generated (Chiles et al., 2004; Plowman & Duchon, 2008; Anderson, 1999; Schneider & Somers, 2006).

Drawing on interdisciplinary sources, Anderson (1999) refers to previous works including Daft & Lewin (1990) that indirectly recognised the surprising, nonlinear and unpredictable nature of organisations and the risk of prematurely settling into a 'normal science' mindset due to the enormously complex nature of organisations and their environments. Complex adaptive systems can be understood by examining four key characteristics of their composition and behaviour: agents with schemata, self-organising networks sustained by importing energy, coevolution at the edge of chaos, and system evolution based on recombination.

2.3.10.1 Agents with schemata

In the case of social sciences, 'agents' are the individuals or groups independently pursuing their own objectives in an interconnected environment. A key attribute of the idea is that agents possess the capacity to carry on multiple competing plans and for the rules guiding their behaviour to be malleable or emergent (Anderson, 1999). During the same year, Macintosh & Maclean (1999), progressed the contrasting notion of emergent, simple rules via the operationalisation of 'conditioned emergence', as complexity theory's tools for practice: *management* of deep structure; *management* of instability; and *management* of feedback loops. Although Macintosh & Maclean (1999) and Anderson (1999) bear no reference to one-another [possibly due to their corresponding publication date], their prepositions reach toward a similar belief: 'complex adaptive system theory has rich implications for the strategic management of organisations' (Anderson, 1999); and 'dissipative structures as presented in this paper is pointing towards a new conceptualisation of strategy' (Macintosh & Maclean, 1999). Both recognise the limitations of a static view of organisations and the importance of understanding the dynamic micro-scale interactions between individual agents within a complex system.

2.3.10.2 Self-organising networks sustained by importing energy

The second element draws on Drazin & Sandelands (1992), importing that complex systems do not have a central point of control, thus no single agent has the capacity to dictate the collective behaviour of a complete system. Individual agents are connected via feedback loops through which each agent mutually affects one-another's behaviour.

Maintaining self-organised structures requires the importation of energy into the system. The concept of interdependence is philosophically analogous to the basic premise of symbolic-interactionism, discussed in further detail at Chapter 3. Despite the holistic viewpoint of complex systems, their application has lacked development on the concept of energy importation and its impact on the refinement of theory. Further operationalisation of theory would benefit from addressing this element to increase its empirical validity (Lichtenstein & Plowman, 2009).

2.3.10.3 Coevolution to the edge of chaos

Taking the previous element one step further, the mutual interaction of individual agents generates co-evolutionary outcomes, as each agent's choices are executed the [fitness] landscape shifts. Anderson (1999) applies the rule of Kauffman (1993), the equilibrium that results from such interactions is dynamic, not static; therein small changes at time t produce compounding, large affects at time $t + 1$ [+1; *ad infinitum*] (Anderson, 1999). The argument proposes that due to the nature of dynamic interactions and interdependency, the future is ultimately unknowable (until it occurs) (Anderson, 1999; Marion & Uhl-Bien, 2001; Prigogine, 1997).

2.3.10.4 System evolution based on recombination

Through the process of changing linkages between agents and shifting patterns of interconnectedness, organisational structure emerges of its own accord. Anderson's (1999) model of recombination resembles that which is later explored in practice by Chiles, Meyer & Hench (2004). Through the dynamic interactions of individual agents, structure emerges at higher levels in the system, these structures may or may not be known to agents at lower levels in the system. Many examples exist in nature where agents have very little or no capacity for cognition on the behaviour of the entire system, yet are capable of participating in the creation of its complex architecture. The application of the same theory to human social and organisational systems calls for a more detailed exploration and understanding of the nature of the interaction between agents, as this is the driving force behind the creation of order, which can be interpreted in many different ways by the differing perceptions and qualities of the individuals concerned.

An important development from the essential components of complex adaptive systems, is the finding that structure emerges from the interactions of agents within a system, without outside control (Drazin, 1992). The nature of the entity itself, and its construction, is a product of interactions and processes within the system. Origins on the idea of emergent structure in social systems has been referred to, via Durkheim (1997) reference to 'methodological individualism', the 'secret of sociogenesis and social dynamics' of Elias (1978), and 'interfunctioning of the parts' of Follett (1998). While each of these writers grapple with cognitive function and social interplay as elements within the co-construction of new realities – none provided a more compelling view of the physical processes of emergent self-organisation than the work of Nicolis and Prigogine (1977) on dissipative structures in chemical systems.

2.3.11 Dissipative Structures

The Dissipative Structures Theory quantitatively demonstrated the spontaneous emergence of complex structures in the conditions of a far from equilibrium state (Prigogine, 1997). Common examples of emergent physical structures include a vortex, convection, cyclone or experiment-based examples such as Bénard cells (patterns found during convection of liquid), Belousov–Zhabotinsky reaction (non-linear chemical oscillation with pattern) (Capra, 1996). Prigogine (1997) tackled the need for a molecular explanation of the irreversibility of time, and defined the processes of self-organisation in chemical systems at far from equilibrium states. The same concept has been applied to the context of social and organisational systems, where individual agents are the autonomous individuals or groups that operate within the system (Anderson, 1999). Each of the following four characteristics distinguish the behaviour of dissipative structures, and are discussed in sequence: (a) far from equilibrium state; (b) amplifying actions; (c) stabilising feedback; and (d) emergent self-organisation (Prigogine, 1997).

2.3.11.1 Far From Equilibrium State

In the years preceding the works of Prigogine (1977) a commonly held notion was that states of disequilibrium were associated with disorder and chaos. Hence, it is not surprising that the concept of a dissipative structure generated such interest and made famous the concept of chemical change at far from equilibrium states (Plowman & Duchon, 2008). The concept comes into play when systems are injected with increasing amounts of energy that is then dissipated through the system (Lichtenstein & Plowman, 2009). As a result of the interactions between agents, unpredictable patterns form, referred to as 'highly complex behaviour' during a phase in which order and disorder coexist (Kauffman, 1993; Plowman & Duchon, 2008), also called the 'edge of chaos' (Osborn et al., 2002) or 'region of complexity' (Maguire & McKelvey, 1999).

The concept of disequilibrium can be applied to social and organisational science, however this abstraction does require conceptual thinking. Plowman & Duchon (2008) argue it is only as organisations move into this far from equilibrium state that adaptations are possible. The application of the term 'disequilibrium' may have less positive connotations in lay terms without full explanation of its meaning in complex systems. Osborn et al. (2002) provide a useful framework to describe this state in an organisational context, describing the presence of five key factors: transition zone poised between order and chaos; future performance in danger but with prospect; changing definitions of success; transient focus on changing priorities; and the diversification of schema and internal/external networks.

In their longitudinal study of Mission Church, Plowman et al. (2007) argued that far from equilibrium conditions were a catalyst for emergent self-organisation, but were unable to identify the precise point at which a new structure emerged. Chiles et al. (2004) propose that organisational communities emerged and remained at a continuous state of disequilibrium, using diversity as an indicator of disequilibrium in a 100-year study of Branson, Missouri's Musical Theatres. The shared theme of these two empirical studies is the focus on a significant shift away from stability that stimulates an emergent structure or process.

2.3.11.2 Amplifying Actions

In 1963, Lorenz published an article in the *Journal of Atmospheric Science* entitled *Deterministic Non-periodic Flow*; the paper argues that 'non-periodic solutions are ordinarily unstable with respect to small modifications, so that slightly differing initial states can evolve into considerably different states' (Lorenz, 1963). Lorenz (1963) referred to the slight change of variables in a weather mapping system and noted their enormous ramifications on the feasibility of long-range weather prediction. Lorenz (1963) equation has been famously extended to many other fields, and refers to the heightened sensitivity to small [or initial] fluctuations in complex adaptive systems that are in a highly dynamic state of disequilibrium (Kauffman, 1993). The nature of interdependencies between components of the system 'amplifies' positive feedback through a cycle of self-reinforcement (Anderson, 1999). In the process of amplifying actions, a cycle of feedback helps a new level of structure gain momentum and stabilise (Chiles et al., 2004).

The application of amplifying actions to organisation science is noted in several works including Plowman et al. (2007), Anderson (1999), Chiles et al., (2004). The preposition inferred from the construct of amplification is that small initial changes can have significant ramifications for organisations in times of unprecedented stress (Plowman & Duchon, 2008). The function of interdependent agents interacting of their own volition implies that uncertainty and unpredictability is not merely a function of external environments but is also a product of internal behaviour. Plowman et al. (2007) propose that empirical research supports the notion that small, even single adaptations can lead to radical, accidental change. The interactions between individual agents that result in the amplification of small changes is important to overall system-level behaviours especially in times of turbulence (Plowman & Duchon, 2008).

2.3.11.3 Recombination/Emergent Self-Organisation

Emergent self-organised patterns of behaviour are the 'anchor point phenomenon' of complex adaptive systems, and refer to the process whereby system level order spontaneously emerges as individual agents pursue individual plans with only local knowledge, casual feedback, and no central point of control (Chiles, et al., 2004;

Anderson, 1999). The phenomenon of emergence is not unique to the internal workings of organisations or between individual people – and may also be observed across organisations (Chiles et al., 2004) or through the emergence of entirely new ventures (Lichtenstein, 2000). Extending further on the philosophical and mathematical treatment of self-organisation across all living and cognitive systems, Maturana & Varela (1987) define a circular method of organisation common to all living things – autopoiesis, as discussed previously.

The emergence of order may also occur between levels of an organisation, where underlying behaviours arise into aggregate structures at higher levels. Mandelbrot (1982) recognised the presence of these recurring 'fractals' in geometry to describe repeating patterns in nature at various scales and complexity. The concept of patterns and scales between aggregates or levels in a 'nested' system is an important consideration in the interplay between individual agents and system level structure (Plowman & Duchon, 2008; Anderson, 1999). Complex adaptive systems have a tendency toward self-organisation as individual agents learn, adapt, interact and intersperse. A useful example is the eusocial systems of termites that follow simple rules with relatively small levels of cognitive power, yet are collectively able to construct elaborate colonies and exploit food sources that would be unavailable to an insect living in isolation (Plowman & Duchon, 2008).

2.3.11.4 Stabilising Feedback

In the case of Mission Church, Plowman et al. (2007) argue that an emergent transformation occurred at a point when a convergence of forces moved the organisation toward instability and disequilibrium. Following the emergence of a new order, stabilising [negative] feedback enabled the new structure to be sustained within its new configuration (Lichtenstein et al, 2006). The presence of stabilising feedback in an organisational system may refer to the institutionalisation (Chiles et al., 2004) of change and its increasing legitimacy as a new format of organisation (Lichtenstein et al., 2006). The importance of the function of feedback is a common element to numerous viewpoints on the operation of complex systems and is a central theme in classical and second order Cybernetics, General Systems Theory and complexity theory. Feedback is necessary to enable the functioning of interaction between components and the quality or strength of feedback or its channels may in turn be a factor in the performance of self-organising systems. Further research applications may benefit from consideration of the importance of feedback, discussed in this study as an element in the direction and increment of influence.

2.3.12 Models of Self-Organisation

Emergent self-organisation, or simply *emergence,* is the anchor point phenomenon of complexity. Emergence is a process whereby system level order spontaneously arises as individual agents interact with only local knowledge or rules, reinforcing feedback and no central point of control (Anderson, 1999; Chiles et al., 2004). Self-organisation is evident across nature, helping to explain how inextricably, coordination and novelty emerges in the absence of external control – anecdotally, it could be said there are no managers in nature (Kauffman, 1993; D. A. Plowman & Duchon, 2008).

The application of principles of self-organisation to modern firms is however not without its obstacles. Among these is the long-held expectation placed on managers and leaders for the delivery of stable, coordinated and predetermined outcomes, particularly in times of crisis or toward collective ambition (D. A. Plowman & Duchon, 2008). However, the conduct of leaders and interactions among individual agents do not need to be opposite sides of the coin (i.e. it is not suggested here that leaders are unnecessary) rather, they are participants in social pattern and system level order. As alluded to in the latter works of Prigogine (1997), complexity dynamics may signify the 'end of certainty', albeit the birth of a new science of organisation to supplant uneven conclusions about the purpose, direction and increment of influence and its impact on the creation of macro-level order.

To assist in a complete assessment of the concept of emergent self-organisation a number of examples are reviewed below with reference to the subject matter to which they apply, supported with brief explanation (see Table 2.9). It would be far too extensive to include all mathematical workings that describe each these models of self-organisation; hence they are detailed in qualitative terms – with reference to the source literature. Only empirically tested examples are included. The variety of each of the models of self-organisation demonstrates the pervasiveness of emergence as a concept to understand complexity, and the important findings they have revealed about the world around us.

Table 2.9 Models of Self-Organisation

Model	*Brief Explanation and Authors*
Ecosystem	In the 1940s, von Bertalanffy coined ecological living structures as ‘open systems’ emphasising their interdependence on the surrounding environment. von Bertalanffy also used the term *Fliessgleichgewicht* [flowing balance] to describe the structure and change across all forms of life, the interrelationships and interdependencies of an ecosystem are a prime example of general systems theory at work, with the properties of emergent self-organisation across each level within the system (von Bertalanffy, 1951). IMAGE REDACTED

	Image credit: Your Article Library.
Bénard cells	In natural convection, a pattern of cells appears as a result of buoyancy and gravity, and the uprising of less dense fluid from a heated bottom layer – thus producing a pattern of cells which is clearly visible without apparatus (Cross & Greenside, 2009). IMAGE REDACTED Image credit: Autodesk research.

Belousov–Zhabotinsky reaction	Nonlinear chemical reaction. Due to *autocatalysis*, the region expands from its origin as the molecules diffuse into the base solution and induce 'tipping', as the rate of diffusion is equal in all directions, the expanding wavefront is circular (Ball, 2009). IMAGE REDACTED Image credit: (Ball, 2009)
Light amplification through simulated emission of radiation	'A passing light wave can simulate … or induce an excited atom to emit its energy in such a way that the light wave is amplified. This amplified wave can, in turn, stimulate another atom to amplify it further, and eventually there will be an avalanche of amplifications. The resulting phenomenon was called 'light amplification through simulated emission of radiation', which gave rise to the acronym LASER' (Capra, 1996). IMAGE REDACTED Image credit: Advanced optical communication By Er. Swapnl Kaware
Patterns in phase space	The Lorenz attractor is an example of how a simple set of nonlinear equations can generate both enormously complex behaviour, in this case for weather modelling, with irreversibility and amplification of small change, but also a

	clear and emergent pattern in three-dimensional phase space (Lorenz, 1963). A further example is the fractal geometry in natural phenomena and Mandelbrot sets (Mandelbrot, 1982). IMAGE REDACTED Image credit: (Lorenz, 1963).
Hypercycles	Progressive organisation at far from equilibrium states in chemical systems, involving feedback loops and a complex of multiple cycles (Thompson & McBride, 1974). IMAGE REDACTED Image credit: Principia Cybernetica [Hypercycle structure. I_i are RNA matrices, E_i are replication enzymes (i = 1,2,...,n).].
Plant cells	Metabolic and respiratory processes of plant cells under normal conditions, also demonstrating autopoiesis (Know, 1994).

	IMAGE REDACTED Image credit: (Capra, 1996).
Daisyworld simulation	Simulation assuming a global population of non-interacting organisms (daisies) that modify their local behaviours, thus self-regulating the temperature of the earth and demonstrating a recursive species-environment interaction. In this model species-environment interaction is the basis of the model, specifying a dynamic fitness landscape and self-regulating ecosystem of adaptive agents that achieve global regulation via feedback loops (Watson & Lovelock, 1983). IMAGE REDACTED Image credit: (Capra, 1996).
Swarms and collective intelligence	The collective behaviours and of numerous agents, which on aggregate exhibit collective intelligence in their behaviour, such as the flock of starlings, schooling of fish, colonies of ants, bees, locusts or terminates and non-random growth of plants (P. Miller, 2007). IMAGE REDACTED

	Image credit: http://hankhehmsoth.com/ [starling flock facing a predator]
Economies	The naturally occurring self-regulation of economies and free markets, arising from the multitude of interactions and self-interests of participating agents (A. Smith, 1776). The image below illustrates a systems view of a basic market, the recursive flow of money, where demand creates supply, which in turn furnishes demand. Systems of this nature are more difficult to provide a complete model. IMAGE REDACTED Image credit: adapted from (McGuigan, Moyer, & Harris, 2014) [circular flow of money in a hypothetical two-sector economy].
Traffic flows	Complexity dynamics and emergence of pattern in modern traffic flows (Adewumi et al., 2016).

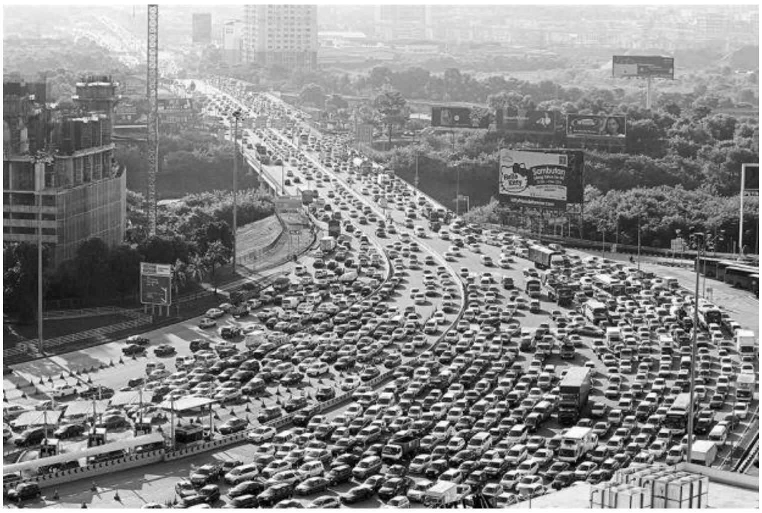
	 Image credit: The Star Online [peak hour in Kuala Lumpur]
Cities	The non-random growth of cities, emergence of clusters, urban centres, efficiencies and distribution of intellectual capital throughout the development and modernisation of cities (S. Johnson, 2001) IMAGE REDACTED Image credit: NASA [London at night]
Societies and social networks, and social systems	Emergence of the social fabric and operations that enable structure, hierarchy and order to emerge in society, through ‘methodological individualism’ and the pursuit of both shared and unique ambitions (Durkheim, 1997). Social systems as autopoietic (Luhmann, 1986; Mingers, 2002). Examples of large scale, big data online social network analysis by (Grandjean, 2014).

	IMAGE REDACTED Image credit: (Grandjean, 2014).
Public opinion	Diffusion and spread of public opinion, demonstrative of the mechanisms for self-regulation, albeit reliant on ‘micro-rules’ as the basis upon which agents interact with their neighbours and collectively adapt to changing landscapes, also through democratic voting systems (Alves et al., 2002; J. H. Miller & Page, 2007). Spatial distributions of vote intentions as subjected to mass media influence, at (a) societies with low and (b) high ideological strength. The density of the majority group (in white) is noticeably increased (Alves et al., 2002). IMAGE REDACTED Image credit: (Alves et al., 2002)
Of organisations	Emergence of new organisational entities (start-ups) viewed through the processes of a dissipative structures theory (Lichtenstein, 2000b). IMAGE REDACTED Image credit: (Lichtenstein, 2000b).
Between organisations	Emergent of a single form arising through organisational interaction, or ‘agglomeration’ through positive feedback, recombination and stabilisation dynamics (Chiles et al., 2004).

	IMAGE REDACTED Image credit: (Chiles et al., 2004)
Within organisations	Radical change emerging within an organisation as a result of the interaction of autonomous agents with schemata (D.A. Plowman, Baker, et al., 2007). The image used below illustrates the distribution of (patterned) opinions in a simulated group. A series of graphs show the growth of (a) initial distribution of opinions, and (b) final equilibrium of majority opinion at the expense of the minority, which survives by forming clusters and final equilibrium clustered around individuals with ‘strong’ influence (Vallacher & Nowak, 2008). IMAGE REDACTED Image credit: (Vallacher & Nowak, 2008)

Source: constructed with paraphrasing from various authors identified above.

In each of the prior examples, common elements are found that can be illustrated visually – using a hypothetical logic diagram to express the relations between elements in the system and the arising pattern. A visual representation of this pattern of explanations and theoretical explanation is demonstrated at Figure 2.13, as a conceptual diagram only, to visualise the relative uniformity across each of the preceding examples.

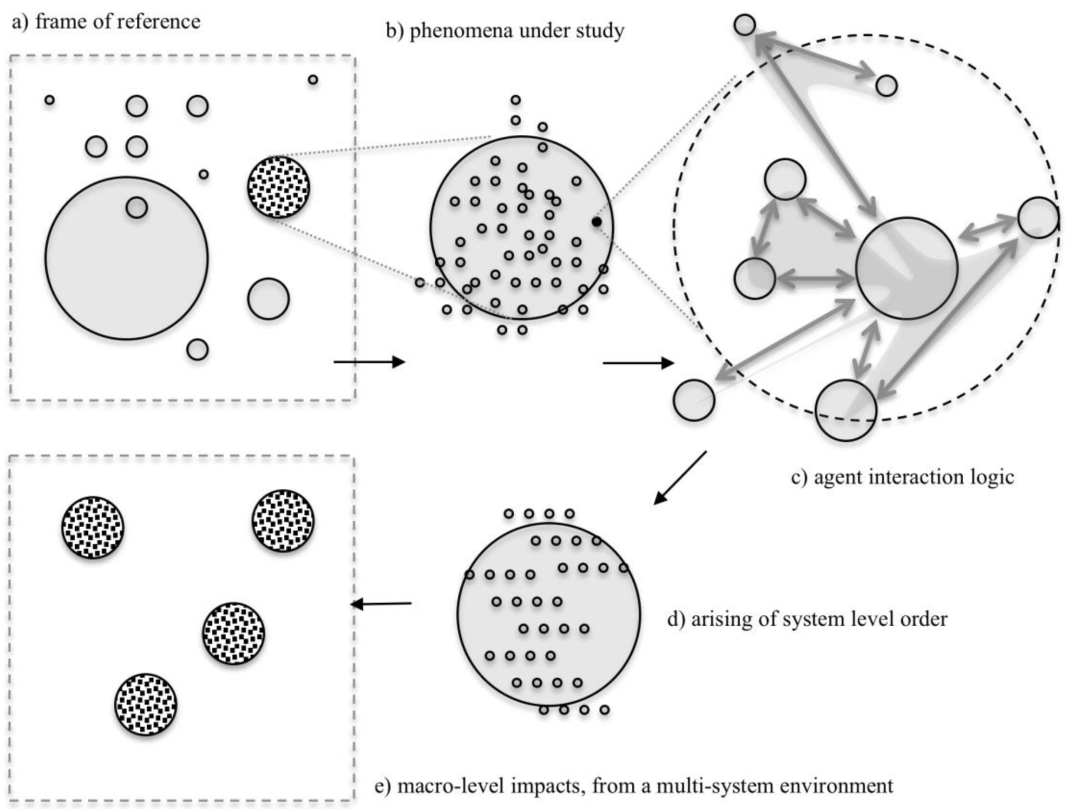


Figure 2.13 Relative Uniformity in Models of Self-Organisation

Source: formed from a distillation of analyses of the preceding authors across this section.

As expressed at each model of self-organisation, a common frame of reference is observed, including: (a) a frame of reference to extrapolate meaning from the system under study; (b) phenomena comprised of numerous interacting agents which in an initial state are in disorder and approaching far from equilibrium conditions; (c) agent interaction logic within the system itself, there may also be further nested systems, or at least the dynamics of interaction are strong enough to cause a change in behaviour among one or many of the agents within the system, resulting in co-construction of new realities, motion or affected actions; (d) these changed actions are put back into the context of the system, thus demonstrating an emergent order or pattern arising at a higher level in the level in the system to the underlying patterns of interaction; (e) changed behaviour causes a further level of organisation within the frame of reference, especially when more than one such system is observable, as the case may usually be for organisations, societies, economies or chemical and biological systems with an uncounted population of nested systems.

2.3.13 Complexity and Organisational Change

'You cannot step twice into the same river, said Heraclitus, for in the interval between your first and second steps, the river has changed as have you', in Ablowitz (1939). In a global economy characterised by uncertainty, the capacity to adapt has become a core organisational capability (Brown & Eisenhardt, 1997; Burnes, 2005; Dawson, 2003; Dunphy, 2003; M. T. Hannan et al., 2003; G. Johnson & Scholes, 2002). Despite rudimentary agreement that change is commonplace among organisations, there exists a plethora of alternatives and accompanying debate when it comes to what approaches an organisation may take in response to these demands. A frequent observation in this regard is that the track record of managing organisational change is relatively poor (Brown & Eisenhardt, 1997; Burnes, 2005; Dawson, 2003; M. Hannan & Freeman, 1984; Stace, 2001; Stacey, 2003).

The concept of change holds a unique place in complexity theory, as its prepositions are related to dynamic interaction and adaptation, where change is necessary, unpredictable and continuous (Marion, 2008; Anderson, 1999; Chiles et al., 2004). An appreciation of the complexity and unpredictability of systems has not always played an explicit role in change management theory (Lichtenstein & Plowman, 2008). The planned approach to change dominated 1950s literature, crowned by Kurt Lewin's 'unfreezing' process, consisting of three stages: unfreezing, changing, then freezing once again (Burnes, 2004). Although the simplistic iceberg metaphor of Lewin's model has been brutally critiqued over the last 20 years, it is arguably not at odds with the fundamental notions of complexity, to be discussed shortly (Burnes, 2004; Pettigrew, 1990).

Complexity theory and its prepositions do not currently provide a precise and explicit method on how to plan, control, organise and lead an organisation or how to handle change in particular circumstances (Marion & Uhl-Bien, 2001; Burnes, 2005; Plowman & Lichtenstein, 2009). Despite its colourful history when it comes to organisation science, elements of complexity theory largely remain in the metaphorical domain without tested empirical support as a change management tool (Burnes, 2005; Lichtenstein & Plowman, 2009; Marion, 2008). The challenge of complexity is not that its prepositions are irrelevant, impenetrable or unreflective of the world around us, but rather that their practical application and commercial viability are not immediately apparent or well understood (Marion, 2008; Smith & Graetz, 2006; Moldoveanu & Bauer, 2004; Brodbeck, 2002).

The opportunity for complexity theory to shed light on organisational change is illustrated by the Brown and Eisenhardt (1997) appraisal of the inadequacy of models for understanding and making use of continuous change, and the possibilities for a new theory of complexity to unlock these opportunities through innovation. A range of organisational theorists have extrapolated the view that organisations are complex and that individuals within those organisations play an important role in the formation of strategy and structure (Mintzberg, 1994; Wheatley, 1999; Marion & Uhl-Bien, 2001; Burnes, 2005). The need for organisations to change to suit their environment could be equated with the need for natural or ecological systems to adapt or evolve over time for the purposes of survival. Brown and Eisenhardt (1997) argue that highly competitive firms will survive only through continuous innovation that relies on the application of a few specific practices.

> Successful multiple-product innovation involves improvisation of current projects through limited structures and real-time communication, experimentation into the future with a wide variety of low-cost probes, and rhythmically choreographed transitions from present to future. These practices form a core capability for creating frequent, relentless, and endemic change that is associated with the success of firms in high-velocity, competitive settings. (Brown & Eisenhardt, 1997).

It may be of value to note the application of either continuous or punctuated models of change in organisations is constrained by numerous cultural and situational factors; these can be referred to as structural inertia (Hannan & Freeman, 2003). Factors that generate inertia at the structural level include physical infrastructure, equipment, personnel, culture, internal politics and the tendency to normalise behaviours (Hannan & Freeman, 1984). The strength of structural inertia is such that it may prevent critical changes from occurring to the point that it results in an organisation's demise. The theory of structural inertia argues that variability in organisational configuration can be explained by the evolutionary processes of natural selection (through organisational failure) occurring at the population-level, such as across an industry or economy (Hannan & Freeman, 1984). Conversely, opposition to the proposition of natural selection in the population ecology of organisation science is that organisational life cycles are based on a 'false analogy' with the life cycles of animals and plants (Levie & Lichtenstein, 2010) often referred to as a form of stages theory. The life cycle model of Lippitt and Schmidt (1967) proposes that: 'like people and plants, organisations have a life cycle'. This life cycle generally consists of three to five stages: birth, growth, maturity, decline and death (Levie & Lichtenstein, 2010; Daft, 2010).

Levie & Lichtenstein's (2010) contrasting view to stages theory argues that organisations are entirely unlike animals or plants, and through adaptation can renew themselves continuously, an argument that follows from Prigogine's (1977) 'perpetual novelty' theorem. Levie & Lichtenstein (2010) argue that the life cycles of organisations are not predicable and are also capable of stagnation then renewal. A contemporary and sociological view of the stages theory of organisations using the lens of complexity theory may benefit from further consideration of the notion of sustainability in an environmental and organisational sense. Further development of theory may also take into consideration the research implications of post-extinction networks, i.e. although organisations perish, the individuals within them continue to live on, therefore extinction may be considered a normative function of population ecology (Levie & Lichtenstein, 2010), and a product of adaptation arising from underlying micro-system behaviours. Also of importance is an understanding of the role of leadership in complex systems in bringing about organisational change.

2.3.14 Leadership, Dynamic Interaction and Influence

This section asks three key questions to explore the relationship between complexity theory and influence as a function leadership: what is the role of leadership influence in emergent self-organisation; how is leadership defined in a complex system; and what are the implications of a complexity-inspired form of leadership theory. Firstly, considering the major thrusts of complexity theory, such as: unpredictability, self-organisation, emergent rules, disequilibrium, chaos, and uncertainty, it would be natural to assume that leadership in complex systems may not exist at all. Earlier works in the pursuit of a new Complexity Leadership Theory have arrived at the conclusion that organisations need to be totally reconceptualised to cater for the dynamic and emergent qualities of a complexity viewpoint (Marion & Uhl-Bien, 2001; Marion, 2008). Rather, this study focuses first on the deficiencies in operationalising complexity in a general sense, followed by its subsequent application and confirmation in practice.

The driving force behind the re-conceptualisation of leadership lay in its underlying premise that is tied to Cybernetic notions of control, predictability, design, specification, direction setting, and achievement (Lichtenstein & Plowman, 2008). The application of complexity theory to leadership does not seek to remove the function of leadership, but rather to apply a more complete understanding of complex behaviours and dynamics through appropriate interactions between organisational actors (Marion & Uhl-Bien, 2008; Plowman & Duchon, 2008). For example, a complexity-inspired view of the function of leadership may help identify localised instances of adaptive behaviour and enable the emergence of behaviours and interdependencies that support ‘bottom-up’ innovations (Meyer, 2005; Marion, 2008).

Secondly, the use of complexity theory in organisation science implies the need for a new understanding of its meaning. Leadership has many definitions and implications in a variety of fields. Table 2.10 demonstrates four prominent variants of leadership, among a range of alternatives and subtypes, with emphasis on the function of influence.

Table 2.10 Definitions of Leadership

Author	*Definition of Leadership*
Yukl (2006), p. 3	Process whereby intentional *influence* is exerted by one person over other people to guide, structure and facilitate activities and relationship in a group or organisation
Katz and Kahn (1978), p. 528	The *influential* increment over and above mechanical compliance with the routine directives of the organisation
Chemers (1997), p. 1	Leadership is a process of *social influence* in which one person is able to enlist the aid and support of others in the accomplishment of a common task
Robbins (1997), p. 138	The ability to *influence* a group toward the achievement of goals
House et al. (1999), p. 1984	The ability of an individual to *influence*, motivate and enable others to contribute toward the effectiveness and success of the organisation
Graen and Uhl-Bien (1995), p. 224	Trust, respect, and mutual obligation that generates *influence* between parties

Note: source of definitions noted within the table, emphasis added.

Two common subtypes of leadership theory, transactional and transformational leadership often appear at opposite ends of the spectrum, however they share a similar emphasis of the leader as the orchestrator (or key influencer) toward social organisation or movement and the focal point of vision and core values (Lord, 2008; Plowman & Duchon 2008). The general application of complexity principles to leadership implies a unique understanding of the direction of influence enacted by 'leaders' whether emergent or explicitly recognised in a formalised structure. Complexity theory proposes that systems arrive at points of order via an essentially 'bottom-up' process (Lord, 2008). This observation suggests that our current understanding of the archetypical role of leaders in predicting, determining, controlling and organising toward desired futures is profoundly incomplete (Marion & Uhl-Bien, 2001; Lord, 2008).

The study of leadership in complex systems as a subset of complexity theory deserves its own fulsome consideration; hence it will not be possible to explore every avenue of its application in this study. To address the need to include adequate consideration of leadership, the element of leadership that is most relevant has been applied – that which relates to its definition concerning influence (Plowman & Duchon, 2008) as highlighted at Table 2.10.

Given the focus of this study on agent interaction, the nature of leadership is taken into account (by its common definition) as the direction and increment of influence in the interaction of agents that lead to an observable outcome (Yukl, 2006; Katz & Kahn, 1978; Robbins, 1997; House et al., 1984). From this point of view, leadership may be exerted as a formalised role or as an emergent quality of individuals within the system.

Finally, the implications of a new understanding of leadership are profound (Marion, 2008; Plowman & Duchon, 2008). The complexity lens raises questions about the underlying assumptions the have driven the conventional view of leadership as one person influencing others to achieve intended outcomes (Robbins, 1997; Plowman & Duchon, 2008). If emergent self-organisation is a characteristic of social and organisational systems, what role do leaders play in enabling emergent behaviours and what level of ownership do they have when intended outcomes are/are not achieved? Moreover, is it possible to achieve a level of organisation in the absence of a conventional form of leadership and management? Within existing literature, it is not possible at this point to answer all these questions plainly. Rather, they are incorporated into the program of research through an exploration on the underlying function and process of emergent self-organisation, with a focus on social influence.

While a complexity-inspired theory for leadership may elicit only small changes in management practice, these may support the capacity for emergence as part of a more significant shift from the suppression of natural tendencies to embracing and enabling more adaptive forms of organisation, sustainability and continuous renewal (Levie & Lichtenstein, 2010; Marion & Uhl-Bien, 2001; Plowman & Duchon, 2008; Lynham, 2002). Complexity principles assert that small changes among interdependent agents can result in a cascade of dramatic and unpredictable impacts the combined effect of which may give rise to new structures or schemata (Goldstein, 2008). From this principle, one individual agent within a complex system can neither predict the future nor can they control it – a profound implication for a world dominated by highly concentrated powers. With this preposition in mind, one may be inclined to ask 'can leaders still lead when they don't know what to do?' so put by Lord (2008).

Despite numerous definitions and theories of management and possibly more of leadership, many arrive at a shared focal point for the concept of leadership as the exertion of influence over others via a range of mainly social mechanisms and from varying points of view. Influence may originate from individuals regardless of their formal leadership responsibilities and may be interpreted by others in a range of ways; for this reason the study of leadership has less clearly defined boundaries than one may initially think (Graen & Uhl-Bien, 1995). Understanding the function of influence, irrespective of its formalisation (or lack thereof), is therefore a key element in unpacking the implications for organisations and management, and in answering the previous questions on the nature and role of leadership in complex human social systems.

2.3.15 Implications for Organisations and Management

As discussed earlier, a dominant theme in leadership and consequently on the structure of firms relates to the function of influence and centralised coordination (Yukl, 2006; House et al., 1999). Hierarchical structures are arguably premised on the notions of post-WWII Cybernetics in which communication and control via circular feedback loops were a central focus. Given the prevalence of the current organisational form, there is reason to believe that human social and organisational systems have a tendency to move towards hierarchical and pyramid formations of command, an expectation of which is that managers and leaders play a pivotal role in determining future states and pathways (Marion, 2008; Plowman & Duchon, 2008; Marion & Uhl-Bien, 2001).

Table 2.11 presents an integrative framework of key prepositions adapted from Plowman et al., (2007), Plowman & Duchon (2008); Schneider & Somers (2004), Marion & Uhl-Bien (2001 and Anderson (1999).

Table 2.11 Complexity Principles and Implications for Organisations and Management

Complex Adaptive Systems Theory Principle	*Cybernetic Organisational functions of Leadership and Structure*	*Implications and Questions for Organisations and Management*
Disequilibrium – importation of energy and information which is dissipated through the system, creating disorder and ultimately leads to some new unpredictable order	Leaders eliminate disorder and the gap between intentions and reality, disequilibrium is avoided (Plowman & Duchon, 2008)	Patterns of behaviour are destabilised, structures are adopted that create adaptive tensions, futures and plans are uncertain, energy is naturally dissipated, and agents generate rules? (Plowman et al., 2007)
Amplifying actions and sensitivity to initial conditions – small fluctuations can have huge, unpredictable consequences	Planned change is designed and executed along a predetermined path, adapting along the way (Mintzberg, 1994)	Small changes flourish, networks are self-organised, innovation comes from anywhere; swarm behaviours emerge, strategy is unknown until practiced? (Mintzberg, 1994; Plowman et al., 2007)
Emergent self-organisation – system level order emerges as interdependent agents act, exchange information, and continuously adapt to feedback about others actions	Organisational structures are planned, roles designated, outputs specified and performance in managed toward ends (Burnes, 2005; Plowman & Duchon, 2008)	Emergent structures are enabled, previous structures or unadapted agents are discarded, and goal directedness determined by agents, simples rules are tested, agent connections are enhanced, leaders and followers interchange, unpredictability perpetuates tension? (Plowman et al., 2007; Anderson, 1999)
Stabilising feedback – in dynamic systems occur because multiple players with diverse agendas are interconnected and affect each other's actions	Leaders influence others to enact desired futures (Robbins, 1997)	Structures stabilise, simple rules are recognised, reinforcing feedback is transparent and universal, agents affirm networks, systems stabilise? (Plowman & Duchon, 2008; Chiles et al., 2004)

Source: Adapted from D. A. Plowman and Duchon (2008).

A number of empirical studies into the emergence of new forms within, across and of organisations have included propositions concerning the role of leadership to enable, encourage and make sense of complex patterns for the purpose of organisational evolution (Chiles et al., 2004; Lichtenstein, 2000; Plowman et al., 2007).

A shared view from the prior list of studies is the observation that the archetype of the leadership function is grounded in an assumption that the primary direction and weight of influence is from the top-down. A serious question for the further development of complexity theory (and of leadership) is what implications and opportunities does the concept of emergent self-organisation hold and are these opportunities realistic or commercially viable? The synopsis of implications presented in Table 2.11 may represent a reality that is undesirable for many organisations and their leaders. However these factors may already be present in the existing 'messiness' of a complex social and organisational world. Hence a more comprehensive understanding would be helpful to make sense its unpredictable behaviours.

There are a number of implications and questions for organisations and management that naturally lead from the lens of complexity. At first glance, many of the antecedent conditions [principles] and implications (see Table 2.11) could be seen as counterproductive, divergent or a reflection of chaos and disorder in an organisation. Typical definitions of leadership are often targeted at eliminating disorder and closing the gap between current states and future goals, while generating a reliable output of value (Plowman & Duchon, 2008). In this case, disequilibrium and chaos are traditionally seen as a barrier to productivity or efficiency.

Although they should not be taken as a practical guide for the conduct of a new form of management, complexity implies a range of unique propositions about the operation of systems and the consequent function of leadership and influence. During a process of disequilibrium and self-organisation, patterns of behaviour may be destabilised and individuals may choose actions and responses based on their own volition, new structures may be adopted that suit changing adaptive tensions (Plowman et al., 2007). In contrast to traditional notions of organisational structure and the roles of management, rules on the operation of the system may come from individual agents and be sustained only via reinforcing feedback rather than being enforced. From the nature of assumptions directly extracted from complexity, it is reasonable to see why principles of complex systems do not immediately translate into much of today's management practice – at least not without major disruption to existing norms.

Most organisations have a need for predictability, stability, and order, to satisfy their public or private beneficiaries and to be able to plan and anticipate their creation of business or social value. The experiences of an organisation that allows for small changes to flourish, networks that are self-organised, innovation that comes from anywhere, swarm-like behaviours, and strategy that is unknown until practiced, are all pieces of the empirical picture that are gradually developing, but are without a common thread. In order to fully appreciate the implications for organisations, an exploration into influence processes and the state of associated literature is required.

2.4 Influence Processes in Organisations

2.4.1 Social Influence as an Organisational Process

A foundation of complexity theory is the proposition that the future is ultimately unpredictable. Nonlinear modelling of the behaviour of complex systems, demonstrate sensitivity to initial conditions and amplification of small changes causing irreversibility and uncertain future states. In human social systems, one of the main reasons why complex systems are unpredictable is due to the dynamic interaction and interdependencies of human agents (Marion, 2008). These dynamic interactions between agents are a product of 'history, random environmental perturbations and idiosyncratic social decision making', which combine to give rise to unpredictable results (Marion, 2008). While human and non-human complex systems share certain attributes, including the capacity for emergent self-organisation – human systems have several special qualities which set them apart from chemical or mechanical systems, by virtue of the dynamic interaction between agents acting as individuals or groups. Hence, this section examines literature to define dynamic interaction via social influence as a key process in complex organisations.

As discussed to this point, complex systems are comprised of numerous interacting agents that act on the basis of simple rules or schemata (Anderson, 1999). Human interaction however, is not akin to 'shaking rocks in a barrel' (Marion, 2008). Interactions between agents are dynamic, subjective, give rise to spontaneous new meaning, are veiled in human perception, subtlety, cognitive process and social structure (Marion, 2008; Vallacher & Nowak, 2008).
Human agents are a qualitatively unique kind of complex system. While the nature of interaction between human agents is substantially complex and unpredictable in itself, interactions do give rise to pattern and are sufficiently robust to generate durable, emergent structures (Anderson, 1999; Chiles et al., 2004; Hazy, 2008b). The dynamic

interaction between human agents is a potent source of influence for changed behaviour.

> Interactive behaviours and outcomes feedback on one another in convoluted fashion, with effects becoming causes and with influence often wielded through extended chains of effect. (Marion, 2008).

Then, complexity and the theory of emergence examines patterns that emerge from these complex interactions, which give rise to system level behaviours and order. In this way, dynamic interaction and *social influence,* even as a black box process, is a principal driver in emergent self-organisation. Social influence is the mechanism by which agents mutually affect changed behaviours, which then form and constitute an emergent pattern.

> Human experience reflects the interplay of myriad forces operating on various time scales to promote constantly evolving patterns of thought, emotion, and behaviour. Yet people's mental states, actions, and social relations are also characterised by coherence and stability. The simultaneous dynamism and coherence of human experience represents a serious challenge for traditional theories and research paradigms in social psychology, but it reflects the essence of dynamical systems. (Vallacher & Nowak, 2008).

As argued by Vallacher and Nowak (2008), human systems are unlike any other, but do possess the fundamental character of non-linear dynamical systems that is then of use to quantitatively model structure and the diffusion of meaning. Social influence is a central feature of the transaction between individuals and groups within the system – hence, a crucial feature in understanding the behaviour of complex human social systems. While the transfer of 'energy' between human agents continues to be applied at an abstract level, it could also be the case that instrumentation to detect and decode data of such magnitude simply do not exist – to quantitatively document and decipher neurological data to the extent it describes consciousness. Regardless, the transfer of information even in non-human and Cybernetic systems wrestles with a similar issue.

> The transfer of information cannot take place without a certain expenditure of energy, so that there is no sharp boundary between energetic coupling and informational coupling. (Weiner, 1954).

With this in mind, it could be argued that the dissipative structures theorem fits to the world of human social systems, on the assumption that order is generated at far from equilibrium states through the dissipation of energy (Prigogine, 1997). Instability builds at far from equilibrium states to a point of adaptive tension breaking, where new forms emerge via nonlinear interactions. The process itself is described by Marion (2008) as follows.

> Unlike criticality, external agents (e.g., leaders, environmental pressures: any agent that controls energy) can influence dissipative structures. Put differently, external agents can control the knobs on Haken's stove'. (Marion, 2008).

However, there are several issues with this idea. Firstly, agents within a social system can control information and ply their trade to also control influence (or the influence of 'energy'), but to suggest leaders *control* energy in absolute terms suggests omnipotence. Second, the likening of 'energetic pressure' in heated oil to human systems is a major leap in empirical analysis, which appears to be largely undercooked with 'the stuff of traditional science' (Marion, 2008). The description of human social system as a 'dynamic soup of interactive agents and mechanisms that continually spawn … emergent changes' (Marion, 2008) is unfortunately vague and relatively imprecise.

From this perspective, it is a 'traditional' view to attach the function of influence only to designated leaders within an organisation, rather than view an organisation as a complex ecosystem of collective behaviour, regardless of title, rank or designation and with permeable boundaries (D. A. Plowman & Duchon, 2008). In this way, leadership itself is a relational process, and a potent source of influence, but is incapable of absolute control over current or future states (D. A. Plowman & Duchon, 2008).
The concept of social cohesion is not a distant strand of thought from the ideas of self-organisation in complex structures, although its conceptualisation as a supreme example of pattern in social systems is taken for granted (Luhmann, 1986). Durkheim's (1997) treatise, *The Division of Labour in Society,* finds a place and insight into the

emergence of organic 'solidarity', and in doing so, notes that social differentiation is not a universal precursor to interpersonal discord.

> If it is true that social functions spontaneously seek to adapt themselves to one another, provided they are regularly in relationship, nevertheless this mode of adaptation becomes a rule of conduct only if the group consecrates it with its authority. A moral or judicial regulation … rests in a state of opinion, and all opinion is a collective thing, produced by collective elaboration. For anomy to end, there must then exist, or be formed, a group which can constitute the system of rules actually needed. … The only one that could answer all these conditions is the one formed by all the agents of the same industry, united and organised into a single body. This is what is called the corporation or occupational group. (Durkheim, 1997).

Durkheim was clear on what the corporate organisation could accomplish, formed by and for the benefit of the agents of which it is constituted. However, Durkheim is vague on the mechanisms for organisation, structure and the communication or control over such a complexly interacting engine room of productivity and social good (Friedkin, 1998). The 'problem of social control' alluded to by Durkheim has not been entangled with complexity theory, despite at least three key areas of intersection between classical and current thinking: (a) a focus on voluntary mechanisms of coordination and control through social influence; (b) legitimised decision-making procedures through social choice; and (c) the operation of the free market and collective bargaining (Friedkin, 1998). Moreover, the cumulative vision of Durkheim is structural, not interpersonal.

Many aspects of the interaction process and resulting interpretations generate emergent dimensions, of emotion, meaning and other temporal frameworks. However, 'structural theory lacks a systemic analysis of the mechanics of the interaction process' (Rosenberg & Turner, 1981). Therefore, in order to understand emergent order in a social context, a cogent analysis of the interaction process is required. Symbolic interactionists have shed light on the formation of various types of agreements, [social] contracts and involuntary or subconscious alignments (Stryker & Statham, 1985). As noted in this work, agreement arises without an explicit demand for consensus; similarly, discord can arise with demands for order (Friedkin, 1998). Numerous autonomous agents with motive to connect, sensitivity to feedback and malleable schemata are precisely the actors required to form a complex adaptive system (Stacey, 1995). Applied research for a structural theory for social influence have enjoined mathematical techniques of network analysis to social structure – forming a relatively new branch of social network analysis, with increasingly sophisticated use of technology to capture and visualise emergent pattern (Grandjean, 2014). Several authors have made connections between social network analysis and complexity, presenting methods for the analysis of social networks in abstract space (Carroll & Burton, 2000; Costa, Rodrigues, Travieso, & Villas Boas, 2007).

Social influence in the domain of organisational processes is a force (or reservoir of potential force) exerted by an agent that results in a change in behaviour of other agent/s, either vertically or horizontally (Porter, Angle, & Allen, 2003). Although the concept of social influence and leadership are not synonymous, social influence is by many accounts a fundamental aspect of leadership in its various definitions (House et al., 1999; Katz & Kahn, 1978; Porter et al., 2003; Robbins, 1997; Yukl, 2006) and can be described not only in qualitative ways, but also in quantitative, probabilistic terms, as illustrated by Hazy (2008b); Howard and Matheson (2005).

If one were to remove the arbitrary lines of organisational structure, they would essentially be left with a complex system of social organisation. From this perspective, an organisation is fundamentally a cooperative social system made up of individuals and groups that collaborate in the pursuit of common interests or goals (C. I. Barnard, 1938; Porter et al., 2003). Social influence is a driver behind many of the productive and unproductive functions within formal organisational structures, and is a fundamental, necessary and immutable aspect of organisational behaviour (Porter et al., 2003). Almost all organisational members influence or attempt to influence others through various means, and all organisational members are subject to the social influence of others (Porter et al., 2003). The function of social influence is firmly embedded as an organisational function, and is frequently discussed in the guise of leadership (Burns, 1978; House et al., 1999; Katz & Kahn, 1978; Porter et al., 2003; Robbins, 1997; Yukl, 2006), particularly in the paradigm of leadership that considers itself an emergent, interactive ‘event’ that occurs spontaneously (Lichtenstein et al., 2006; D. A. Plowman & Duchon, 2008).

It is noted however, that leadership is not solely confined to the duty of influencing others (Yukl, 2006). Understanding social influence and its effect on the emergence of structure is especially important given its presence in almost every organisational type (Porter et al., 2003). Further, a structural theory of social influence posits that differentiation can make organisational outcomes difficult to achieve and maintain (Friedkin, 1998), whereas current theory of emergent self-organisation suggests that heterogeneity is an essential ingredient in the creation of emergent order (Kauffman, 1993).

A review of previous literature in the framework of theory building research (Lynham, 2002), reveals that although a history of empirical evidence for emergence exists in its origin fields, such as physics, chemistry and mathematics (Goldstein, 2008), transposing the theory of emergence into the social sciences relies on a theory-phenomena link, which at this point remains relatively underdeveloped (Burnes, 2005; McKelvey, 1999; Moldoveanu & Bauer, 2004; Yezdani et al., 2015). If leadership is to be properly understood as an emergent, interactive event that occurs between individuals (Lichtenstein et al., 2006), an explanation is needed to make sense of the role of influence in the emergence of self-organisation that occurs naturally, without explicit direction or formal designation (Hazy, 2008b), such as leadership influential increment (Katz & Kahn, 1978). The emergence of consensus through social process is explored through an exploration of how individuals are considered as the source and target of social influence, through the lens of social impact theory and dynamic social impact theory – the latter of which applies non-linear equations and adds complexity dynamics, and a structural perspective of social space.

2.4.2 Dynamic Social Impact

Social Impact Theory is based on three basic propositions: (a) *Individuals differ from one another* – in a multitude of ways people are different, therefore the theory uses the term *strength* that is the net of all factors that make a person influential; (b) *Individuals have relatively stable locations in space* – social impact theory uses the term *immediacy* to describe the locality of communication channels, based on the understanding humans remain relatively stable at their positions in physical and social space; and (c) *social impact is proportional to a multiplicative function of the strength, immediacy, and number of influence sources in a 'social force field'* – referring to how many individuals are either sources or targets of influence, *multiplicative* meaning if the component is low the result will also be low (Hogg & Tindale, 2008).

The methods of Social Impact Theory have been applied to restaurant preferences and tipping, voting participation, electronic juries, bystander helping in emergencies, stage fright, physical proximity, and social loafing (Hogg & Tindale, 2008). These applications of Social Impact Theory are static and do not attend to the dynamic interaction that more correctly characterise human social systems. Hence, in an extension to the original theory, *dynamic* interaction has been added in an attempt to humanise base assumptions (Hogg & Tindale, 2008). Dynamic Social Impact Theory adds three additional elements: (d) individuals vary in their strength of influence and are distributed in social space; (e) each individual in the system is influenced by their own bias and others within the system; and (f) a person will adapt their attributes of the persuasive impact outweighs the supportive impact (Hogg & Tindale, 2008).

While the work of Friedkin (1998) addresses the phenomenon of social structure of coordinated activity and consensus in differentiated communities and organisations, it is not a work in complexity theory *per se*, nor does it tie together the non-linear dynamics as a known property of dissipative structures. Coincidentally, while Friedkin was at work in the development of a structural theory of social influence, so too was a neighbouring explanation forming in Dynamic Social Impact Theory (Latané, 1996; Latané & Nida, 1981; Nowak, Szamrej, & Latané, 1990).
Dynamic Social Impact Theory draws from the principles of non-linear dynamical systems and applies them to the emergence of patterns of human consensus, opinion and culture.

Dynamic Social Impact Theory seeks to explain how patterns of consensus, common opinion and culture emerge from the interactions of humans in a social environment (Latané, 1996). Dynamic Social Impact Theory is essentially a theory of emergence for social norm and culture. The theory is general and applies to anything about a person that can be influenced – lifestyle, choices, moods, attitudes and beliefs. While the precepts of Dynamical Social Impact Theory are both attractive and promising, a pragmatic viewpoint is not currently applied. The patterning of social relations and formation of rigid structure is observable through network measures, as Friedkin (1998) and others (DiFonzo et al., 2013; Macy & Willer, 2002; Postmes, Spears, & Lea, 2000) have illustrated. However, describing the resulting network and observing its formation in a variety of settings is incomplete without supplying an understanding of the *process* by which these patterns form.

> One must look hard, in both the past and present literature in social psychology, for theoretical models of the social influence process that account for the emergence of collective decisions and opinions in natural settings and that take into account the network of interpersonal influences in this process. (Friedkin, 1998).

The formation of a working theory would benefit from merging an empirical understanding of the potential rigidity of social structure and dynamical processes of social impact, and defined (increments) of measurement for metrics such as *influence.* In an absence of definitive measures for opinion, influence and consensus, the work of Friedkin (1998) has been considered unable to deliver a model which predicts consensus with high levels of accuracy beyond a simulated environment (Strang, 2000). Nonetheless, Friedkin (1998) makes very good use of a probability of interpersonal attachment and influence, based on a salience test.

One of the main ties with complexity thinking in Dynamic Social Impact Theory is the finding that complex patterns emerge as a result of simple rules (Nowak et al., 1990). Even where differences or a diversity of opinions are found in a heterogeneous group, patterns of consensus emerge over time (Vallacher & Nowak, 2008).

> Computer simulation may reveal emergent properties of a social system stemming from laws assumed to operate on the individual level. When such properties do arise, we then need not assume group-level processes to explain them. For example, our simulations have shown that no special forces attracting people of similar attitudes to move closer together must be assumed to explain group coherence. Likewise, no

> special process of greater majority persuasion is required to explain group polarisation, nor any notion of greater minority influence to account for the fact that polarisation is incomplete. Latane's (1981) theory of social impact can unexpectedly explain such phenomena, showing that simple laws about individual social reactions can, when applied reciprocally and recursively predict emergent group effects. (Nowak et al., 1990).

The isomorphism of this idea has been achieved using a model of attractors in mathematical phase space, such as those discussed earlier on weather pattern formation, adding that this new model of analysis represents abstract ‘social space’, and is used by a number of authors (Bongini & Fornasier, 2014; DiFonzo et al., 2013; Friedkin, 1998; Hogg & Tindale, 2008; Latané, 1996; Lichtenstein et al., 2006).

> The essence of a group is not the similarity or dissimilarity of its members, but their interdependence. A group can be characterised as a ‘dynamical whole’. (K. Lewin, 1997).

An important distinction in using a non-linear analysis of human social systems is the nature of influence itself. For instance, individuals in a social group may attempt to exert influence over others in order to advance a private agenda. In such cases, it is feasible that patterns appear to emerge from the ground-up, but are actually a distributed response to potent actor/s with a special agenda (Vallacher & Nowak, 2008). In such cases, no comfort can be taken in an assumed righteousness of emergent order – which is exposed to many competing and subversive interests, and may very well be an emergent network of terror.
In this way, Durkheim’s (1997) vision of a transformational social order and state of self-regulating ‘corporate organisations’ that vests its judiciary in collective opinion is exposed to significant risks. With appreciation of his vision for corporate organisation, it is clear what Durkheim wished for corporations to achieve as manifestations of emergent consensus and order, while maintaining a sense of wellbeing, however the mechanisms of coordination and control are far from clear.

Dynamic Social Impact Theory goes some way to answering this question of social mechanics. One of its limitations however, is that it applies a very wide brush stroke.

With respect to socially influence-able attributes of the person, the theory applies to '*anything* … that is affected by the presence or actions of other people' (Hogg & Tindale, 2008). Its mathematical basis makes Dynamic Social Impact Theory suitable for computer simulations, but presents practical limitations when applied more broadly to an open-ended analysis of decision choices effecting populations. Simulations have certainly provided many of the base concepts for complexity and emergence, where complete models on the population are too complicated or otherwise beyond reach – this challenge and opportunity is the promise a nascent theory of emergence has operated on for several decades (McKelvey, 1999).

There are several implications of relying only on simulations for a theory of social influence; the following are six reasons to be doubtful that Dynamic Social Impact Theory is mature as a universal theory. (1), a simulation requires predefined choices thus causing a narrowing of parameters to binary choices; (2), the study of dynamics is a branch of Chaos Theory, which uses non-linear equations in deterministic systems. In other words, while the system itself is predictable, behaviour is non-random – an example is a weather pattern that is highly sensitive to initial conditions but behaves according to physical laws; (3), the contextualisation and stickiness of pre-existing culture is absent from analyses, despite its importance in root theory to define initial conditions; (4), far from equilibrium state is ill-defined and potentially misused to wed the theory to the tenets of Chaos Theory; (5), dynamic social impact theory does not completely account for emergent schemata, agent influence and inseparability from the environment and the system itself of which they constitute; and finally (6), the intention to define a complex non-linear dynamical system as 'predictable' runs counter to the foundation principles of complexity.
'Computer simulations can serve as a test of a theory' (Nowak et al., 1990). However, if the concept fails to move from the laboratory to the streets – it will continue to be incomplete as a recursively applied and pragmatic theoretical framework (Lynham, 2002). This is especially important for the social sciences, where the properties of agents and systems are in constant perturbation, and where the basic assumptions of a simulation cannot be taken for granted in the real world.

> Perhaps some day we will be able to model not only the temporary equilibria reflected in laboratory groups and social surveys, but the shifting fads of popular culture and the

> deeper recurrent cycles of conservatism and liberalism (Schlesinger, 1986) that characterise society as a whole. (Nowak et al., 1990).

Perhaps the most pertinent limitation of Dynamic Social Impact Theory is in its inevitable link to interpersonal synchronisation, a topic that is also studied using simulations but in the very different context of 'C2' (command and control) organisational forms (Zhigang et al., 2013).

> The dynamical theory of social influence portrays how the state (e.g. attitude) of a single individual depends on the state of other individuals. As noted earlier; however, many psychological processes are defined in terms of intrinsic dynamics. This implies that individuals cannot be adequately described as a set of states but rather are best conceptualised as displaying patterns of change. Since the influence process is ongoing as individuals interact with one another, social influence is manifest as the coordination over time of individual dynamics. Building on this observation … social influence can be understood in terms of synchronisation, a phenomenon that characterises coupled dynamical systems. (Vallacher & Nowak, 2008).

In summary, if the above reference to Dynamic Social Impact Theory can only be observed at the level of the system – underlying processes are effectively a mystery to those conclusions, and not so dissimilar to Ablowitz (1939) explanation of the transformation of quantity into quality. Nonetheless, the authors conclude such systems are 'predictable' (Hogg & Tindale, 2008), which runs counter to most complexity literature, as does the idea that observing system behaviours enables one to wield control over the underlying processes of which the system is constituted.

While substantial progress is made in extrapolating meaning from system level behaviour, by adding non-linear dynamics to the toolkit, examples provide only a partial explanation of organisational behaviour – where choices are known and patterns can be detected using dynamical variables and control parameters (Vallacher & Nowak, 2008).

As touched on earlier, human social systems are not the equivalent of atoms or ants but have plans, agendas, sudden impulses and irrational idiosyncratic tendencies, their ability for symbolic construction and scientific observation of reality is a wholly unique property. Therefore, the task of making sharp predictions on the emergence of social order from a straightforward application of raw complexity theory is problematic, ‘ultimately the properties that separate us from other systems in the world must be incorporated into theory and research. It is only fitting that a coherent theory of social psychology should be assembled from elements that are both universal and unique to human experience’ (Vallacher & Nowak, 2008).

2.4.3 Influence Behaviours and Tactics

One of the top questions of contemporary business thinking is how leaders influence the performance and survival of an organisation (Yukl, 2008). Influence tactics are not the sole purview of leaders and managers, but reflect behaviours scattered throughout an organisation and at all levels. In this way, the influence culture of an organisation is a tapestry of behaviours to which everyone contributes. Similarly, it could be argued that many of the core influencing capabilities required to achieve success in an organisational endeavour are distributed throughout an organisation and not entirely vested in any one actor. A leader of an organisation is not omnipotent, and is reliant on dynamic social processes of actors throughout the hierarchy.

> Influence is essential for effective performance by managers. To be effective a manager must influence others to carry out requests, support proposals, and implement decisions. The success of an attempt by one person (the ‘agent’) to influence another person (‘the target’) depends to a great extent on the influence tactics used by the agent. Influence tactics can be classified according to their primary purpose and time frame. Proactive tactics are used in an attempt to influence someone to carry out an immediate request, and they are especially important in situations where the agent has little authority over target persons. (Yukl, Seifert, & Chavez, 2008).

Unlike the Dynamic Social Impact Theory, Yukl et al. (2008) Influence Behaviour Questionnaire attempts to define the tactics (see Table 2.12) in use when two agents within an organisation attempt to change one another’s thinking or behaviour. Influence ‘tactics’ are defined and measured as a proxy for interpersonal influence behaviours in organisations. The scales also give instruction for developing leaders to hone their craft by applying influence tactics that are most suited to certain interactions with subordinates, peers or supervisors.

Table 2.12 Influence Tactics

Tactic	*Definition*
Rational persuasion	The person uses logical arguments and factual evidence to persuade you that a proposal of request is viable and likely to result in the attainment of task objectives
Inspirational appeal	The person makes a request or proposal that arouses enthusiasm by appealing to your values, ideals, and aspirations or by increasing your confidence that you can do it
Consultation	The person seeks your participation in planning a strategy, activity, or change for which your support and assistance are desired, or the person is willing to modify a proposal to deal with your concerns and suggestions
Ingratiation	The person seeks to get you in a good mood or to think favourably of him or her before asking you to do something
Exchange	The person offers an exchange of favours, indicates willingness to reciprocate at a later time, or promises you a share of the benefits if you help accomplish a task
Personal appeal	The person appeals to your feelings of loyalty and friendship toward him or her before asking you to do something
Coalition	The person seeks the aid of others to persuade you to do something or uses the support of others as a reason for you to agree also
Legitimating	The person seeks to establish the legitimacy of a request by claiming the authority or right to make it or by verifying that it is consistent with organisational policies, rules, practices, or traditions
Pressure	The person uses demands, threats, or persistent reminders to influence you to do what he or she wants

Source: (Yukl & Tracey, 2003).

‘Research with influence incidents suggests that the tactics most likely to elicit target commitment are rational persuasion, consultation, inspirational appeals, and collaboration’ (Yukl et al., 2008). A further finding of this research is that certain types of persuasion are more or less effective depending on where in the organisational hierarch a person is in relation to another. For example, ‘ingratiation’ is more effectively deployed with peers than subordinates, whereas ‘pressure’ is more effective on subordinates than peers (Yukl et al., 2008). Research opportunities exist to further explore the effectiveness scores of influence tactics, probabilities and impacts in connection with the generation of emergent, system level behaviours.

Given what is currently known of emergent properties in complex social systems, it is surprising more detailed ‘scale and type’ studies of influence behaviours have not been more prominent in either Dynamic Social Impact Theory or a theory of emergence for human social systems. If indeed social influence is the nucleus of self-organisation in human social systems – why then is there not a great deal more interest in quantifying large scale social influence processes. The answer potentially rests in two main issues: first, complex social systems are fluid in both structure and form, patterns emerge, dissipate and re-emerge often without quantifiable trace; second, influence exists only in a transitive state, it cannot be preserved, reused or redeployed without new effort. Influence is a concoction of human consciousness and exists only via the uneven terrain of symbolic interpretation and interpersonal construction of meaning.

This is a good reason why Dynamic Social Impact Theory is not a theory of influence, but rather of the resulting patterns of behaviour that are premised on exchanges of assumed influence (Latané, 1996); and similarly, the Structural Theory of Social Influence is also not a theory of influence, but rather the structural probability of influence between agents based on knowledge of others attitudes or work (Friedkin, 1998). Neither theory deals directly in the matters of exchanging ‘energy’, nor do they define it, despite this fact being an assumed foundation throughout complexity theory (Marion, 2008). As discussed in this section, Dynamical Social Impact Theory attempts to quantify social behaviours, whereas Structural Theory attempts to give social pattern a shape and form, based on probabilities of interpersonal attachment.

2.4.4 Structural Theory of Interpersonal Influence

The structural bases of interpersonal influence used by Friedkin (1998) is premised in one simple and elegant assumption – *salience*. An organisational actor’s ability to exert influence on other actors depends entirely on their knowledge of the first actor’s opinions (or other influence factors). Then, influence itself is determined by the salience value of the opinion, primarily because unknown opinions have no ability to influence others. Unsurprisingly, if one sits in a room alone and has no communication with the outside world, their opinions will have very little influence on others – referred to here as ‘the silent room theorem’. Conversely, the better others know and understand one’s opinions, or work, and a number of other situational variables, the more likely interpersonal influence will become. Friedkin (1998) refers to this as the 'probability of interpersonal attachment', to apply quantitative structure to the social space in which agents reside within an organisation, also assuming heightened used of these salience networks during the course of an issue resolution process. In this way, the structure of social influence depends on salience.

Similar to the second assertion of Dynamic Social Impact Theory, 'individuals have relatively stable locations in space' (Latané, 1996). Friedkin (1998) also claims the probability of interpersonal attachments are rigid, therefore structures are durable and 'govern' the distribution of interpersonal influence. Using relatively tangible measures such as salience, a number of common social patterns can be found in human social systems, including social cohesion, structural similarity and structural centrality. Furthermore, the application of a dynamical approach to social influence, and non-linear models of self-synchronisation are evident in both command and control organisations, and the typical corporate entity. Each is discussed briefly and in turn, as follows.

Social cohesion – as proposed by Durkheim, societies tend toward cohesion and organisation of productive groups through self-organisation (Durkheim, 1997). With the general assumptions of Dynamic Social Impact Theory, we can infer two important factors about social cohesion: (a) agents remain relatively stable in social space; and (b) social influence is directly proportionate to physical proximity (Latané, 1996). Research in this area strongly argues that distance does matter.
However, a more contemporary application in technology-enabled corporations that rely on multiple modes of communication across significant physical boundaries, where these behaviours are normalised, is yet to be fully developed. Friedkin (1998) provides a quantitative explanation of social cohesion based on configuration, density and diameter which are a function of joint location where members of a group a 'mutually reachable'. In such an environment, information diffuses rapidly, greater awareness of emergent issues is likely, communication is frequent, interpersonal influence more likely and collective action readily feasible. Due to the sustained interconnectedness and self-referencing behaviours (comparison of opinions), uniformity and behavioural similarity can become an emergent property of the group.

Structural similarity – while the uniformity of opinions and behaviours in cohesive groups is evident and reasonably explained by both salience measures (Friedkin, 1998) and non-linear models (Nowak et al., 1990), so too should the structural bases of actors in social groups exhibit this similarity, if based on a simple rules hypothesis. A structural theory of similarity has a quaint description: 'because actors initial orientation on issues are influenced by their definitions of the situation, the more similar two actors structural positions are, the more similar their initial positions on issues are likely to be' (Friedkin, 1998). The formation of rigid structures that proliferate throughout the organisation and govern probabilities of international attachment describes the nature of social space from a structural perspective. A complexity perspective would be that structural similarity emerges as a result of simple rules, complexity dynamics and fitness landscapes (Anderson, 1999).

Structural centrality – a structural perspective argues that actors which are central to networks of interpersonal attachment more readily acquire information resources that in turn allow them to exercise greater degrees of influence than those on the periphery (Friedkin, 1998). However, network centrality is a proxy measure for what is otherwise a complex, dynamic and hybridised system for the exchange of knowledge, information, meaning and ultimately influence. Assuming the argument of structural centrality explains the formation of typical groups in an organisation, the probability of interpersonal influence is far higher in these central nodes, therefore these are arguably the places one might search to find emergent leadership, or in clandestine operations – the location of network 'leaders' (Tyler et al., 2005).

Self-synchronisation – network centric warfare using command and control (military) organisational structures have demonstrated a real example for the application of self-synchronisation of decisions and actions, derived from an understanding of dynamical influence and social cohesion (Zhigang et al., 2013). The self-regulation and adoption of strategies is regarded as operationally precise to give parameters that guide the deployment of large-scale resources even in a conflict environment. In this same context, an adapted model for 'cognitive entropy' has been developed and applied, albeit with limitations in its application to similar organisational forms (Manso & Moffat, 2011). The application of similar concepts to corporate organisations is attempted by Vallacher and Nowak (2008), using the (black box) assumptions of Social Impact Theory, so as not to carry the weight of explanation for interpersonal processes – but simply the pattern of behaviour that follows. Such a model would be ideal to apply to self-synchronising attributes of markets and organisations that, in particular, involve repeatable behaviours – such as financial markets.

Structure of social space – analysis and interpretation of the structure of social space is centred around two key assumptions: (a) the probability for interpersonal attachment is tied to the frequency and depth of opportunities for communication and contact; and (b) physical proximity in social space increases the probability of social ties and interaction, uniformity, cohesion and therefore influence (Friedkin, 1998). The matter of physical proximity and proximity of opinion and social order are worth further exploration. While the idea of physical proximity has its rationale, it ought not to be universally assumed that physical proximity is in absolute proportion to influence, or that those beyond the immediate work area have no influence over how culture is formed and work gets done. For this reason, a structural theory is a conception of probabilities – not absolutes, and is helpful in understanding how the pattern is produced. In the absence of a definitive classification system to plot the scale, type and character of emergent phenomena, there is no sharp line between collective pattern where agent interaction is limited, and the emergent forms that arise along a continuum of influence increments.

Reverse engineering a social structure – it could be assumed that many derivations are possible with established propositions on probabilities, interpersonal attachments, salience, physical proximity and the generic structure of social space. Real world application of this understanding of social pattern limits practicality of extrapolating data on the real time formation of opinions and interpersonal salience measures. Hence, it would be logical that using derivations of each proposition, a hypothesis can be reliably formed and tested, assuming structural forms are as universal as the universality of conditions that underlie them. For example, if one claims to have a detailed working knowledge of the emergent issues being faced by a colleague or peer, it is probable they are either a source for, or recipient of, influence behaviours. Similar assertions could be said for larger and more complex organisational system, which are explained in more detail in the discussion chapter.

As discussed earlier in this chapter, a working use for the function of influence in organisations is through the role of leadership. Many definitions of leadership refer to a process that involves influence exerted over others for the purpose of achieving desired ends. The previous chapter illustrates this common thread across numerous definitions in the study of leadership. Theories also agree leadership is a phenomenon that has an important impact on the effectiveness of organisations and is therefore of interest to understand as a process within emergent self-organisation (Yukl, 2006).

2.4.5 Leadership as a Relational Process and Emergent Event

A recent approach that has been adopted to understand the effect of leadership in organisations, focuses on leadership as an influence process that can be exerted by any member within a social system (Yukl, 2006). From this point of view, leadership can be viewed as a pattern of shared influence processes, where there is no assumed distinction between leaders and followers – therefore, research attention is directed towards the complex influence processes that occur between members (Lichtenstein et al., 2006; Yukl, 2006). It has been argued that 'traditional' forms of leadership are inadequate to cope with the complexity of the modern organisation and its milieu of social nuance and subtlety (Goldstein, 2008; Hazy, 2008b; Houglum, 2012; Lichtenstein & Plowman, 2009a; Lichtenstein et al., 2006; Marion, 2008; Marion & Uhl-Bien, 2009; McKelvey, 2008; M. Uhl-Bien, Marion, & McKelvey, 2007).
From this standpoint, 'leadership theory must transition to new perspectives that account for the complex adaptive needs of organisations' (Lichtenstein et al., 2006). That is, rather than adopting a focus solely on leaders as individuals, a focus on the function of leadership is taken, where leadership itself is understood as a distributed and complex process that emerges in the 'spaces between' people and ideas (Lichtenstein et al., 2006). Then, leadership is a segment of action, a fibre of social process and an emergent property of dynamic interaction that is in itself patterned meaning and patterned influence.

A summary of this recast perspective on leadership is provided below, at Table 2.13. The table demonstrates the 'myths' of Cybernetic (i.e. traditional forms of) leadership and emergent (complexity) leadership theories. The new reality of leadership draws on complexity theory principles, which are taken directly from the four sequences of the dissipative structures theorem of Prigogine (1977): emergent self-organisation, sensitivity to initial conditions, far from equilibrium states, and non-linear interactions. This reconceptualises the function of leadership as a distributed pattern of sense making, facilitating linkages, disruption and re-culturing (D. A. Plowman & Duchon, 2008).

Table 2.13 Myths of Cybernetic Leadership

Complexity theory principle	*Cybernetic Leadership – Role Functions (Myths)*	*Emergent Leadership – Enabling Behaviours (New Reality)*
Disequilibrium	Leaders eliminate disorder and gap between intentions and reality	Leaders encourage disequilibrium; disrupt existing patterns of behaviour
Amplifying actions and sensitivity to initial conditions	Leaders direct change	Leaders make sense of patterns in small changes
Emergent self-organisation	Leaders specify desired futures	Leaders provide linkages to emergent structures; enhance connections among organisational members
Stabilising feedback	Leaders influence other to enact desired futures	Leaders encourage processes that enable emergent order

Source: adapted from (D. A. Plowman & Duchon, 2008). [Central column is shaded for emphasis on the 'myths' of leadership]

In this manner, leadership is a relational process that occurs through the interactions of actors within a human social organisation, and its product – the cohesion, motivation, influence or directed action toward any intended or unintended ends are an emergent product of those relations between agents within the system. In 'founding' this approach, complexity leadership theorists propose to adopt a systems view by moving away from a focus on component parts but rather on actions, interactions, outcomes and behaviours (Lichtenstein et al., 2006).

While not intended to be a zero sum game, complexity leadership theory tends to replicate one concept of leadership and replace it with another albeit placed within the system, i.e. ‘extending current theory and practice by focusing on micro-strategic leadership actions across all organisational levels and across organisational boundaries’ (Lichtenstein et al., 2006). That is, despite characterising the modern corporation as ‘neural-like networks of interacting, interdependent agents who are bonded in a collective dynamic by common need’ (Mary Uhl-Bien & Marion, 2009). It is unsurprising a theory of leadership would be reluctant to let go of the prime function of the leader, as highlighted at Table 2.13 (D. A. Plowman & Duchon, 2008). Rather, it would be a pure emergentist view to completely redefine the function of leadership as a successive layer in a complex system, ‘there are certain kinds of material substances specific to each level. And the kinds of each level are wholly composed of kinds of lower-levels, ultimately of kinds of elementary material particles’ (McLaughlin, 2008).

There is no *form* of substance without that substance itself to comprise it. To rephrase in organisational terms, leadership is an emergent property seen in the patterning of follower behaviours, not necessarily in the otherwise impotent conduct of the leader; to which I recall the *silent room theorem*. Therefore, contrary to the assertion that complexity requires a deeper analysis of a single system component (a leader) to understand its overall behaviour, an holistic view would be that leadership is a process *of* and belonging to the system, not solely of the actor; and secondly, that if any kind of influence or cohesion should come about – it would in itself be an emergent event that is the product of multiple interacting components within a complex dynamical system. In this and many other respects, there remains a question as to the autonomy of emergent phenomena from their emergent base, or substrate layer.

2.5 Toward a Theory of Emergence

2.5.1 An Emerging Theoretical Framework

In the world of social and organisation science, there are only a handful of cases that have explored the possibilities of emergence as a viable business strategy. Examples include: the decentralised and non-hierarchical format of VISA Inc. (Burnes, 2005), distributed network of Tupperware (Plowman & Duchon, 2008), high-tech start-ups referred to as ServiceCo, ApplySci and DevelopNet (Lichtenstein, 2000), Mission

Church (Plowman et al., 2009) and Branson Musical Theatres (Chiles et al., 2004). The integrative theme of these studies describes a critical threshold or 'self-organised criticality' (Marion, 2008) at which point the system either collapses or recombines/reorganises into new, often surprising configurations (Lichtenstein & Plowman, 2009).

Fewer studies identify the phenomenon of deconstruction of an organisational system that does not result in an emergence of new configurations. This potential outcome is alluded to by Schneider & Somers (2006), proposing that not all systems have the capacity to evolve; Levie & Lichtenstein (2010) in their assessment of stages theory giving reference to continuous renewal but not specifying the exact parameters of systems; and finally the concept is earmarked by Lewin & Volberda (1999) as a possible area of research for new organisational forms. Lewin & Volberda (1999) propose: 'populations of organisations undergoing discontinuous change should become the focal object of such studies – industries undergoing deconstruction'. The challenges of such a study of post-extinction networks would be substantial, but of great empirical value.

Self-organisation may also be an underlying characteristic of command-control structures; as the presence of centralised control may not substantially inhibit forces necessary to the creation of sub-structural organisational forms. The four known behaviours of complex adaptive systems, discussed earlier in this chapter, may not actually occur in sequence and may deviate and coalesce in nondescript fashion.

Prigogine's (1977) original theorem is based on the sequences observed in a chemical system and although similar patterns have been noted in self-organisation of animals and plants, there is simply not enough empirical evidence to comprehensively attribute intrinsic and qualitative tendencies of human social and intra-organisational emergence beyond basic levels, such as the behaviour of crowds, group intelligence, social network analysis, traffic flows, population movements and economic behaviours (Burnes, 2005; McKelvey, 1999; Lichtenstein & Plowman, 2009). Furthermore, the magnitude of a complete reconceptualisation of organisations in light of the capacity for emergence requires an empirical test of the concept in practice, which at this point is sparse and limited (Burnes, 2005).

2.5.2 General Method for Theory Building Research

As affirmed in the opening remarks of Lynham (2002), there remains a commonly held view that the sphere of theory is distinctly separate from the real world, as expressed by the colloquial statement ‘well, that is all very well in theory, but it does not work like that in practice or in the real world.’ (Lynham, 2002). On the contrary, Lynham (2002), Van de Ven (1989), Eisenhardt (1989) and Lewin (1945) all propose that there could be nothing better or more practical than a good theory. The challenges of developing good theory in Lewin’s time are not so different from those of today, in agreement to Lynham (2002) and Dublin (1978), the central principle of theory is to explain how things work and to help us act in certain ways based on an increasingly comprehensive understanding of the world. The central goal of scholars has been to contribute to the body of knowledge and understanding, but on the other hand to apply and test that knowledge to the practice of management (Lynham, 2002; Storberg-Walker, 2003). Achieving both feats requires a practical and insightful model informed by the methods and criteria for building robust theory.

Theory building is ‘the purposeful process or recurring cycle by which coherent descriptions, explanations, and representations of observed or experienced phenomena are generated, verified, and refined’ (Lynham, 2000). Lynham’s (2002) general method of theory-building research in applied disciplines can be generated from a multi-paradigmatic perspective and places a critical importance on the point of view and application of the theory through the eyes of the practitioner.

The benefits of Lynham’s general method are that it provides a holistic approach to the theory building process, capable of incorporating multiple paradigms with practical application of central importance (Storberg-Walker, 2003). Scholars can also use the general method for the purposes of evaluating the contributions of previous works. The general method provides a robust framework to test the application of theory to real world scenarios that assist in informing deficiencies in existing literature. The general method has therefore been applied to existing literature in this study to evaluate their respective merit against the criteria of the theory-building model and to support the systematic identification of deficiencies and opportunities for future research.

Figure 2.14 illustrates the major processes of theory building, incorporating deductive and inductive logic and the five phases of theory building: conceptual development, operationalisation, application, confirmation/disconfirmation, and continuous refinement and development (Lynham, 2002). Each component of the model can be manipulated in representation of the relative weight and development of each stage, incorporating selected works under review.

The following is a brief synopsis of each of the five stages of Lynham's (2002) general method for theory building.

1. Conceptual Development: key elements and constructs applicable to the phenomenon are identified and formulated in a way that is relevant to a real world context. Interdependencies, limitation and conditions are identified. Primary output is an informed and explicit conceptual framework.

2. Operationalisation: this second phase of the theory building method aims to provide an explicit connection between conceptualisation and practice, in a real world context. To achieve this stage, the explanation of the phenomenon must be empirically confirmed in its relevant context. Therefore the primary output of this stage is an operationalised theoretical framework that converts the theoretical framework into observable components for further inquiry.

3. Confirmation or Disconfirmation: planning, design, implementation and evaluation of research that inform and confirm/disconfirm the applicable theoretical framework. When confirmed, this phase provides trust and confidence in ways that help inform practice.

4. Application: advancing from the confirmation of a theory in its contextual world, application is the practice element of the theory building method. The application of theory in the real world enables the use of experience and learning from its practical application for further refinement.

5. Ongoing Refinement and Development: this continuing phase represents the recursive nature of applied theory building and signals the overlap between practice and theorising. The outcome of this phase is to ensure the theory is kept current and discarded or adapted when necessary.

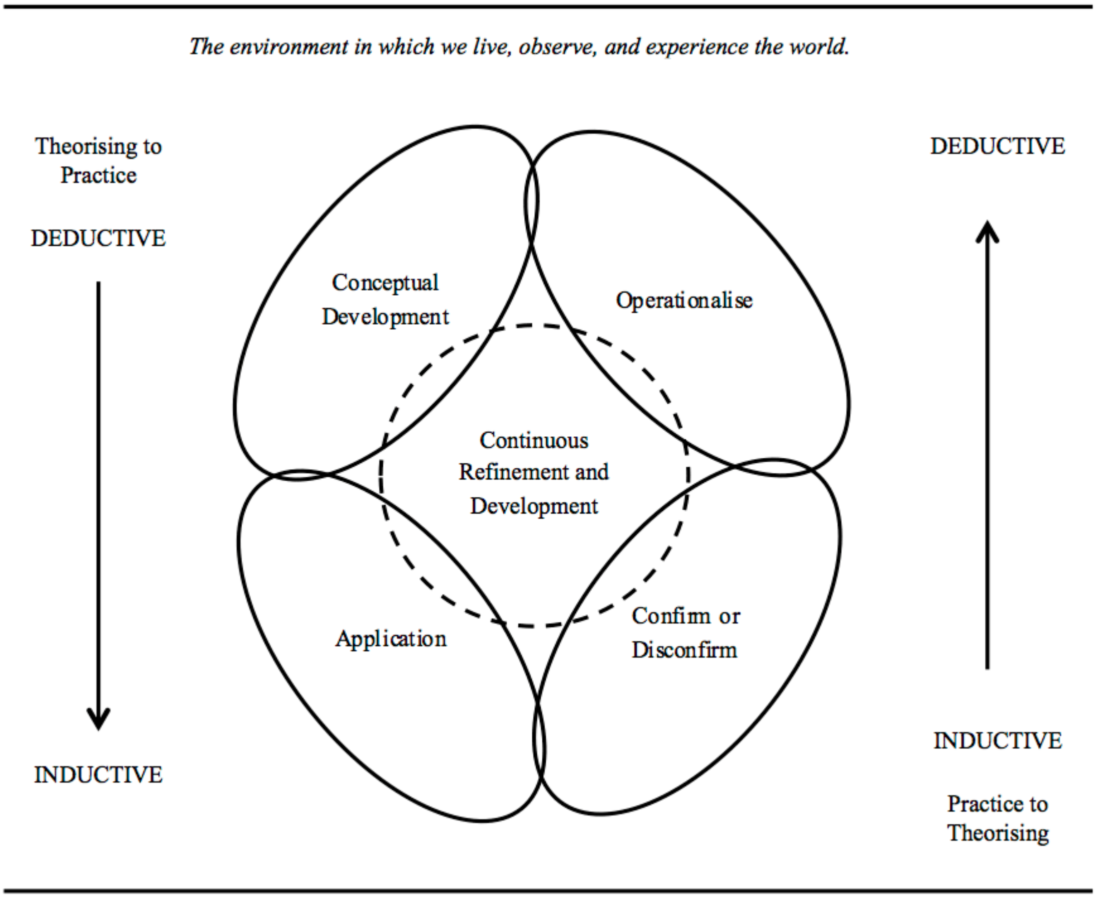


Figure 2.14 General Method for Theory Building Research

Source: Reproduced from Lynham (2002).

Lynham's (2002) general method provides a robust way to consider further advances in theory building from a range of perspectives, it is not however without its limitations. Lynham's (2002) model proposes that theory building can occur non-sequentially in any of the five phases and simultaneous developments then respectively contribute and affirm one another. It is not possible however to oversee the creation of a body of knowledge from a central point of coordination. This process could be viewed as disorderly and risk premature or improper theory application. Lynham (2002) also proposes a critical relationship with practitioners in the testing of theories as a method to enhance their utility value.

The reliance on this relationship with practitioners to support the recursive cycle of theory building may then be exposed to subjective interpretations from practitioners that only apply to specific areas or industries and are not generalisable to a wider cross section of the business community. Storberg-Walker (2003) argues that challenges can be made to reliance on interdependencies between application and operationalisation and conceptual development and confirmation/disconfirmation. Despite the interdependency of Lynham's (2002) general method – similar assertions have also been made by Corbin & Strauss (2008), Van de Ven (1989) and Gioia & Pitre (1989) in the belief that utility value is part measure of good theory, and this utility is best tested in the world of practice.

2.5.3 Note on the Utility of 'Good' Theory

Theory can be broadly defined as 'coherent description, explanation and representation of observed or experienced phenomena' of practical use to describe, explain, diagnose and further understand phenomena (Gioia and Pitre, 1990). The real-world practical utility of theory is ideally the antithesis of reflections posed by Blumer (1954) on the state of 1950s social theory that suffered 'glaring divorcement' from empirical science and a series of 'grave shortcomings' as a result of defective modes of inquiry. Thankfully, several modern variants that define 'good' social theory assert there is no need for an artificial divide between theory and practice, hence theory has utility value to help us act in certain ways, and is continuously informed by and applicable to real world practice (Corbin and Strauss, 2008; Lynham, 2000; Van de Ven, 1989).
Consistent with this assertion, theory building can be described as the 'ongoing process of producing, confirming, applying and adapting theory' (Lynham, 2000), to this end, theory building methods ideally possess two inherent qualities: *validity*; and *utility* (Van de Ven, 1989). As surmised by Gioia and Pitre (1990) 'it would be useful for theory building to be viewed not as a search for the truth, but as more of a search for comprehensiveness stemming from different worldviews.'

Among the most difficult prospects in the process of theory building is to overcome broadly accepted views, by posing new ways of viewing or understanding everyday phenomena. This is a sentiment that has not shifted significantly since the science of the renaissance, the most difficult thing in science, as in other fields, is to 'shake off accepted views' (Sarton, 1929). With its own emergent qualities, theory faces this challenge. Although the existence of a greater number of alternate paradigms to explain, predict or define organisations and their actors are likely to deliver more comprehensive understanding of organisational realities, the incommensurability of paradigms is also likely to produce scholarly fragmentation – a possible cause of confusion among practitioners (Burnes, 2005; Gioia and Pitre, 1990). Further strategies available to aid this dilemma include the development of a multi-paradigmatic bridging tool, for instance that which is described by Gioia and Pitre (1990). Such a tool may be capable of exploring the permeability between parallel constructs, and may be conducted as an extension of a semantic conceptualisation process [explained at Chapter 5], to address compatibility issues arising from inter-disciplinary borrowing.

2.5.4 Current State of the Theory of Emergence

The following section provides a review of selected contributions to the development and application of a theory of emergence in modern organisations and their respective contribution to theory development. The current state of these works are summarised into the five phases of Lynham's (2002) general method for theory building as a reflection of the previous discussion. Works have been selected using three criteria: firstly, in consideration of the materiality of contributions to the development and application of complexity theory in organisations.
Secondly, studies are reviewed for the comprehensiveness of their empirical elements and applicability to Lynham's (2002) five phases of theory building. A number of works may not contribute to all of the phases, but advance a single stage. Finally, publications are chosen for their representative value, meaning that the lines of argument correlate strongly with the main thrust of numerous other works, thus representing a broader spectrum of literature. The references at Figure 2.15 are exemplars of the expansive literature reviewed within this study.

Conceptual development: a large body of work has amassed to confidently begin the operationalisation of core constructs to the social and organisational sciences, such as Anderson (1999); Brown and Eisenhardt (1997); Chiles et al. (2004); Goldstein (1999); Lichtenstein and Plowman (2009b); Marion and Uhl-Bien (2001); McKelvey (2008); D.A. Plowman, Baker, et al. (2007); Vallacher and Nowak (2008). These works however have not come without their risks and limitations, the central theme of which relates to the difficulties of application. The literature review to this point outlines many areas for further development, revisited at the end of this chapter.

Operationalisation: many of the previous works [listed above] and Moldoveanu & Bauer (2004) outline or propose the operationalisation of concepts through a range of methodological approaches. Despite the shared aim of bringing complexity closer to real world application and averting a premature death for a theory of emergence, a number of these strategies to operationalise the theory have not succeeded in linking with tools that would likely be adopted in practice by managers and organisations. The operationalisation of various elements of the theory of emergence remain somewhat disconnected from one another and have often been imposed on the world of social sciences, rather than being led form within it, using the qualitative tools appropriate to understanding complex human interaction. An operationalised theoretical framework to advance the application of intra-organisational emergence from a social and organisation science viewpoint is suggested.

Confirmation/disconfirmation: the theory of emergence has not reached a level of trustworthiness necessary to argue that it is confirmed in the world of practice (Lynham, 2002). While the limited application of theory has provided a new way of understanding practice, it has in most cases not informed practice to the extent that its theorists would argue is necessary (Marion & Uhl-Bien, 2008; Anderson, 1999; Lichtenstein & Plowman, 2007). Marion & Uhl-Bien (2008) and Plowman & Duchon (2008) propose a complete 'reconceptualisation' of organisations and leadership in light of the new understandings the theory of emergence provides. Other viewpoints are more modest Anderson (1999):

> We are not on the verge of a revolution that will render a century of organisation theory obsolete, but remarkable new vistas are opening up thanks to the melding of the science of complexity and organisation theory and the increasing availability of new techniques. (Anderson, 1999).

The shifting viewpoints between the radical and the moderate resemble a swinging pendulum that has not yet come to rest. Strengthened links to practical application through further empirical work and further development in confirmation / disconfirmation would support a more balanced perspective on the validity and usefulness of complexity (Van de Ven, 1989).

Application: the practical application of emergence is present but to a limited extent. Plowman et al. (2007) delivers possibly one of the largest quanta of data on the emergence of intra-organisational forms over a ten-year period and presents these findings in reference to other paradigms for change. Tools for the application of theoretical constructs are set out in a summary of propositions, including the use of: organisational tension, resource availability, language, symbols, amplifying actions and interaction (Plowman et al., 2007). The propositions from the study may also not appear to be distinct from those already in practice, but labelled with complexity terms, such as 'amplification' and 'empowerment' (Plowman et al., 2007). Discussion on the congruence between operationalised theory and current practice is limited in Plowman et al. (2007) that would have benefited from a strengthened multi-paradigmatic bridge such as proposed by Gioia & Pitre (1990). Plowman et al. (2007) do not directly address the implications of organisational structure as a contextual factor for emergence; and finally, the important element of organisational culture is noticeably absent. The impact of culture and the possibility of intrinsic motivations being present in particular organisational contexts are omitted from the study (Plowman et al. 2007).
Continuous refinement and development: In addition to contributing to the previous four phases, Brown & Eisenhardt (1997) effectively proposes a paradigm that combines practical insights with the theory of emergence to understand organisations as dynamic and continuously changing entities, rather than static objects. Given the limitations on the operationalisation, application and confirmation of theory, the continuous refinement phase of Lynham's (2002) general method has suffered from a lack of feedback from the world of practice.

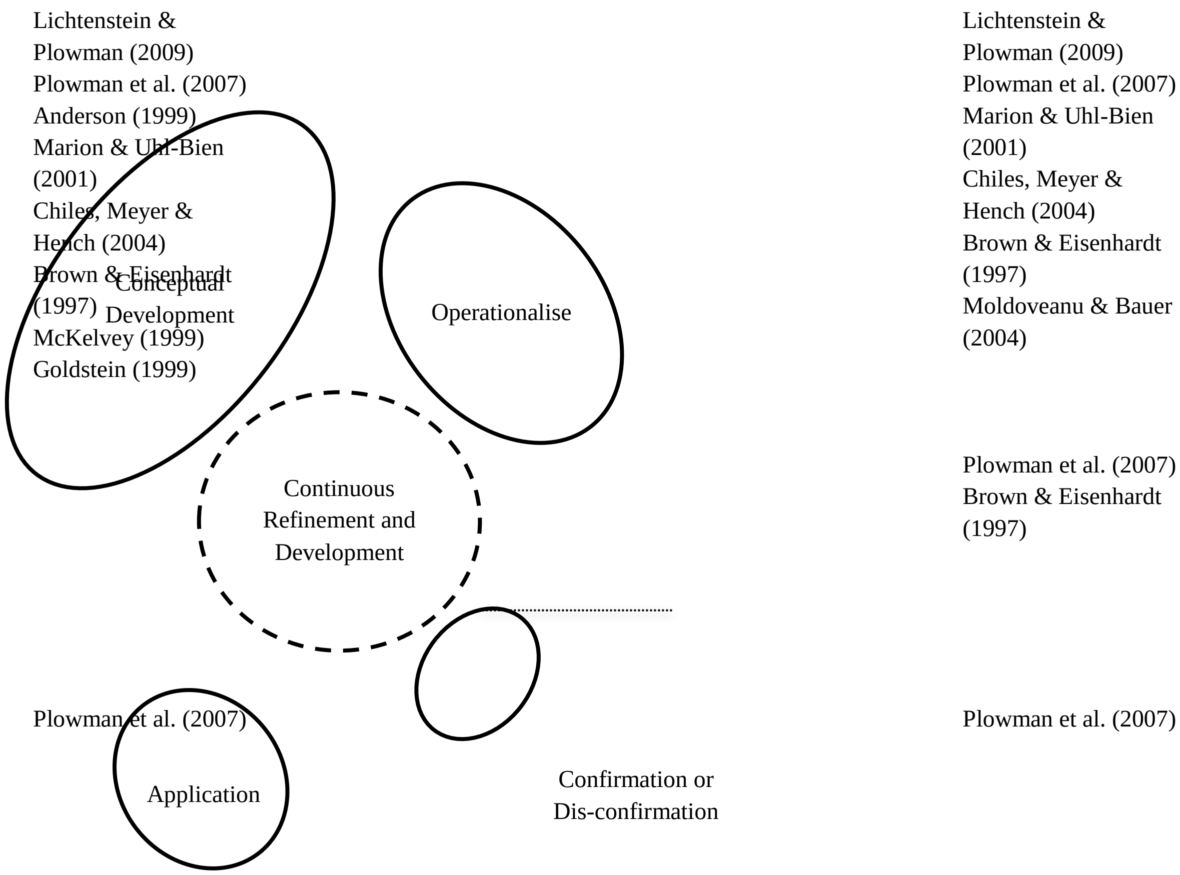


Figure 2.15 Selected Contributions to a Theory of Emergence

Source: Based on (Lynham, 2002)

2.6 Synthesis and Limitations of Current Literature

2.6.1 Critique of Existing Literature

This chapter has provided a detailed overview of the conceptual foundations of the theory of emergence, viewed in context of its historical development. Among the major origins of complexity and emergence in social and organisation science, Cybernetics and General Systems Theory principles are still an integral part of its application and development today. The importance of mathematical and computational modelling is noted in addition to implications relating to the installation of complexity-inspired forms of leadership, management and organisational structure, built around the anchor point phenomenon of emergence.

Complexity theory, generally, resembles a superstructure of variegated ideas and constructs that share interest in the study of complex systems. The interdisciplinary nature of this convergence of ideas and principles implies that while value can be created in melding frameworks and notions from a neighbouring fields; its application in any one discipline using the constructs of another is then reliant on multiparadigmatic bridging or ontological assumptions. In the case of social and organisational science, a theory of emergence remains in a nascent state of development, ripe for further development, application and refinement.

This review of literature has provided a broad synopsis of the many strands of thought and science that comprise the rich tapestry of the study of emergent self-organisation. In presenting, summarising, contrasting and comprehensively evaluating the current state of a theory of emergence, the review itself documents the major contributions to the body of knowledge on emergence and is among few accounts of such breadth and depth on the topic. Within the review, a substantial number of literature gaps, inconsistencies and areas of ambiguity are identified, which are often subtle, but of serious importance in considering the existence of a developed theory. While embedded within the text, for the sake of clarity, a summary critique is provided here for ease of reference, derived of the Chapters thus far. This is then followed by discussion to complete the evaluative cycle back to the epistemological and ontological traditions on which this study is grounded.

2.6.2 Summary of Limitations in Existing Literature

There are many benefits of applying a theory of emergence to the field of human social systems, as highlighted throughout this review. Foremost among these are the ability to apply a more comprehensive understanding of emergent behaviours that are prevalent across organisations and society – yet, are not completely understood. A focus on agent interaction, non-linear dynamics, and the ability to adapt under pressure are all features of a greater comprehension in making sense of perpetual novelty, longevity and flourishing of societies, cultures and economies. However, a number of significant gaps within existing literature have been identified.

Human social systems are not the equivalent of electrons, daisies or tornadoes; but have schemes, impulse and irrational tendencies. The ability among agents for the symbolic construction, and metaphysical reasoning is a unique property of humans. Therefore, the task of making direct translation of theoretical frameworks derived of the natural sciences is a challenge and with many unresolved limitations. It is therefore fitting that such limitations be dealt with in detail, to form a coherent theory that is assembled from an understanding of human existence – rather than a raw application of chemistry or physics.

This comprehensive review of literature has discovered 41 key limitations (inconsistencies, ambiguities, incommensurability and gaps) in the review of literature that underscore the current state of a theory of emergence, as it applies to human social systems. These are presented in summary, given each limitation is explained and referenced in detail within the literature review itself and is therefore not exhaustively recited.

Limitation 1: *the term 'energy' and its transmission between agents are used with ambiguous meaning and inconsistent application.*

The idea of 'energy' and its transfer in human social systems holds little materiality within the ordinary laws of physics. Despite its presumed ontological application, and aside from physical properties of a complex system, there remains much ambiguity and very little universality in the use and definition of this central feature in complexity literature. 'The transfer of information cannot take place without a certain expenditure of energy, so that there is no sharp boundary between energetic coupling and informational coupling.' (Weiner, 1954). It could be assumed the necessary coupling of information and energy is sufficient to transmit the idea of dissipative structures throughout all other systems, however, the extrapolation of this result currently lacks empirical support.

Limitation 2: *the popular use of complexity science as a metaphorical device has exceeded its practical application as a management tool.*

The idea of emergent order without a central point of control is a difficult concept to grasp if it were not for the use of metaphorical device. However, the problem is well described by Burnes (2005) ‘there is a world of difference between restructuring an organisation because science has discovered that this action is necessary, and doing the same thing because that is what a computer simulation has shown that a flock of birds would do if faced with wind turbulence.’ Further refinement and application of theory via a general method is vital, particularly within a pragmatic viewpoint. For example, to describe a human social system as a ‘dynamic soup of interactive agents and mechanisms that continually spawn … emergent changes’ (Marion, 2008) is vague, imprecise and suggestive that the theory of emergence is in its current state a *black-box science*.

Limitation 3: *studies of social influence and complex dynamical behaviour in human systems are inadequately incorporated into the broader science of complexity and the study of self-organisation.*

As discussed previously, there are multiple competing paradigms that describe complexity in organisations, management and leadership. Within a complexity view of organisation, it is the capacity for emergent self-organisation that is the distinguishing characteristic of adaptive potential in complex systems, emergence is complexity’s anchor-point theme. The process of emergence occurs in the spaces between individuals, where knowledge, information and meaning is exchanged and made, where changed ideas become action, and behaviours – the transmission of interpersonal or social *influence* is the nucleus of emergence in human social systems. However, detailed investigations into a structural theory of social influence and dynamic social impact are peripheral to the extrapolation of meaning at a component level, and are derived primarily of computer simulations. Just as Nicolis and Prigogine (1977) opened the door to dissipative structure by explaining the fundamental mechanics in the emergence process, a similar, concrete explanation of self-organising processes are required in human social systems that give a general basis for the development and refinement of theory.

Limitation 4: *the lack of an established practice of linking disciplines through conceptual models has resulted in direct theory-phenomena applications, referred to here as the 'organisation-science problem'.*

Emergence in complex organisations is a growing field of inquiry with many remaining research opportunities, yet a number of its central themes continue to be loosely connected to practical application and reliant on equivocal translations from root meaning. Strengthening this link holds significant potential, including making sense of complex organisational dynamics and supporting a wide range of theory-building research methods in applied social science and interdisciplinary research. A programme of semantic conceptualisation to expand real-world application of the theory of emergence is proposed in the paper Yezdani et al. (2015).

Limitation 5: *the concept of cognitive entropy is underdeveloped and inadequately applied in a commercial setting.*

Prior authors have argued that the 'tacitness' of knowledge can be evaluated through cognitive entropy (Sigov & Tsvetkov, 2015). This approach reflects the uncertainty of information loss and impact on cognitive process, caused by an imperfection in its cognitive mechanism (Manso & Moffat, 2011). Therefore, there are multiple states as a result of cognition, arising from information transmission asymmetry and cognitive entropy. Despite its mathematical application in a military setting, the conceptual link from entropy to cognitive process and back to the complexity dynamics which require several other environmental conditions and self-organising processes in social systems requires several empirical leaps of faith.

Limitation 6: *a large body of evidence for a theory of emergence relies on computer simulations with simplified conditions that may not translate to the real world.*

Cellular automata, Daisyworld, Quasispecies, cognitive entropy, dynamical social impact, the structure of social space, autopoietic networks, traffic flows, population dynamics, restaurant preference, and voting patterns are all examples of computer simulations used to confirm hypotheses in the development of a theory of emergence.

While simulations have demonstrated significant value on a variety of matters, there is a theory-phenomena break in the conceptual link, which is described here as the 'organisation-science problem'. In simple terms, the lab conditions for a chemical experiment are more readily transferable to the natural world than a computer simulation of cognitive process – with current levels computing power and sophistication.

Limitation 7: *a focus on single points of influence via complexity leadership theory is inconsistent with the dissipative structures theorem, darkness principle, and laws of requisite variety.*

The application of complexity theory to leadership does not seek to remove the function of leadership, but rather to apply a more complete understanding of complex behaviours and dynamics through appropriate interactions between organisational actors (Marion & Uhl-Bien, 2008; Plowman & Duchon, 2008). However, it is rare for discussion on complexity leadership theory to provide concrete definitions that support a direct theory-phenomena link, when transposed from interdisciplinary borrowing. Despite the implications of a new understanding of leadership being 'profound' (Marion, 2008; Plowman & Duchon, 2008), empirical evidence and concepts of complexity leadership theory apply a change only to perspective, and retain a focus largely on single actors – rather than the collective whole, which is paradoxically reductionist. Numerous definitions of leadership (as reviewed earlier) understand the core function of leadership to be the exertion of influence over others, usually to mobilise behaviour toward desired ends.

While the construction of an empirical real-world structural theory of social influence are onerous, linking interpersonal connections with system level pattern have arrived only at a display of a current state (Strang, 2000). The alternative dynamical social impact theory is unable to quantify interactions between agents and as a result describes only the resulting behaviours at a system level, and is therefore a black box explanation. 'Individuals cannot be adequately described as a set of states but rather are best conceptualised as displaying patterns of change' (Vallacher & Nowak, 2008). While this study acknowledges this is a research challenge, it is then empirically unsubstantiated that a model exists for complexity leadership that is single-agent oriented, or a 'relational process' that occurs in the 'spaces between' an individual and a group (Lichtenstein et al., 2006). If those spaces and interrelations between individuals are a mystery to complexity leadership theory and provide no concrete role for a leader, in light of accepted principles for darkness and requisite variety – complexity leadership theory is essentially a model that suggests leadership is mostly a matter of luck.

Limitation 8: *the use of non-linear equations to quantitatively explain emergence through dynamic social impact are limited mainly to computer simulations, or narrow choices which are an inadequate reflection of complex organisational realities.*

Dynamic Social Impact Theory goes some way to explaining complex, dynamical social mechanics. One of its limitations however, is that it applies a very wide brush stroke. With respect to socially influence-able attributes of the person, the theory applies to '*anything* … that is affected by the presence or actions of other people' (Hogg & Tindale, 2008). Its mathematical basis makes dynamic social impact theory suitable for computer simulations, but presents practical limitations when applied more broadly to an open-ended analysis of populations, which have far less limitations on available choices.

Limitation 9: *the processes of interpersonal influence and the cascading chains of effect that give rise to system level behaviours are not well understood and rely on black box assumptions often from a very different field of application.*

Human interaction is not akin to shaking rocks in a barrel. Complex systems are comprised of numerous interacting agents that act on the basis of simple rules or schemata (Anderson, 1999). Human agents are however, a qualitatively unique kind of complex system. Interactions between agents are dynamic, subjective, give rise to spontaneous new meaning, veiled in human perception, subtlety, cognitive process and social structure (Marion, 2008; Vallacher & Nowak, 2008). While the nature of interaction between human agents is substantially complex and unpredictable in itself, interactions do give rise to pattern and are sufficiently robust to generate durable, emergent structures (Anderson, 1999; Chiles et al., 2004; Hazy, 2008b). Social influence is the mechanism by which agents mutually affect changed behaviours, which then form and constitute an emergent pattern. Further evidence is required to properly apply the mechanics of dissipative structures to emergent self-organisation in human systems.

Limitation 10: *second-order Cybernetics is infrequently referred to in complexity theory, but is a major innovation in conceptualising emergent self-organisation.*

While the theories of autopoiesis have been enlarged to encompass social systems, cognition and language, the originating link via an extension of Cybernetics is less frequently acknowledged. Second Order Cybernetics uses a more literal application of the (circular) causal feedback loop to the study itself. Similar to the later notions of autopoiesis, in this manner Cybernetic systems are self-making, and in our case a system which observes itself, rather than being observed by a third party. The notion is also important for ontological reasons, given the uniqueness of systems that are self-observing – which would be of use in crafting a general classification system for the social sciences.

Limitation 11: *complexity and emergence in human systems are to a large extent studies of the arising patterns from interacting agents, yet there is limited concrete knowledge about the interface between agent interaction and system behaviour*.

Undertaking studies at a meso-scale of analysis are notoriously difficult, and account for less than 20% of published papers in management (House, Rousseau, & Thomashunt, 1995) and in leadership (Porter & McLaughlin, 2006). However, ‘if the meso-scale of the multiple organisations within which we work and live are not seriously studied with the objective of how individual effort can be coordinated through the means of these diverse meso-scale institutions, the global ecosystem will, to that extent, be much worse off’ (Goldstein, 2010).

Limitation 12: *theories of complexity and emergence should be redefined in the social sciences, rather than borrowed, therefore the limitations of direct translation of all attributes from root meaning is unnecessary and often fruitless.*

Best described with regard to Cybernetics, 'the truths of Cybernetics are not conditional on their being derived from some other branch of science ... (They) depend in no essential way on the laws of physics or on the properties of matter ... The materiality is irrelevant, and so is the holding or not of the ordinary laws of physics' (Ashby, 1956). Ashby draws reference to the ontological application of energetic transfer, system openness, immateriality, and therefore the irrelevance of designating Cybernetic systems by their mechanistic properties alone (Ashby, 1956). Despite Ashby's work being a cornerstone of complexity and emergence, a definitive meaning to principles such as energy has not yet been achieved.

Limitation 13: *the application of the second law of thermodynamics to human social systems remains ambiguous.*

It is a baseline assumption that the processes of dissipative (chemical) structures work in an equivalent manner for human social systems as though it were simply a broader application of entropy and the Second Law of Thermodynamics (Gleick, 2011). This is an obvious source for criticism and an area that requires attention if a theory of emergence is to advance.

Limitation 14: *the epistemological and ontological foundations for emergence require deep interrogation and discourse, yet are frequently assumed to be universally compatible across all fields.*

As an ontological notion, knowledge itself is continuously emerging and re-emerging, evolving and changing; whereby our understanding of the world influenced by perceptions, interactions and history (Proulx, 2008). There is an indirect causal relationship between the physical world and the emergence of our understanding of it. However, the ontological question of emergence is as pertinent in mathematics and physics as it is in the social sciences. A deep interrogation of the 'ontological notion' of emergence is required to understand its application to human social systems. This has been aided somewhat by publications such as (Bedau, 2008). However, the appeal of the concept appears to outweigh its opaque definitions. Regarding emergence and explanation, if it is impossible to explain the behaviour of a compound, the behaviour in question is said to be emergent (Huttemann, 2005). Such a boundless leap is problematic, without adequate empirical support.

Limitation 15: *the use of metaphorical device is necessary to give simplicity to complex ideas, but presents a double-edged sword if the metaphor itself succeeds over root theory as the primary explanation.*

This is principally a concern regarding the practical application and refinement of theory in a real world setting, via real life case studies. A perverse outcome on the use of metaphorical device (e.g. the flock of birds), gives overly simplistic explanation to the complexity dynamics in play. It is a frequent habit for popular press publications to 'simplify' or 'conquer' complexity, thereby illustrating examples of system-level behaviours that emerge without properly examining the underlying processes, as illustrated in detail throughout the review. The tendency to simplify complex pattern by attending only to the emergent pattern and not underlying mechanisms risks implying predictability to complex phenomena in a frame of retrospective bias.

Limitation 16: *a focus on state rather than process signals a reliance on black box explanations and / or assumptions.*

The patterning of social relations and formation of rigid structure is observable through network measures, as Friedkin (1998) and others (DiFonzo et al., 2013; Macy & Willer, 2002; Postmes et al., 2000) have illustrated. However, describing the resulting network and observing its formation in a variety of settings is incomplete without supplying an understanding of the *process* by which these patterns form – if one proceeds without the other it is effectively a black box science.

Limitation 17: *discourse on the application of autopoiesis to human social organisation and the definition of a living system is incomplete.*

At an abstract and conceptual level, philosophical, sociological and political arguments have been formed to define social systems as autopoietic, (Capra, 1996; Fuchs, 2003; Luhmann, 1986; Mingers, 2002). The application of autopoiesis to the web of life as a whole is however, significantly problematic. As Maturana and Varela realised, organisms are living systems containing closely coupled cells with definitive boundaries (Maturana & Varela, 1987). However, populations of organisms and species within the patterned web of organisation or society are very different, comprised of loose coupling, porous boundaries, and abstract notions of production. Maturana and Varela, were careful to step around this issue, mostly avoiding the topic altogether 'regarding the explicit for that of organisation, we shall not speak further' (Maturana & Varela, 1980).

Limitation 18: *the idea of 'emergence' is at risk of becoming a catchall phrase to describe any subsystem behaviour that cannot be quantitatively understood.*

Despite its principal importance to all other matters concerning the adaptive potential of complex systems, the idea of emergence holds the status only as a thing that is observable and exists – a phenomenon, or in its interdisciplinary state, an 'ontological notion' (Huttemann, 2005). The use of emergence as a phrase to describe phenomena that are not properly understood is not useful empirically.

Limitation 19: *the study of complex human systems is fractured with multiple competing paradigms and limited coherence on basic assumptions, but which is ultimately an emergent body of knowledge.*

It is a natural product of multiple competing pursuits in the body of knowledge to arrive at numerous, often incommensurable perspectives on complex human social systems. Paradoxically, the emergence and proliferation of consensus on theoretical assumptions and accepted views is an example of a pattern of knowledge dissipating across the field and within literature. Unsurprisingly, there is no central point of control (nor should there be) to determine the superstructure of this body of knowledge. The body of knowledge is not accompanied by a universal observer – it is not possible to see its entire shape or form, we see only the 'multiplicity of stitches' (Deleuze & Guattari, 1988). Despite the phenomena of the field being entirely applicable to the pursuit of knowledge in itself, research to date provides no guidance on how to condition, lead, influence or manage this broad, complex and multifaceted aggregation of activity and work.

Limitation 20: *the paradox of hierarchical systems of control that emerge from complex dynamics remains unresolved.*

The natural world has a tendency to form systems within systems, in a nested hierarchy (Capra, 1996). There are however, no 'managers' in nature, or at least they are indistinct from the system itself. Human organisational systems of government, corporations and to some extent society tend to form in a pyramid hierarchy, where decision making powers are vested in the few, rather than the many, where the larger majority are co-creators and collective influencers, but authority is usually concentrated, not dissipated. Theory holds that order is found in far from equilibrium states through the dissipation of energy (transmission of influence), why then are the prevailing hierarchical systems of today not structured in accord with their natural and organic tendencies. This is a major limitation for the application of a dissipative structures theorem to human social systems and relates to the universality for abstract use the second law of thermodynamics.

Limitation 21: *the major sequences of self-organisation in a human social system are inadequately understood, refined and tested.*

The dissipative structures theorem quantitatively demonstrated a necessary basis for the chemical sequence of spontaneous emergence of complex structures in conditions of a far from equilibrium state (Prigogine, 1997). Despite several key studies using the dissipative structures model to describe the equivalent sequences in human systems, the direct theory-phenomena application of the chemical model to a human system has no logical basis and is imbued with methodological bias and vagary, to retrofit a new theory of leadership to achieve a reconceptualisation of leadership using the model of emergence. This issue is evident in Chiles et al. (2004); Lichtenstein (2000b); Lichtenstein and Plowman (2009b); D.A. Plowman, Baker, et al. (2007).

Limitation 22: *the relationship between energetic and informational coupling in the dissipation of structure in human systems is not comprehensively described or explored.*

'The transfer of information cannot take place without a certain expenditure of energy, so that there is no sharp boundary between energetic coupling and informational coupling.' (Weiner, 1954). It could be assumed the necessary coupling of information and energy is sufficient to transmit the idea of dissipative structures throughout all other systems, however, the extrapolation of this result fails basic logical inference. While information and energy are necessarily coupled, they are not equivalent. For instance, information readily transfers between humans, energy does not. Energy as a quantitative property, is bound by physical laws, unlike social objects.

Limitation 23: *deterministic non-linear systems are often confused with predictability, by reconceptualising 'actors' as 'attractors'.*

Chaos Theory is a mathematical study of the non-linear dynamics of complex systems (Capra, 1996). What Poincare referred to as a problem that needed to be overcome, a 'fortuitous phenomenon' would later be referred to as sensitivity to initial conditions, where infinitesimally disturbances may give rise to radically altered trajectories (Peterson, 1993; Poincare, 1892).

While chaotic systems are deterministic (non-random), they are inherently unpredictable (Simon, 2008). Their behaviour is unpredictable due to a number of factors that characterise and describe chaotic systems: *non-linearity*, *sensitivity to initial conditions*, *determinism*, *instability*, and from a topological point of view – *attractors* (Adewumi et al., 2016). Attractors are a mathematical abstraction, an arising of pattern in phase space and are not a complete isomorphism of social behaviour. An attractor is an emergent property in a social system, whereas an individual is (generally) not. Human beings, as physical entities, do not form as a result of the complex processes of an organisation, whereas behaviours, relationships and influence are emergent properties, and relational events that form as a result of system dynamics and interaction. Therefore, an attractor model of dynamic social psychology, such as Vallacher and Nowak (2008) is a useful model to describe a network as it is, but is unable to predict how it will be in future if any variable is infinitesimally altered.

Limitation 24: *an understanding of the correlation between influence increment as a mechanism for information transfer and cognitive entropy is absent from the literature.*

The effectual transmission of information, that gives rise to changed ideas that become actions, could be considered a derivation of Information Theory's cognitive entropy – to describe the extent to which the source of that influence has *potency*. Very limited research has been located which makes an explicit and complete correlation between the concept of *influence increment as a mechanism for information transfer* and *cognitive entropy*, both leading to information transmission decay, and as mechanisms of self-organisation in complex human social systems.

Limitation 25: *a comprehensive classification system based on self-organising systems (not complexity) is absent from the literature, to differentiate patterns which are simply a reflection of self-referential mechanisms (e.g. tiger stripes) and those which are adaptive to a larger purpose (ecosystems).*

The Boulding (1956) system for the classification of complex systems, in addition to a range of reviews of complex adaptive systems and complexity theory provide adequate descriptions of the field under study. However, there is a lack of a comprehensive classification system for self-organising systems, which are able to differentiate self-organising mechanics into self-referential mechanisms and those that arise for the purposes of survival or adaptation to environmental pressures. Maturana and Varela (1980) provide a baseline understanding for differentiating living systems, but choose not to apply this to human systems, which was offered later by Mingers (2002). There is no sharp line between emergent phenomena that simply exhibit the formation of pattern, and those patterns that are the result of more complex processes, via influence increments in human social systems.

Limitation 26: *the definitions of 'life' and 'survival' with respect to autopoietic and adaptive systems is not adequately reconceptualised for human social systems or organisational science.*

Further to Limitation 25, Capra (1996) offers a grand view, to: (a) understand autopoiesis as the *pattern* of living systems (Maturana & Varela, 1987); (b) use dissipative structure as the *structure* of livings systems (Prigogine, 1997); and (c) cognition as the *process* of life (Maturana & Varela, 1980). The definitions of 'life' and 'survival' with regard to human social systems require further exploration (see Table 2.14).

Table 2.14 **Key Criteria of a Living System**

Key Criteria of a Living System
Pattern of organisation The configuration of relationships that determines the system's essential characteristics --------------------------------
Structure The physical embodiment of the system's pattern of organisation --------------------------------
Life process The activity involved in the continual embodiment of the system's pattern of organisation

Source: adapted from (Capra, 1996).

Limitation 27: *There are only a handful of cases that have explored the possibilities of emergence as a viable business strategy; therefore the theory has not completed its due course of development, application and refinement.*

As discussed earlier, the field has a reliance on computer simulations, in part due to the methodological difficulties in placing a comprehensive study in the field. Regardless, such research is necessary given the serious limitations on both a direct theory-phenomena link (a problem in itself), and based on this assumption the use of simulations alone to test theory. A number of cases are reviewed, referenced and listed in the state of play at the previous section of this chapter.

Limitation 28: *the application of theory to emergent system deconstruction and the pattern of organisational collapse are limited.*

Few studies identify the phenomenon of deconstruction of an organisational system that does not result in an emergence of new configurations; this potential outcome is alluded to by Schneider & Somers (2006) proposing that not all systems have the capacity to evolve. Levie & Lichtenstein (2010), in their assessment of stages theory give reference to continuous renewal but do not specify the exact parameters of systems. Finally, the concept is earmarked by Lewin & Volberda (1999) as a possible area of research for new organisational forms. Lewin & Volberda (1999) propose: 'populations of organisations undergoing discontinuous change should become the focal object of such studies – industries undergoing deconstruction'. The challenges of such a study of post-extinction networks would be substantial, but not impossible.

Limitation 29: *the use of complexity principles and emergent patterns to detect subversive networks is not widely published.*

The latent potential to detect source of influence to counter or decouple subversive networks is alluded to by Tyler et al. (2005), and is presumably already used but not widely published. However, advances in understanding or identifying the mechanics to deride self-organising capabilities, prevailing networks, self-synchronisation, communication modes, channels, self-organising networks and the dissipation of influence may be valuable in pursuits of national and international security.

Limitation 30: *human agents are a qualitatively unique kind of complex system; therefore, arguably, the entire field of complexity ought to be redeveloped via an approach characterised by inductive reasoning.*

This limitation is primarily a derivation of the 'organisation-science problem', discussed in detail in the paper Yezdani et al. (2015). In short, concepts and theories should define themselves within their field of application, rather than seek to alter the fundamental understanding of human systems by likening them to atoms or ants.

Limitation 31: *far from equilibrium state is ill-defined in the context of human social systems, rather uses common assumptions of 'chaos' and 'disorder' which differ considerably from the adherence to universal physical laws in the chemical world.*

Osborn goes some way to describing this in a contextual theory of leadership, wherein 'organisations confront dynamism, nonlinearity, and unpredictability. The context is not so dynamic, nonlinear, and unpredictable that organisms cannot survive (as in chaos); but it does not permit firms to linger or seek even a dynamic equilibrium. They must often move to a different 'fitness' landscape or suffer the consequences. Fitness, not goals or strategic accomplishments, becomes the criterion of interest. In this context, systems do not evolve to merely adjust to isolated changes.' (Osborn, Hunt, & Jauch, 2002). Criteria for use in the selection of suitable cases in the study of complexity theory or emergent self-organisation are currently under development. It is anticipated this would be of use in a handbook to support the study of complexity and emergence in human social systems.

Limitation 32: *following from a more concrete definition of 'energy' and its transmission between agents in a human social system, the ability to exercise control over this force also requires scientific explanation.*

This limitation is exemplified in the following quotation: 'unlike criticality, external agents (e.g., leaders, environmental pressures: any agent that controls energy) can influence dissipative structures. Put differently, external agents can control the knobs on Haken's stove'. (Marion, 2008). There are several issues with this idea.
Firstly, agents within a social system can control information and ply their trade to also control influence (or the influence of 'energy'), but to suggest they *control* energy in absolute terms would suggest these leaders wield omnipotence. Second, the likening of 'energetic pressure' in human systems to heated oil in a frypan is a major leap in empirical analysis, which appears to be largely underdeveloped.

Limitation 33: *a pragmatist view is noticeably absent from the application of complexity theory, dynamic social impact theory and the theory of emergence.*

Complexity, emergence and dynamic social impact theory share the ambition of attempting to explain how patterns of consensus, common opinion and culture emerge from the interactions of humans in a social environment (Latané, 1996). The formation of a working theory would benefit from merging an empirical understanding of the potential rigidity of social structure and dynamical processes of social impact, and defined (increments) of measurement for metrics such as *influence,* and in particular from a pragmatist viewpoint to resolve the separation of theory from practice in this important understanding of emergent process.

Limitation 34: *the field lacks quantifiable measures to define increments of influence with varying degrees of potency.*

Such a measure would be useful in better understanding the diversity of social systems and influence behaviours. Lord (2008) and Hazy (2008a) support this notion by suggesting a better understanding of 'influence increment' is necessary to properly conceptualise complexity leadership. Furthermore, it is essential in order to understand what is occurring at the nucleus of self-organising process in human social systems.

Limitation 35: *a study on the general cognition on emergence and its impact on various measures of organisational performance or social cohesion in the workplace would be a valuable contribution to literature.*

Cognition itself is an emergent product of complex dynamics that occur within the human brain, the height of this capacity is a property unique only to humans.
With this in mind, a distinction is possible from other complex systems and those that are comprised of human agents – given their (potential) capacity to skilfully comprehend the system itself. Concepts of second order Cybernetics and autopoiesis are relevant also in classifying these systems. Reliable models for quantitative measure of cognition and impacts on other organisational factors are entirely feasible.

Limitation 36: *the problem of the rope at the end of the anchor – the fluidity of social structure and transitive state of social influences that exist and vanish without trace.*

As we have discussed, emergent self-organisation is the anchor point phenomenon of complexity science. This limitation refers to the ability for emergent pattern and structure to arise and vanish, similar in analogy to Einstein's gravitational waves. With reference to social structures that are less tied to physical proximity and the notion of influence existing only in an intermediate space between states of cognitive entropy, again by analogy to find the 'rope at the end of the anchor' that defines general laws on which these dynamics operate.

Limitation 37: *limited evidence exists in the presentation of real world data on the emergence of patterns via social influence in complex organisations where agents are* *mutually reachable but widely distributed in physical space, moreover the resulting implications of new technology and new channels of workplace engagement.*

The structural theory of social influence and dynamic social impact theory refer to the importance of physical proximity to the probability of interpersonal influence in a human social system (Friedkin, 1998; Latané, 1996). However, it is argued both assumptions need revision in light of the great advances in information and communications technology, and non-traditional workplace environments that distribute workers in physical space, but perform well. This limitation is not consequential to the literature review but is reported as found.

Limitation 38: *the emergence of universal, simple rules. If human social systems behave in a similar manner to other complex dynamical systems – why is it that the simple rules that govern them are unable to be located.*

Anderson (1999) makes compelling reference to the idea of 'schemata' used to drive self-organising tendencies in human organisation. While this model of simple rules differs from the chemical word, in being malleable and loosely based around a course of action or idea, the mechanics for the emergence of rules themselves is yet to be comprehensively demonstrated. Cellular automata provide an exceptional demonstration of the operation of simple rules in a simulated environment, but not the emergence of the rules themselves (Wolfram, 1983). Considering human social systems as autopoietic, it would be expected these rules or schemata are an emergent property of the system, and are not necessarily imported and unalterable, when in operation to generate system level order become a component of the system itself, wherein more self-reinforcing rules are created. In this way a human social system can be considered self-making or autopoietic.

Limitation 39: *limited evidence is available on the use of principles of self-organisation in observable patterns to reverse engineer complex networks, to test theory and remove the self-referential bias in quantitative analysis.*

Partly arising from the frequent use of computer simulations, the observation of pattern appears to be probable, when timescales are advanced and conditions configured to promote self-organising tendencies. Using the basis of these simulations, evidence is needed to reverse engineer pattern into real-world complex systems to ensure theory is not biased by self-referencing methodologies. In other words, a data model is needed that does not foreshadow the emergent outcome but is able to capture pattern as it occurs. The analysis would then enable reverse engineering on the sequences and processes the system experienced in order to arrive at its ordered state.

Limitation 40: *an opportunity exists to reconceptualise leadership as an emergent property or event, seen in the patterning of follower behaviours and resulting from a relational process; in this way autopoietic leadership is a transient quality that belongs to the system – not the individual.*

Further to the limitations above in relation to complexity leadership theory, an opportunity exists to further conceptualise leadership as an emergent property. While complexity leadership claims a major shift in thinking for the practice of leadership, it remains centred on (formally or informally) designated individuals and their interaction with others. This is a limitation, as the focus on mechanisms for order are not centralised or coordinated by a single actor. A viable case for conceptualising leadership in this way may be challenging and could be feasible in some cross-cultural environments.

Limitation 41: *literature is unclear on the scope, definition and autonomy of emergent phenomena.*

Many examples and definitions are given to describe emergent phenomena throughout this thesis. However, it is problematic to apply a universal definition to all, without a general theory on the horizon. For example, is it viable to define consciousness and snowflakes on the same classification scale? A definition may also go to how we research, test and understand the mechanics of emergent properties in their various natural settings. Emergent phenomena may also require an ontological category – process, pattern, law, living system, etc. (Bedau, 2008). The objective notions of emergence are also vague. A real case of emergence in the world of business may be the equivalent of spontaneous symmetry breaking in a chemical system (Anderson, 1999). The final limitation is the philosophical and practical question of how autonomous *emergents* are from their underlying base. While many (or perhaps most) emergent phenomena cannot be separated from their foundation processes given that is what they are a product of, the degree or threshold of autonomy has significant implications. This has led to some discussion around 'downward causation', in which emergents have a causal relationship on their emergent base (Bedau, 2008).

2.6.3 Concluding Remarks

Even though the ideas of emergence have long been associated with the social sciences and organisation of economies, cities, political systems and networks, the mechanism for the creation of order remains derived principally of the chemistry lab. It is not enough empirical evidence to simply observe emergent patterns and assume an interdisciplinary translation is valid. To develop, refine and apply a theory of emergence, first, an understanding must be achieved on the mechanism by which system level order is created. Hence, the *function* and *process* aspects of a potential theory of emergence are deficient in this regard. Without such a definitive general process, there is no reason to believe a theory of emergence exists beyond the constructs and ideas that are proposed for each respective field and perhaps individual systems. Hence, few of the underlying mechanics that explain the mechanisms for order can be universally applied – as there is no accepted theory or conceptual bridge to link phenomena to their axiomatic bases.

The limitations above are revisited once more in the discussion chapter, with resulting propositions (where possible) arising from the executed program research. While the breadth of limitations uncovered through literature review may appear to be significant, it may also be unsurprising such matters are not yet resolved for a theory in its nascent stages. The resolution and common ground between ideas and concepts on complexity dynamics requires imagination, but with a larger view is 'just around the corner'. While not a literature gap in itself, given the many practical issues faced by complexity researchers in the social sciences, a handbook for the study of complex systems in applied social science would be a great asset, and would benefit from use of the findings of this study.

2.6.4 Issues and Limitations of the Review of Literature

While the review of literature presented here is uniquely comprehensive, it is not without limitations. The works used in this review represent a chosen sample and there is a risk they may not reflect the entire body of knowledge that relate to complex and emergent phenomena. Complexity has reached various stages of advancement in different fields and this is evident in the presentation of findings that are drawn from a wider range of sources (Manson, 2001; Burnes, 2005; Moldoveanu & Bauer, 2004).

The stages of application may reflect the ease with which original mathematical and computational models of complexity's traditional application can be applied – that rely less on the 'messy' world of human and social interaction (Uhl-Bien & Marion, 2008). From the selection of literature it is possible that there have been parallel findings in other paradigms that may have a relationship to those that are discussed here. Location and discussion on these competing perspectives is provided, however further conceptual frameworks through an operationalised theoretical framework would benefit from a dedicated investigation into these discrete relationships and multi-paradigmatic links.

Research strategies of McKelvey (1999) proposed a less semantically driven research agenda grounded in mathematical and computational models derived of the traditional application of complex systems. However, as noted by Marion (2001) this approach lacks a qualitative element to make sense of complex and multifaceted social phenomena, applicable to the world of human social interaction prevalent in organisations. A balanced and encompassing research agenda does not yet exist that illuminates the theoretical space occupied by current theories and sheds light on what has so far been achieved and what remains necessary to operationalise, apply, confirm/disconfirm and refine or discard. Overall, it is the assessment of this review of literature that a theory of emergence is in a state of transition – from conceptualisation to application and refinement, thus overall it is in a nascent stage of development and is not yet confirmed.

3 Methodology

3.1 Research Foundations

This study explores how organisations adapt through emergent self-organisation, with particular focus on the role of social influence among interdependent agents in a complex human social system. For this purpose, an interview driven multiple case study approach is used to observe the interactions and behaviours of agents within a complex system, and to further explore the development, operationalisation, application and refinement of research outcomes as they apply to a theory of emergence in complex organisations. As discussed at Chapter 2, many strands of possible research exist under the umbrella of complexity theory that are indelibly connected – it is acknowledged this study is but one of these many strands. To provide further assurance this particular strand of inquiry is of materiality, a detailed map of literature (Figure 2.1) has been provided that positions the study in relation to existing literature and theory-building paradigms.

It is of relevance to note that the interview-driven method adopted in this study builds on the mathematical simulations and computational modelling employed in many previous studies, which also seek to interpret complex behaviours in systems (Moldoveanu & Bauer, 2004; Marion & Uhl-Bien, 2001; Anderson, 1999; McKelvey, 1999). The rationale for a pragmatic approach is supported by Lynham's (2002) general method that calls for the application, confirmation and continuous refinement of theory informed through real world practice. Data derived only of simulations and computational models neither fulfils this requirement for recursive theory development, nor provides the necessary information to deliver a qualitative understanding of the dynamic and subjective interactions of interdependent *human* agents – that differ fundamentally from the agents under study in the origin fields of chemistry and physics. The following sections provide an overview of the research foundations, purpose, methods and limitations of this study.

3.1.1 Conceptual Framework

This study is positioned within the broad and interdisciplinary framework of complexity theory. The lens of complexity theory proposes an understanding of organisations as complex adaptive systems, capable of self-organised patterns of behaviour arising from the relatively simple interactions of individual agents (Goldstein, 1999; Anderson, 1999; Chiles et al., 2004). Emergent self-organisation is adaptive change that occurs from the ground-up as opposed to the top-down. Order is achieved at the system-level as a result of the dynamic interaction of individual agents within a complex system of numerous components (Chiles et al., 2004). Emergence is the anchor-point phenomenon of complexity (Anderson, 1999), and hence the focus of this study. Irrespective of the field of study or worldview, it is the capacity for emergence that distinguishes complex adaptive systems from all others.

The capacity to adapt to complex and unpredictable change is a core competency for the modern organisation (Burnes, 2005; Brown & Eisenhardt, 1997; Hannan et al., 2003). Despite being surrounded by pressure for change and a high rate of failure to successfully manage change, organisations are still frequently thought of as the machine-like control systems of the post-WWII era (Suchman, 2011; Plowman & Duchon, 2008; Wheatley, 1999). A greater understanding of the complexity of change in unfamiliar and uncertain environments and the capacity for organisations to efficiently and effectively respond without explicit instruction is a valuable endeavour given the continuously shifting and dynamic landscape of contemporary business practice (Plowman & Duchon, 2008; Moldoveanu & Bauer, 2004; Marion, 2008).

Due to the elusive nature of applying complexity principles to everyday problems, this study is grounded by the traditions of pragmatic inquiry which provide extrapolations from and which apply to the real world of practice (Lichtenstein & Plowman, 2009; Yolles et al., 2011; Metcalfe, 2008). Fortunately, there are a range of research methods that meet the unique demands of complexity science and enable observation of subtle dynamics of agent interaction that in turn form system-level behaviour (Dooley & Lichtenstein, 2008; Anderson, 1999; Lichtenstein & Plowman, 2009).

3.1.2 Epistemological Foundations

Qualitative methods rest on symbolic-interaction and pragmatic traditions of inquiry. Symbolic-interactionism has specific relevance to qualitative research methods of this study in seeking to understand the self-constructing realities that emerge through patterns of human interaction and the context in which they occur (Blumer, 1969). It is noted that symbolic interactionism research is usually applied in qualitative research, and is appropriate in this regard. The foundation is relevant at several levels, due to its focus on human interaction in specific situations and through the emergence of organisation or meaning (Reynolds & Herman-Kinney, 2003). Furthermore, key principles are relevant to the foundations of complexity, *human agency* – the actions of individual agents in the system; *interactive determination* – non-reductionism of complex systems; *symbolisation* – arising of meaning in human systems; and *emergence* – transformations of social organisation (Reynolds & Herman-Kinney, 2003).

Understanding context is key to making sense of parts interacting as a whole system (Osborn et al., 2002). The pragmatist research tradition further compliments this study, importing that ‘knowledge resides in the changed idea it enforces into action’ (Dewey, 1929). Thus, the epistemology sought is one that accommodates pluralistic behaviours, useful in emerging environments and for everyday practical affairs, with no need for an ‘artificial divide’ between theory and practice (Corbin & Strauss, 2008).

Complexity theory itself, in addition to neighbouring or contributing concepts has emerged and developed throughout the last 50 years, not necessarily adhering to an organised structure of theories or in any one field. The abstraction of concepts crosses many interdisciplinary traditions of inquiry, without a conceptual model for recursive validation or interdisciplinary borrowing. Given the transcendent nature of complexity, it is argued here that a process of semantic conceptualisation is necessary and of value to understanding complex systems, by providing vehicle for exploring phenomena across an interdisciplinary divide. Table 3.1 explores and contrasts key epistemological traditions and draws reference to the direct relevance of each, to the process of theory building for emergence.

Table 3.1 Theory Building Paradigms and their Application

Research Element	*Positivism*	*Post-positivism*	*Pragmatism*	*Interpretivism*	*Criticalism*
Epistemology	Objective, stable pre-existing patterns or order can be discovered	Realism, empiricism, being objective is an essential aspect of competent inquiry	We need to stop asking questions about reality and laws of nature	Social constructionism, constructivism, context dependent	Scientific knowledge is imperfect but can fight false consciousness
Focus of research	Concentrates on description and explanation	Attempts to predict and identify antecedent conditions; focuses on causality; scientific method central to process	Focus is on 'what works' and solutions to real world problems	Concentrates on understanding and interpretation	A critique that reveals true conditions and helps people take action; identification of false beliefs that hide power and objective conditions
Methodology	A logical, deductive system of interconnected definitions, axioms, and laws	There are laws or theories that govern the world and these need to be tested and verified	Practical, recursive, non-simulated, focused on real cases	Aim is to understand and describe meaningful social action	Aims to penetrate the surface level
Direct relevance to complexity theory building research	Less applicable	Limited application: integrative and multi-paradigmatic constructs to describe the external environment	Informing the utility of conceptualisation and research outputs. Drawing from quantitative and qualitative approaches as necessary, ensuring application and continuous refinement	Primarily qualitative data collection and analysis, focus on interaction between individuals and co-constructing realities	Less applicable

Source: adapted from social research methods in Neuman (2010).

3.1.3 Limitations of Existing Research

Despite a rich history in the natural sciences and mathematics, complexity is a relatively new addition to social and organisation science; as a result there are many research applications yet to be explored (Marion, 2008). Three key empirical studies undertaken during the last decade exemplify the variety of explanations for emergence *within* an organisation (Plowman & Baker, et al., 2007), emergence *of* organisations (Lichtenstein, 2000), and emergence *across* organisations (Chiles, Meyer & Hench, 2004). The shared theme of all three studies is a detailed exploration of why theoretical constructs apply to organisations and a documentation of the presence of the four previously discussed conditions of complex adaptive systems.

However, further research is required to understand the function and process of emergent self-organisation in complex human social systems, which underlie system-level observations and give rise to adaptive potential. Furthermore, a deeper understanding is necessary on the unique application of emergent processes, intrinsic to human systems, and the mechanisms of dynamic interaction that give rise to coherent pattern in turbulent conditions. Research questions of this study are a focused and logical extension of the existing body of knowledge, positioned relative to its limitations, which are described in detail at the previous chapter.

3.2 Research Questions

This study explores how complex organisations adapt through emergent self-organisation, with a focus on the role of influence between agents. Data-driven conceptual models are developed and applied to two case studies, characterised by significant levels of uncertainty in their operating environment, and substantial levels of knowledge-based activity and operational complexity.

An interview-driven, multiple case study approach has been chosen to contribute to a deeper understanding of how emergent self-organisation occurs in a socio-organisational context, the inner workings of complex human social systems, and the role of inter-agent influence and interdependence on the capacity of firms to adapt.

For this purpose, two primary research questions are in scope, their definitions and explanations are outlined as follows.

1. What role does emergent self-organisation play in adapting to new or acute internal/external pressures? Can emergent self-organisation be reliably observed and predicted?

   Underlying questions:

   a. What does the literature tell us about the nature of emergent-self organisation in the context of the modern firm?

   b. What universal features, if any, identify the pattern of emergence in complex organisations?

2. How do (emergent) patterns of behaviour coalesce in complex organisational systems, can a conceptual model for the theory of emergence be applied to this process?

   Underlying questions:

   a. What is the role of inter-agent (social) influence on the emergence of coherent structure and system level behaviours in such a conceptual model? How do we define this concept in the context of the social sciences?

   b. How can the conceptual model be applied, measured, and managed in a real world scenario of emergent self-organisation in complex firms?

   c. What are the broad implications, potential applications, and challenges in the application of a theory of emergence for organisations and management?

3.2.1 Research Elements and Definitions

In working toward the overarching research area of how organisations adapt to internal and external pressure through emergent self-organisation, this study employs a progressively refined pathway of inquiry to focus on the critical elements that make up the phenomenon of emergence, summarised at Table 3.2.

Table 3.2 **Research Elements and Definitions**

Elements	*Explanation*
Emergence (or emergent self-organisation)	Emergent self-organisation within an organisation, i.e. the emergence of pattern, structure, processes or rules (utility of phenomena) *and* the creation of novelty, efficiency, survival, sustainability or innovation (performance of phenomena)
Complex firm (complex organisational system)	A complex firm is defined as having sufficient agent interdependency, interaction and adaptive characteristics to enable the occurrence of emergent phenomena, requiring sufficient organisational actors, high levels of agent interaction and dependency. The term *complex human social system* is used to describe such systems in an organisational setting
The role of	Exploration of the function and process of the phenomena, occurring within richly described environmental conditions, referencing the moderating role of social influence on the generation of coherent structure. Applied via qualitative, multiple case study research suited to theory building research
Influence (esp. social influence)	The role and effect of influence, i.e. on the creation of micro-strategy or simple rules, decision making, horizontally or as a function of leadership, probability of an interpersonal action, attachment or reaction, a force that can be employed by an agent to change the behaviour of another/others
Knowledge and information	Firms or organisations involved in the delivery of services that have a significant focus on the use of professional knowledge or expertise that is related to a specific technical discipline or domain, as such the business is not solely involved in transactional activities, and hence there is a high capacity for subjective and intelligent use of information and knowledge

While the focus of this study is appropriately narrow, a range of situational factors and phenomena are observable during data collection, which describe internal and external environmental factors. These factors that are relevant to the study and provide situational context, are explained by the following research logic: Contextual Factors [*cf*] + Internal Complexity Dynamics (Critical Values) [*cv*] +/- Moderating Factors (Influence) [i] = Emergent Self-Organisation [E], as follows:

$cf + cv +/- i = E$

This method for defining the path of inquiry is derived of the concepts and ideas from existing research that defines the phenomena under study, as illustrated at Figure 3.1. These are expanded on further through the presentation of findings and the use of conceptual models. In summary, complexity theory holds that at certain points in the life of an organisational system, critical threshold can be reached, as a product of internal and external conditions (Anderson, 1999), as these threshold states become critical or at the 'edge of chaos' (Osborn et al., 2002), the conditions are ripe for experimentation, adaptation and the emergence of new forms, in the manner described by previous authors including Kauffman (1993); Lichtenstein (2000a); Prigogine and Stengers (1984). This study aims to develop a more comprehensive understanding of what role emergence has on the system's adaptation to new or acute pressures (Research Question 1); and how this behavioural process works (Research Question 2). The figure below describes the narrowing probability of emergence, and the equivalent focusing of research within this study, a concept aptly coined by Prigogine (1997) as a journey along 'the narrow path'.

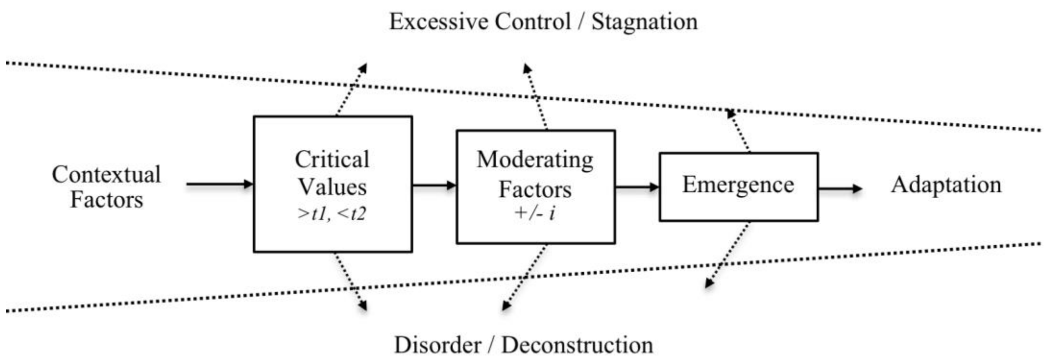


Figure 3.1 **Path of Inquiry**

The lens of complexity theory offers a novel contribution to understand the realities of what is occurring within organisations for the purpose of extending the longevity and many other possibilities of the modern firm. Table 3.3 summarises the Research Inquiry Focus Areas, including a short statement on internal complexity dynamics, moderating factors, and observable conditions and the likely emergence / output. Implications of current literature on the matter range from metaphorical device to the transformation of paradigms.

Table 3.3 Research Inquiry Focus Areas

Contextual Factors	*Internal Complexity Dynamics* (a)	*Moderating Factors*	*Observable Phenomena*	*Emergence / Output*
Emerging / intensely competitive marketplace	High frequency agent interaction and interdependency	Influence (b)	Patterns, schema, structures	Adaptation
Complex organisation/s	Alliance coadaptation	Simple rules	Micro-strategy, diffusion (k,i)	Novelty
High potential / growth sector	Distributed intelligence	Heterogeneity	Goal-oriented social networks	Efficiency, survival or growth
Post-crisis or significant change	Complex product / service / processes	Motivation		
Uncertain future prospects or instability	Driven by innovation, quality and efficiency	Human / social capital		
Changing industry, shifting priorities	Diversification of schema and networks			*Research Process Factors*
Single industry, multiple players	Multiple levels of organisation			Analytic generalisability
Strategic regional significance	Adaptive tension			Application to real-world scenarios
Far from equilibrium state / dynamics				Cross-case synthesis

Note: shaded areas reflect primary research interests; (a) Internal Complexity Dynamics also refer to the 'Critical Values' required, i.e. above than the 1st critical value [t1] – *edge of order;* and within the 2nd value [t2] – *edge of chaos* (McKelvey, 2008); (b) This study employs an understanding of leadership as a function of social influence between one and many agents. (k=knowledge, i=innovation). The table suggest multiple potential relationships across elements (columns), not according only to items that appear in each row.

3.2.2 Research Process Overview

In the interests of ensuring rigor and effective project management throughout, this study has been conducted in three phases, as outlined below. The summary of planned research phases, objectives, method and output are outlined at Table 3.4, and described in further detail as follows.

Table 3.4 **Summary of Planned Research Phases**

Phase	*Objective*	*Method*	*Output*
1	Review the current state of the field, refine and positioning research	Extensive literature review, identification and articulation of assumptions, gaps in literature, antecedent conditions, propositions, hypotheses and limitations, refined research questions and methodology	Thesis development Publication
2	Data collection	Interview-driven, multiple case study data collection, transcribed interviews, supplementary data and case notes	Thesis development Publication
3	Analysis, synthesis and presentation of results	Open coding, cross case synthesis, data driven conceptual models, summation of findings, contextualisation, analytic generalisations, conclusions	Thesis development Publication

Phase One: Review

An extensive literature review has been conducted sufficient to encompass scholarly and empirical works relevant to the study. In light of common criticisms of the field, a substantial process of cross-validation is applied to theories and concepts, in addition to Lynham’s general method for theory building research, to evaluate the stage of theory development, its limitations and to locate the value of this study within the context of existing works. Base assumptions of complexity are noted and evaluated within the review of literature, and serve as a lens for the examination of data in guiding observations to meaningful conceptual domains. For example, dynamic agent interaction is required in to generate novel forms.

Phase Two: Data Collection

Using an interview-driven, multiple case study approach, data has been collected and used from in-depth interviews with key actors with direct involvement and recollections of events for each of the two case studies. The interview method is described in detail at Section 3.3.2. Transcriptions of audio recordings have been made and checked. A total of 47 interviews have been recorded and transcribed, resulting in over 3.2 million words of transcribed interview data, the largest on record for both cases.

Phase Three: Analysis, synthesis and reporting

The final stage of the research process consists of a detailed and structured analysis of data, cross-case synthesis, concept analysis and mapping, reflection on previous studies, and conceptual model in light of findings. Conceptual models can be considered as an empirical tool for 'sensitising concepts' suited to testing and refining theory (Blumer, 1954). An iterative process of research and theoretical refinement is used to test the conceptual model and report findings. The empirical work allows for the identification of further deficiencies that are unable to be resolved or that have arisen unexpectedly. Data analysis and findings provide meaningful contribution to the existing body of knowledge to make sense of emergent self-organisation in complex firms. Data collection and refinement processes also lend to the development of an operationalised theoretical framework. The relative contribution to theory is assessed, its relevance, practical application, limitations and opportunities for further research are evaluated and reported.

3.2.3 Justification for the Methodology

Theory building can be described as the 'ongoing process of producing, confirming, applying and adapting theory' (Lynham, 2002). With this in mind, theory-building research ideally comprises two main qualities: validity and utility (Van de Ven, 1989). While the laboratory isolates phenomena from their real world context, case studies deliver a richness in real-world context derived from authentic experience (K. Eisenhardt, 1989). Therefore, it stands to reason that the most ideal location to situate research on nascent theory, which investigates the emergence of human behaviours and organisational systems, is via real world practice. Fortunately, with the use of well-established case study practices, there is no need for an artificial divide between theory and practice, theory can be continuously informed by and linked with real-world practice (Corbin & Strauss, 2008; Lynham, 2002; Van de Ven, 1989). Theory building from case studies is 'one of the best (if not the best)' methods to derive a qualitative understanding that can inform later deductive reasoning (K. M. Eisenhardt & Graebner, 2007).

An interview-driven multiple case study approach has been adopted in order to enable observation of the inner-workings of organisations operating in their natural setting (K. Eisenhardt, 1989; Langley, 1999; Pettigrew, 1990). The case study approach draws on previously tested case methods that lend to theory building outputs, combining an interview-driven collection method (Fawcett, Fawcett, Watson, & Magnan, 2012; Harris & Sutton, 1986) with multiple case analysis (Burgelman, 1983; Gersick, 1988).

The advantages of a qualitative case study method are that it provides flexibility for exploratory lines of inquiry in support of an inductive approach, not possible through only quantitative means (Corbin & Strauss, 2008; K. Eisenhardt, 1989). This study draws primarily on qualitative collection methods appropriate to observing the intricacies of how dynamic interactions affect system-level change (Lichtenstein, 2000b; Spee & Jarzabkowski, 2011). Further strengthening the method, is the combination of multiple sources of data, including synthesis of multiple case studies which are accompanied by objective datasets to verify accuracy of claims made regarding the status of the internal and external environment (Creswell, 2009; K. Eisenhardt, 1989).

3.3 Data Collection

3.3.1 Selection of Cases

Drawing from existing literature, the most likely place to observe emergent self-organisation is between 'threshold-states' (or critical values) where organisations are confronted with substantial disequilibrium from internal and external pressures beyond the normal range of activity (Anderson, 1999; Osborn et al., 2002). Table 3.5 explains each of the threshold state criteria and their application to case one and two.

Further information and explanatory notes in the application of the criteria are included in case notes at Chapter 4 – Findings. Theoretical frameworks that contribute to defining threshold-states have been used to inform a set of macro and micro-level criteria upon which cases have been selected and contextualised, including consideration of: (a) changing market expectations; (b) critical and immediate pressures to adapt; (c) shifting definitions of success; (d) uncertain future performance capabilities; (e) diversification of schema, networks and competitive forces; and, (f) characteristics of apparent structural inertia (Anderson, 1999; M. Hannan & Freeman, 1984; Lichtenstein & Plowman, 2009b; Osborn et al., 2002).

The threshold states described at Table 3.5 provide a framework for the identification of likely situations in which emergence occurs, but are not a *fait accompli*. The application in this study to two real world scenarios is very much subject to the many factors at play in each case – beyond those that would be considerable in a laboratory setting. The application of threshold state criteria are used in this study as a logical guide and contextual yardstick, but should not be interpreted as a straightjacket that limits broader or more targeted research.

Table 3.5 Threshold State Criteria and the Selection of Cases

Threshold State Criteria	*Brisbane Floods Crisis*	*Global Financial Crisis*
(a) Changing market expectations	HIGH – shifting expectations of the public and government to avoid inundation at all costs and a long period of drought immediately prior	HIGH – increasing expectations on market returns, normalisation of risky behaviour and increasing complexity in securitisation methods
(b) Critical and immediate pressures to adapt	HIGH – immediate environmental pressures causing the need for rapid decisions with irreversibility	HIGH – sudden realisation of vulnerability and risk exposure in collateralised debt
(c) Shifting definitions of success	HIGH – unclear and changing definitions of acceptability in inflicting damage to urban areas	HIGH – from profitability to survival in a new landscape of competition
(d) Uncertain future performance capabilities	MODERATE – uncertain performance criteria or objectives	HIGH – rapid change from status quo to insolvency risk
(e) Diversification of schema, networks and competitive forces	MODERATE – changeover of personnel, inadequate communication of key data, competitive pressures	HIGH – highly interconnected market with decentralised controls
(f) Characteristics of apparent structural inertia	HIGH – risk averse culture, uncertain risk appetite or tolerances	MODERATE – tendency to break norms, with questionable risk tolerance and limited regard for systemic failure

Explanatory Note: HIGH – the criteria is highly applicable to the case based on an assessment by the research team of the operating environment and known market conditions; MODERATE – the criteria is moderately applicable to the case; LOW – the criteria has a low level of relevance for the case.

Extending from the theoretical propositions of Marion (2008), Lichtenstein & Plowman (2009), Chiles et al. (2004), Anderson (1999), Stacey (1995) and Meyer et al. (2005), this study aims to generate a deeper understanding of how emergent self-organisation occurs in human social systems and the effect of emergent behaviours on the capacity of firms to adapt in crisis. While the focus of the study is not especially on the anatomy or causes of the crisis itself, both cases exhibit behaviours that are on the edge of a certain threshold that gives rise to disequilibrium and calls into question organisational norms. Hence, situational factors and context are described in detail.

Complexity and emergence is concerned with a large worldview where a crisis could quite simply be an observation of the mechanics through which a system moves from one state to another. Crisis management in itself is therefore not the focus of this research. This study adopts a focus on the emergence of new forms, the patterns that give substance to organisation, without explicit control and the shape of things that autonomously manifest in certain conditions. The two cases provide an ideal location for the study to take place, given the high level of complexity inherent to the situation, environment and organisations under study.

3.3.2 Interviews

Interviews used open-ended and (evidence-based) direct question methods to gather data from informants across functional areas, including those with direct involvement in the event, to deliver exploratory and context-rich data from a sample of 47 informants. This data was collected via official channels during commissions of inquiry following each crisis event and during the ensuing period of around six months. Semi-structured interviews provide the most fitting method to: (a) gather detailed insights from informants on how adaptive change occurred at successive organisational levels; (b) allow comparability of findings and links with individual and group behaviours; and, (c) provide flexibility to unpack findings with a source of rich data. Interviews were recorded and transcribed, with accuracy verified by a professional audio transcription team.

3.3.3 Theoretical Sampling

Theoretical sampling is a process of choosing appropriate sites for further analysis using information derived from the initial data extraction process, and is therefore not random (Corbin & Strauss, 2008). Given the focus on emergent behaviours, theoretical sampling from targeted interviews, combined with objective data have been used as tool to focus data analysis on the epicentre of activity where the majority of relevant decision-making and activity has occurred. Explanatory notes from each case are described below in further detail.

Case Study One, Brisbane Floods Crisis: objective rainfall and flood release data were used to identify the trigger points for the crisis and the critical timeframes at which decisions were made that pertain to the immediate management of the crisis. This enabled a focus on the actions, behaviours and decisions of engineers on duty immediately prior, during and after the actual events. Objective data are described in more detail in Chapter 4 – Findings.

Case Study Two, Subprime Mortgage Crisis: objective financial data was used to identify the epicentre of (economically significant) amplification on collateralised debt obligations passed between investment firms. While the participation and spread of toxic assets in this case is complex, the field can be simplified by examining participation in the Troubled Asset Relief Program (TARP) – Capital Purchase Program (CPP), an emergency economic stabilisation program which targeted subprime related collateralised debt problems. Furthermore, the criteria for participation in the program calls for transparency and the release of data (enabling this study), fitness for survival and the ability to quantify the magnitude of troubled assets, and therefore substantial participation in the activities immediately precipitating the crisis. The approach above, assists with the aim of identifying the most ideal location to observe the phenomena, drawing on contextual factors, a targeted method suggested by prior case study research (K. Eisenhardt, 1989; Harris & Sutton, 1986; Pettigrew, 1988; Spee & Jarzabkowski, 2011).

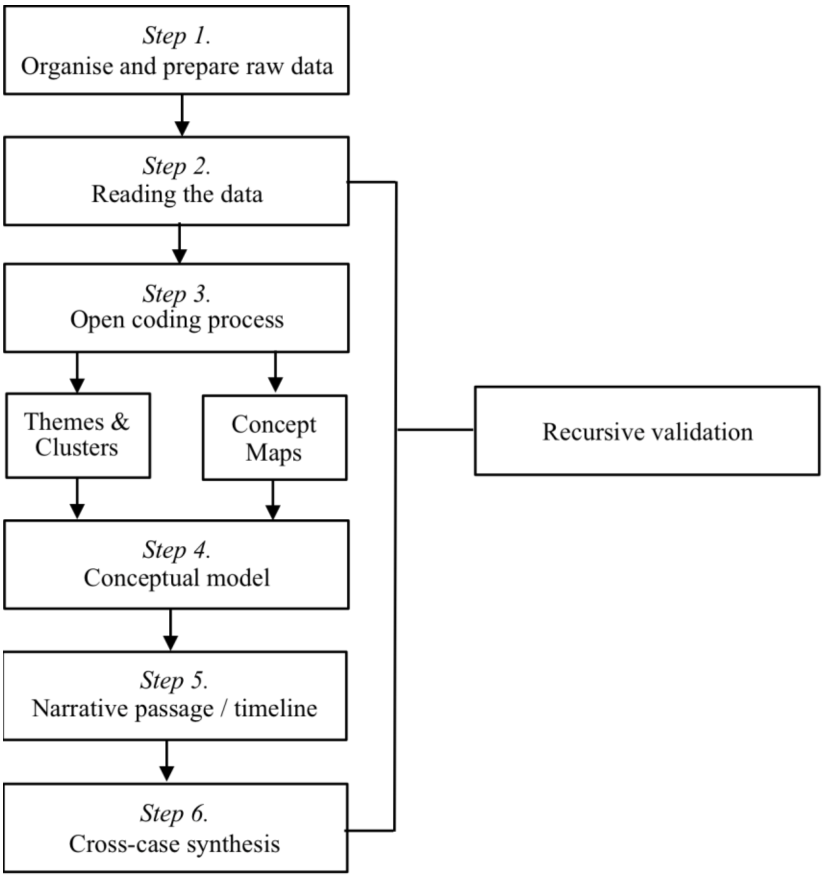
3.3.4 Supplementary Data

Various sources of supplementary data have been used and referenced to place actions, behaviours, and decisions in context of the crisis event and environmental conditions. In Case One (Floods) these include government and official publications on flood release and rainfall data, inundation levels and hydrology maps; Case Two (Subprime) refers to financial data on transactions related to collateralised debt, government assistance programs, historical stock prices, peak subprime mortgage origination years, mortgage backed security structures and quantities, and derivative product counterparty exposures, to further understand the environmental conditions and timing in which decisions were executed.

3.4 Data Analysis

Data analysis was undertaken in stages to enable within case analysis and external validation, allowing themes, concepts and patterns to emerge from the data (Lichtenstein, 2000; Yin, 1981). Following individual analysis of interviews, a synthesis between interview transcripts was used to generate a robust outcome and identify consistencies and differences between statements from key actors, and the broader observations of the event itself (Eisenhardt, 1991).

Analysis and coding was conducted in a stepwise manner, as illustrated at Figure 3.2, and explained thereafter.



Source: adapted from Creswell (2009).

Figure 3.2 Data Analysis and Validation Process

Step 1: Raw data was collected, organised and prepared for analysis. Interview audio files were transcribed. Interview transcripts were read and marked in chronological order relevant to key decisions and events.

Step 2: Reading the data. This step involved a second reading through the data to gain a deeper awareness and understanding of the ideas and thoughts expressed throughout the transcripts. Case notes and mind maps were made to assist with this understanding.

Step 3: An open coding process was used to further organise the data into segments (Creswell, 2009). Grounded by relevant literature, data was organised into provisional categories then final codes as themes, interrelationships and concepts emerged through successive stages of analysis and review (Lichtenstein, 2000; Corbin & Strauss, 2008). Three types of codes emerged during analysis and were applied in a recursive process: theme codes, concept codes and code counts (Creswell, 2009). An open-coding process is used to identify common themes, form provisional categories and explore interrelationships between categories through a recursive validation process (Corbin & Strauss, 2008).

a. Data was organised and prepared for analysis and coding. Data was sorted and extraneous information was removed (administrative data such as page numbers). Stoplists were created to exclude certain commonly occurring but non-conceptual terms, such as ‘and’, ‘is’, ‘the’. Data was processed using the Leximancer software tool. The software tool assists with the generation of concept clusters and a logical concept analysis and mapping display.

b. Concept Analysis and Mapping (CAAM) techniques were used to assist with the creation and analysis of concepts, concept clusters and the interrelationships between them in the data Trochim, Cook & Setze (1994), Kane & Trochim (2007) and Rice & Martin (2011). The background and evidence of this approach is described in further detail below at Section 3.4.3. Concepts are derived of the data to ensure validity and replication.

c. Concept frequencies, proximity, summed co-occurrence and relationships are used to discover clusters of meaning within the data. The aim of this approach is to identify and understand the relationship between concepts (their summed co-occurrence) that extrapolates meaning within the given circumstances of the narrative.

d. The coding and concept cluster analysis process is repeated for each component of data (interview transcript) then the dataset as a whole, to provide recursive validation for each concept and cluster of concepts revealed. The entire coding and concept mapping process is repeated until the concepts and themes are unchanged, therein theoretical saturation has been achieved (Corbin & Strauss, 2008).

Step 4: Advancing from the concepts and themes represented and understood in the narrative, a data informed conceptual overview is developed and verified through the remaining steps. 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 (Creswell, 2009; Lichtenstein, 2000b).

Step 5: A narrative passage in the form of a timeline was constructed (where possible) of the key decisions that occurred during the events and externally validated using a range of objective measures, as described earlier at Section 3.3.4 (Creswell, 2009).

Step 6: Context building, triangulation of data sources, cross-case synthesis and a validated conceptual model assisted in the interpretation of data to identify patterns, themes, interrelationships and irregularities in the data (Pratt et al., 2006; Creswell, 2009). Coding and analysis of data were placed within relevant contextual factors as defined by Yin (2009) as analytic generalisability.

Replication of data extraction and analysis processes has been undertaken throughout the analysis and coding process to ensure replication logic and validity (Corbin & Strauss, 2008). A recursive process of validation has allowed for the interpretation and extrapolation of meaning to be verified against the data and across cases throughout the process and in using the tools described above (Creswell, 2009).

Analysis has been undertaken in stages via two streams: within-case and cross-case analysis (K. Eisenhardt, 1989). Individual case analysis is first undertaken to appreciate the unique contextual factors of each case. The study maintains replication logic by initially treating each case independently, allowing themes, concepts and patterns to emerge from the data prior to identifying their differences. Following individual analysis, cross-case synthesis further supports the possible identification of common themes to form a more robust outcome. Analysis has been conducted in three stages using a range of techniques to overcome limitations of a single method (Lichtenstein, 2000b).

3.4.1 Qualitative Analysis

Context building, triangulation of data sources, data displays/matrixes have been used to assist in code analysis to identify patterns, themes, interrelationships and irregularities in the data (Pratt, Rockman, & Kauffman, 2006). The intention is not for findings to be generalised to populations, rather to place observations within their relevant contextual factors and analytic generalisability (Yin, 2009). To strengthen the positioning of research outcomes with respect to existing literature, theory-building tools are used to position research output within an existing body of knowledge and relevant literature.

3.4.2 Cross-Case Synthesis

Cross-case analysis has been conducted to strengthen research validity and consider findings in varying circumstances. Method of difference is used in conjunction with method of agreement to identify differing outcomes in light of the unique conditions present in each case. Complex chains of events and chronology visually demonstrate phenomena using a data-inspired system-level logic model (Burgelman, 1983). Analysis is then presented as separate single cases with a final cross-case synthesis to appreciate the individual circumstances of each case and validate findings while avoiding over-generalisation.

3.4.3 Concept Analysis and Mapping (CAAM) Techniques

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 & Setze (1994), Kane & Trochim (2007) and Rice & Martin (2011). Originally referred to as structured conceptualisation (Kane & Trochim, 2007), the CAAM technique involves focusing on a construct of interest, gathering input from several participants, sorting data, interpretation, and the visualisation 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 CAAM technique is applicable to a range of research pursuits, as elaborated on by Rice & 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 & 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 and calculations of the strength and dynamics of association between concepts and concept clusters. The use of software offers an efficient and manageable way to handle the large quantum of data analysed in this study – including more than 3.2 million transcribed words acquired over more than 68 days of interviews. A growing body of literature demonstrates the use of similar methods in social science and management (Smith & Humphreys, 2006; Gapp, Fisher & Kobayashi, 2008; Chen & Bouvain, 2009; Rice & Martin 2011).

3.5 Methodological Limitations

The multiple case study method provides many opportunities to observe the intricate details of emergent self-organisation within organisations in their natural environment. There are however, limitations on the generalisation of results to organisations in differing circumstances. Interview transcripts are the primary source of data for the study, complemented by contextual data gathered from additional material available from official reports, prior investigations and supplementary data. It is noted that various limitations exist in the dataset, inherent to the interview process. A strategy to mitigate bias caused by interview-driven case study, also includes using informants who are highly knowledgeable and who offer diverse perspectives, including from different hierarchical levels in the organisation, market analysts and regulatory bodies (K. M. Eisenhardt & Graebner, 2007). Data in this study draws on informants from a variety of organisations, disciplines and perspectives.

Interviews were conducted within the setting of a post-crisis inquiry, at which time participants were required to draw on their recollection of past events. For this reason, multiple testimonies have been gathered, crosschecked, and validated with objective data to limit retrospective bias. Each dataset remains the most comprehensive account available and has been subject to a number of internal validity tests, as discussed. Objective data places decisions within a timeline of quantitative observations, e.g. hydrology maps, release data, transactions and securitisation structures.

In consideration of the relevant limitations and risks, this study is concentrated on the phenomena of emergence as the most tangible and commercially relevant facet within the theoretical lens of complexity, mindful to avoid a too-broad view. The proposed method is sequenced and structured, commensurate with risk and in harmony with the growing methodological experience of organisational complexity research of the last decade. Careful attention has been given to external validation by accurately defining the context in which findings are observed and through cross-case analysis. Multiple sources of data, triangulation, an extended period of collection, member checking, context rich analytic generalisation, cross-case analysis, and expert supervision is used to mitigate the limitations of a single method, and to assist in validating research outcomes.

4 Findings

4.1 Background and Context

Findings of two case study investigations undertaken during this study are presented. As noted in the methodology, qualitative methods used in this study are grounded the epistemological traditions of symbolic-interaction and pragmatism. Not only are these research approaches suitable, they are a novel extension in complexity research. There are relatively few studies of complexity that explore, test and refine concepts and theories from a real-world and pragmatic standpoint. Symbolic interaction assists in explaining self-constructing realities that are discussed throughout the thesis, which are both a product, and component of emergent phenomena (within complex systems) arising through patterns of human interaction. Symbolic interaction and pragmatism provide strong foundations for the findings in this study, thereby importing that 'knowledge resides in the changed idea it enforces into action' (Dewey, 1929).

The chapter is structured in five main parts and two cases: Case Study One – Brisbane Floods Crisis; and Case Study Two – US Subprime Mortgage Crisis. Each case is placed within the context in which they occur, using a detailed description of known situational factors and conditions, and case notes. Case One includes a visual diary of flood events, standard operating procedures for business as usual conditions and a hydrological timeline drawn from an expert panel of hydrologists and engineers. Concept analysis and mapping techniques, thematic analysis, coding and theme results are presented and assessed in detail with a summary of findings and concluding remarks for each case. Additionally, attention is given to technical aspects of the subprime crisis, to explain the general structure and operation of financial institutions and instruments used within subprime markets, also the function of the Troubled Asset Relief Program (TARP). These aim to assist the reader and give clarity in the interpretation of findings. Finally, a cross-case synthesis is used to locate divergent and convergent themes, followed by a brief discussion on analytic generalisability and research limitations.

4.2 Case Study One – Brisbane Floods Crisis

4.2.1 Introduction

The city of Brisbane, like many major towns in Australia, is built on a floodplain. Although governments and communities seek to reduce the potential impact of crisis they are incapable of completely eliminating the risk of natural disaster. For this reason, understanding the contributing factors and causes for risk during crisis, planning and management are of principal concern to enable governments, corporations and societies to learn from and effectively handle natural disasters in the future, especially for residential areas such as Brisbane city – or other cities situated in or near floodplains. Prior to the 2011 floods, it is likely many Brisbane residents had a limited awareness of the importance and capabilities of the Wivenhoe Dam to mitigate flooding of downstream residential areas. Wivenhoe is approximately 80 kilometres from Brisbane CBD, and largely 'out of view' for residents in proximity to the lower Brisbane River. Since its construction in 1984, Wivenhoe had never before been tested with a flood of such magnitude and is one of only three dams in Queensland with a flood mitigation function, others being Somerset Dam and North Pine Dam.

In the ensuing discussions and media coverage that follow disaster of major proportions it is not unusual to observe an early tendency to assign blame. In the case of Brisbane in January 2011, questions were raised about the operation of the city's largest catchments, Somerset and Wivenhoe Dams, and the consequences of untimely catchment releases on the flooding of large residential areas of downstream Brisbane. This investigation focuses on the use of operating manuals and the decisions of engineers immediately before and during the floods from 8 to 12 January 2011. Qualitative analysis of interview transcripts documented in this report, reveal significant levels of uncertainty and subjective judgement in interpreting data used to make critical decisions, and a surprising process of post hoc strategy labelling, attributed to actions already taken. Analysis of decision making during the flood crisis reflect a distinctly emergent quality to management strategies that were adopted, despite the presence of detailed operating plans, procedures, manuals and policies. The results of qualitative analysis are discussed in the following sections. Decisive mechanisms of engineers and the implications are outlined, using interviews 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 two separate cluster networks. This is followed by discussion on the development and analysis of a cluster analysis and concept map, thematic analysis, and summary of findings.

4.2.2 Case Notes

Floods in Brisbane and others areas of Queensland in 2011 resulted in 33 deaths, inundation of 29,000 homes, and an economic impact of around $5 billion as estimated by the Queensland Reconstruction Authority (QFCI, 2012b). Due to the unprecedented scale of the disaster, a Commission of Inquiry into the Queensland Floods was established on 17 January 2011, under the *Commissions of Inquiry Act 1950* [State of Queensland] ("Commissions of Inquiry Act," 1950). The Commission exercised wide-ranging powers of investigation, unparalleled in a research-only initiative. In addition to the importance of the event, this provides an ideal context in which to draw from evidence and materials gathered via the imperatives of the Commission’s work plan. The Commission was led by Hon Justice Catherine Holmes, supported by two deputies, Mr James (Jim) O’Sullivan AC and Mr Phillip Cummins, together with a range of experts from a variety of fields.

4.2.3 Threshold State Criteria

The Brisbane Flood Crisis is an exemplar case for the study of emergent behaviours, confirmed by the presence of the six threshold state criteria (or critical values) being met at the time events unfolded. The criteria define conditions when an organisation is faced with significant disequilibrium from internal and / or external pressures, which are beyond the normal range (Anderson, 1999; Osborn et al., 2002). As outlined in Chapter 3, threshold-states have been used to inform a set of criteria upon which case conditions are evaluated. The criteria are developed through an amalgam of the work of (Anderson, 1999; M. Hannan & Freeman, 1984; Lichtenstein & Plowman, 2009a; Osborn et al., 2002). The criteria are repeated at Table 4.1

Table 4.1 **Threshold State Criteria – Brisbane Floods Crisis**

Threshold State Criteria	*Brisbane Floods Crisis – Initial Assessment*	*Notes and Confirmed Assessment*
(a) Changing market expectations	HIGH – shifting expectations of the public and government to avoid inundation at all costs, immediately following a long period of drought	Confirmed, reclassified - MODERATE. There has been some reverse pressure after the event, a class action to re-map affected areas outside the flood zone due to the negative impact on property values. The case assumes floods caused by mismanagement of the catchment are not a completely 'natural' disaster
(b) Critical and immediate pressures to adapt	HIGH – immediate environmental pressures causing the need for rapid decisions with irreversibility	Confirmed - HIGH. Findings also note it is the view of engineers that the severity of a flood is generally not known at the time of the first rainfall. The case is a good example of environmental build up and an aggregation of small decisions
(c) Shifting definitions of success	HIGH – unclear and changing definitions of acceptability in inflicting damage to urban areas	Confirmed - HIGH. As events unfold and the situation deteriorates, what is considered acceptable changed dramatically, despite flood mitigation plans
(d) Uncertain future performance capabilities	MODERATE – uncertain performance criteria or objectives	Confirmed - HIGH. Performance against current and future objectives uncertain, combined with shifting definitions of success
(e) Diversification of schema, networks and competitive forces	MODERATE – changeover of personnel, inadequate communication of key data, competitive pressures	Confirmed - MODERATE. Diversification of schema through subjectivity and predictions with bolstered and expanded links, some diversification of networks, although the number of agents with decision making powers is limited in this case
(f) Characteristics of apparent structural inertia	HIGH – risk averse culture, uncertain risk appetite or tolerances	Confirmed - HIGH. Natural aversion to aggressive risk taking evident in operating practice, and for sound reasons

Source: threshold state criteria formed through an amalgam of work by Anderson (1999); M. Hannan and Freeman (1984); Lichtenstein and Plowman (2009a); Osborn et al. (2002).

Interview transcripts from the Queensland Flood Commission of Inquiry (QCFI) 2011 were used for reasons of public accessibility and comprehensiveness unmatched by any other account of the event. The focus of the analysis is on the critical decisions that took place in relation to the management of Brisbane's major catchment, Wivenhoe Dam between 8 and 12 January 2011. Extensive interviews were conducted over a period of 68 days, resulting in a total of 345 interview responses and 6,133 transcribed pages of evidence. Of note were interviews held with four flood engineers on Days 59 and 60 of the inquiry, then employees of Seqwater. Interviews are supported by more than 1,200 exhibits, some of which are used in this study – those being flood manuals, plans, hydrology reports and operational procedures, to understand the operating context for the organisation under study. To further appreciate the conditions of the event, a visual diary of the Brisbane Floods Crisis is provided.

4.2.4 Visual Diary of the Brisbane Floods Crisis

Event / Location	*Description and Image*
Brisbane City	View of Brisbane city from the S/West, during the flood crisis. Note the high water levels and extensive flooding in the foreground. The University of Queensland can be seen to the mid-left, the Eleanor Schonell Bridge between St Lucia and Dutton Park, with the central business district in the background.  Image credit: Queensland Government
Eagle Street Pier, Brisbane City	Eagle Street Pier at Brisbane City demonstrating extremely high flood levels and the inundation of commercial infrastructure, riverside walk, restaurants and

piers. Floodwaters penetrated the inner city via underground waste water systems, many of which did not have backflow plugs. Much debris, such as those pictured in the lower part of the image was seen floating downstream and into Morton Bay.

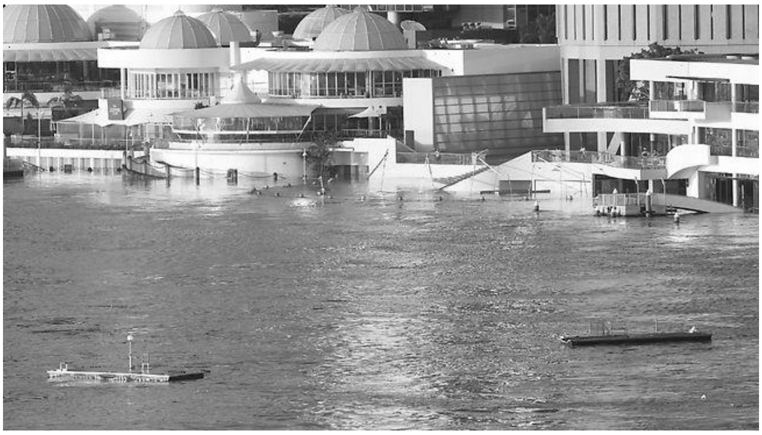


Image credit: Queensland Government

Cook Street, Oxley

Residential area of Cook Street in Oxley demonstrating a dangerous area with unseen hazards below surface. Note the height of the floodwaters on the residence at the centre-right of the image.

Image credit: Queensland Government

Clean Up in Rosalie

Thousands or Brisbane residents voluntarily engaged in a large-scale cooperative effort after the event to clean up affected areas, an important part of the overall recovery effort for many residents of Brisbane.

Image credit: Queensland Government

Story Bridge and Riverwalk

View of Brisbane city from the N/East, with the Story Bridge connecting Kangaroo Point and Fortitude Valley. Note the very high river levels and damaged Riverwalk to the left of the image. The Riverwalk required complete reconstruction after the event.

Image credit: Queensland Government

Average Rainfall Map

Average rainfall between January 2010 and December 2011. Prior to this extensive period of heavy rainfall, much of the State of Queensland and other regions of Australia had experienced a decade-long drought.

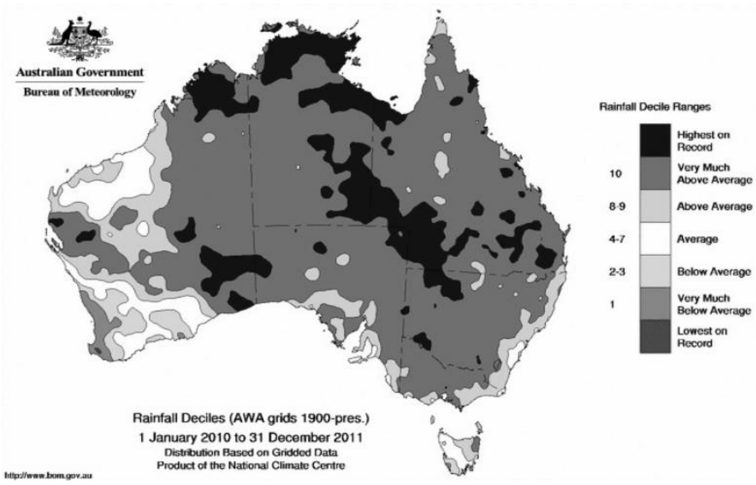
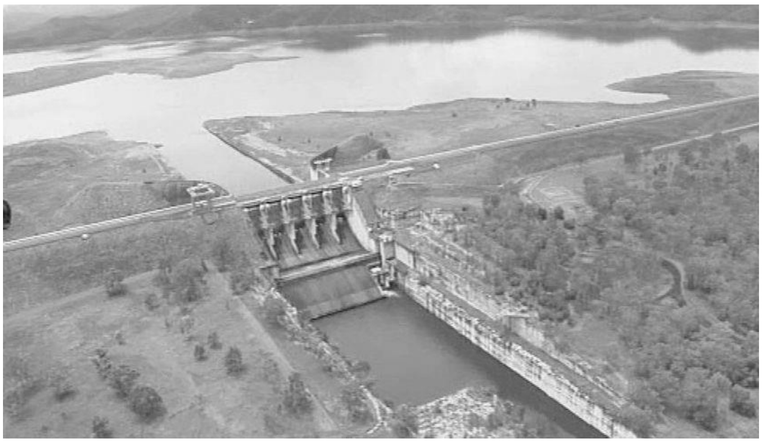


Image credit: Australian Government

Wivenhoe Dam and Spillway Gates	Wivenhoe Dam illustrating gated spillway at its Southern juncture. The dam structure, completed in 1984 at a cost of $450 million is 2,300 metres long and 59 metres high. The purpose of the dam is to provide drinking water for the city of Brisbane and flood mitigation capacity.  Image credit: Queensland Government
Wivenhoe Dam and Spillway during flood	Wivenhoe Dam and spillway at full mitigation capacity and in catchment release phase, during the height of the 2011 floods. The gated spillway has five steel crest gates that are 12 metres wide and 16.6 metres high, with a discharge capacity of 12,000 cubic metres per second.  Image credit: Queensland Government

Wivenhoe Dam and spillway channel	Wivenhoe Dam spilling around 12,000 cubic metres of water per second into a spillway channel which is normally a dry rural area. The spillway leads into a floodplain and to the lower Brisbane River. Releases are mainly intended to protect the integtrity of the dam structure.

Image credit: Queensland Government

Wivenhoe Dam Hydrology Data	Wivenhoe Dam in/out flow data and headwater elevation. Note the significant peaks of the inflow caused by surrounding rainfall in the 7,020 km^2 catchment area. Dam outlfow is primarily via the spillway pictured above and controlled by engineers. Release strategies and decisions are evident in the release changes.

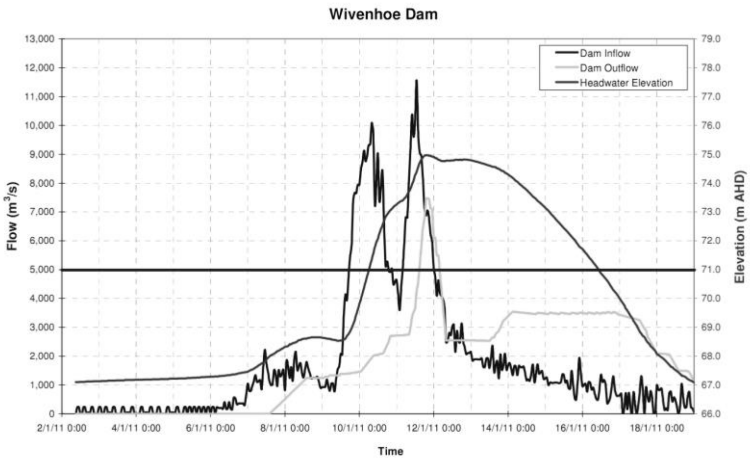


Image credit: Queensland Government

South East Queensland Flood Map	Lake Wivenhoe is visible at the top left of the image. Brisbane river is shown with enlarged areas indicative of inundation occuring during the flood event. Flood impacts were evident throughout the Brisbane River system downstream from Lake Wivenhoe.

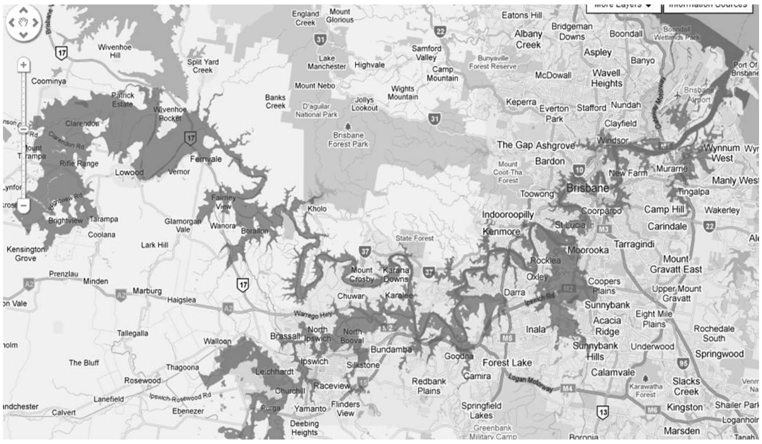


Image credit: Google Maps

Brisbane City Flood Map	Satelite image of the Brisbane River in the CBD, at the top right series of ‘s-bends’. The image demonstrates the concentration of inundation for property in proximity to the river, with most nearby creeks and streams generally unaffected.

Image credit: Queensland Government

First Day Of Inquiry Hearings	Commission of Inquiry hearings commenced on 11 April 2011. An extensive range of extertise and evidence was called to witness, and heard before the Commissioner and inquiry staff. Courtrooms were used to host the inquiry hearings.  Image credit: The Courier Mail

4.2.5 Standard Operating Procedure

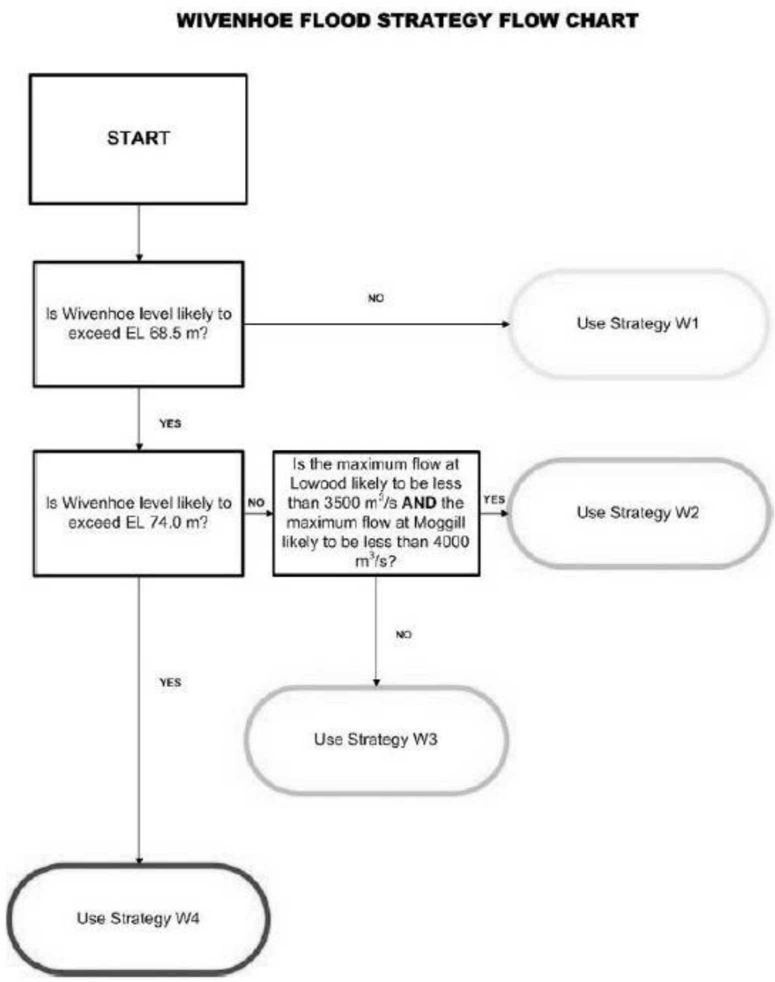
A flood mitigation manual governed the management of Wivenhoe Dam during the flood events of January 2011. The purpose of the manual was in effect to reduce the impacts of flooding ‘by the proper control and regulation in time of the flood release infrastructure at the dams, with due regard to the safety of the dam structures’ (QFCI, 2012b). For this purpose, the manual sets out ‘strategies’ to execute the proper operation of catchment releases and thereby achieve the objectives of the manual. There are four strategies included in the manual – labeled as: ‘W1’, ‘W2’, ‘W3’ and ‘W4’. The ‘W’ is indicative of ‘Wivenhoe’, with associated strategies to be used for the concurrent management of Somerset with equivalent ‘S’ strategies. Management of the two dams is undertaken in synchrony as an upper and lower catchment area. For the purposes of this study, Wivenhoe is of primary interest. Somerset was not managed in isolation; therefore decisions for Wivenhoe are the major asset in this case.

The use of the flood mitigation manual is helped with the following explanation provided through the transcription itself, by the engineer who developed the manual.

> The flowchart is on page 23 and the sentence prior to the flowchart says: ‘A flowchart showing how best to select the appropriate strategy’, so previously we have got all our information together, now we’re coming to the stage where we’re going to select the

> appropriate strategy – 'a flowchart showing how to best select the appropriate strategy to use at any point in time is shown below.' So once you've got all your information together, now you have got to select your strategy, now you go to the flowchart. You will notice in the flowchart that forecast is not mentioned at all, but the engineer that has to choose the strategy has to make an engineering judgment or a judgment about what is likely. He is asked essentially two questions about what is likely. The first question is about the likely level in Wivenhoe Dam. Again, he has got to make a judgment on what is likely. He can assign whatever weight his judgment feels worthy in terms of the forecasts. Now, as I said, generally given the great uncertainties in the QPF [quantitative precipitation forecasts] as provided by BOM [Bureau of Meteorology], no weight is provided to those forecasts. However, as I said, there are three circumstances under which you may provide – assign some weight to those forecasts. (Q. Transcript, 2017).

In other words, release strategies on rainfall predictions are a game of chance. Engineers use 'whatever weight his judgement feels worthy', in consideration of likelihood and probabilities. That is, regarding the weather. Interestingly, there is a direct cue that links to the concept of deterministic non-periodic (turbulent) flows (Lorenz, 1963) and the amplification of small change (D.A. Plowman, Baker, et al., 2007), which were discussed earlier in the literature review. Following the explanation provided above, the Wivenhoe Flood Strategy Flow Chart is reproduced at Figure 4.1, visually demonstrating the operating procedure for the assignment of strategies, based on assessment of rainfall and existing dam levels. The process flow suggests a structured decision making process with regard to strategy choice.



Source: Manual of Operational Procedures for Flood Mitigation at Wivenhoe and Somerset Dams (QFCI, 2012a).

Figure 4.1 Wivenhoe Flood Strategy Flow Chart

The use of the operating manual for Wivenhoe requires the engineer to predict expected rainfall and apply a release strategy in light of those predictions. For instance, if the dam levels are expected to rise beyond a certain point, the engineer should adopt a release strategy to ensure the volume of water within the dam structure does not exceed an acceptable level. The acceptable level is defined for engineering purposes – to protect the structure, public safety is a downstream risk. A meteorological process is used by engineers to manage infrastructure, however, this is ultimately for public safety. As noted in at Table 4.2, the primary objective during high-level strategy 'W4' is to ultimately protect the integrity of the dam structure. The reason for this is explained in the manual.

> The structural safety of the Wivenhoe Dam is of paramount importance. Structural failure of Wivenhoe Dam would have catastrophic consequences. Wivenhoe Dam is predominantly a central core rockfill dam. Such dams are not resistant to overtopping and are susceptible to breaching should such an event occur. (QFCI, 2012a).

Table 4.2 Wivenhoe Dam Flood Mitigation Manual – Strategies

Strategy	*Objective*	*Conditions*
W1	Minimising disruption to downstream rural life	Storage level predicted to be less than 68.5 AHD Maximum release less than 1,900 $m^3/_s$
W2	Transition strategy	Storage level predicted to be between 68.5 and 74 AHD Maximum release less than 3,500 $m^3/_s$ This is a transition strategy where consideration changes from minimising impact to downstream rural life to protecting urban inundation
W3	Protecting urban areas from inundation	Storage level predicated to be between 68.5 and 74 AHD Maximum release 4,000 $m^3/_s$
W4	Protecting structural safety of the dam	Storage level predicted to exceed 74 AHD No limits on releases Lower level objectives considered, but in order of importance

Source: QFCI (2012b).

The ‘catastrophic consequences’ noted in the operating manual are not elaborated on, nor is public safety an explicit (quantitatively assigned) operational principle for decision making. Despite a level of ambiguity in the operating manual for Wivenhoe and its different interpretations through the interviews, two basic conclusions can be made: (a) the operating manual requires significant judgement to be exercised in order to choose actions, which is open to subjectivity and perception; and (b) the choice of actions, regardless of strategy labelling, would be known to engineers and therefore able to be readily communicated, having high potential salience in a small network.

4.2.6 Situational Factors and Conditions

In the decade preceding the Brisbane flood crisis, water levels in the dam had reached an all-time low of 15% capacity in August 2007, with deteriorating levels occurring over a sustained period of eight years (Seqwater, 2017), as illustrated at Figure 4.2. With no significant rainfall occurring for an extended period, strict water restrictions were in place to minimise loss of the city's drinking water supply. Wivenhoe is the primary source of drinking water for the city of Brisbane and an essential infrastructure asset in that regard.

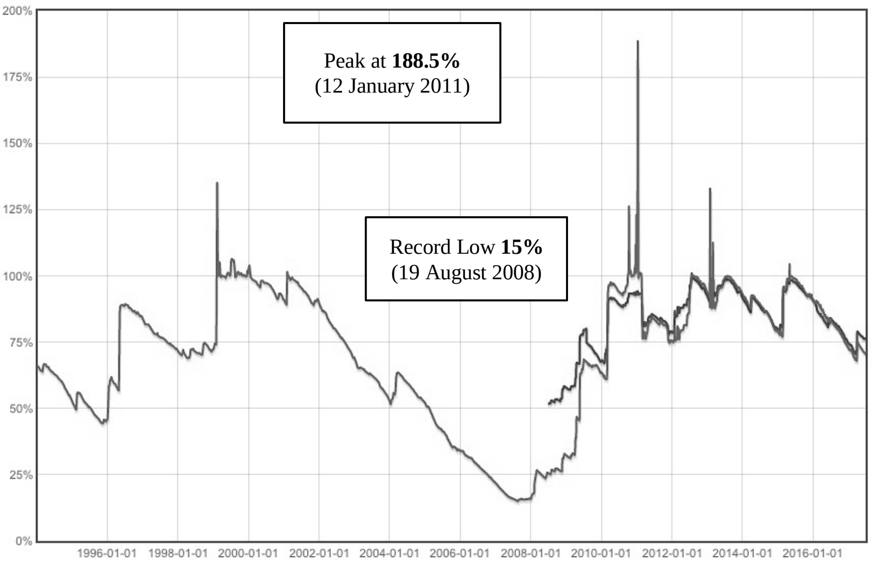


Figure 4.2 Historical Storage Data – Wivenhoe Dam
Source: (Seqwater, 2017).

Given the preceding conditions, it is understandable residents of Brisbane and the operators of the catchment were significantly concerned at the lack of rainfall and the potential for the city to exhaust its water supply. Drought conditions were likely to have been a normalised condition. The drought conditions preceding the flood event present a psychological dimension and motivation toward a risk averse treatment of flood risks, but are not a factor in standard operating procedures.

4.2.7 Concept Analysis and Mapping

Results of the analysis reveal seven key concept clusters that emerge through interview transcripts: *flood, information, water, people, strategy, evidence*, and *property*, as illustrated at Figure 4.3. Despite the underlying disconnect between cluster networks, which are discussed shortly, 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 4.3. Concept analysis clearly shows that strategy deployed during the flood crisis was a primary 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'. This suggests that although the primary concerns in the assignment of strategy were human impacts, the sources for information were most commonly related to property issues. This finding is significant for two reasons: firstly, the primary objectives and considerations for decision making should be known, predetermined where possible and salient; second, given the nature of social and emotional impacts, this gives greater potential for decisions to shift away from organisational directives and pre-existing plans.

This finding is also of interest because the human factor in decision-making and room for subjectivity and an emotional response were absent from the operating procedures for Wivenhoe. To avert this, the manual would need to take into account how organisational actors will behave normally, and the changed conditions under which they find themselves in during crisis.

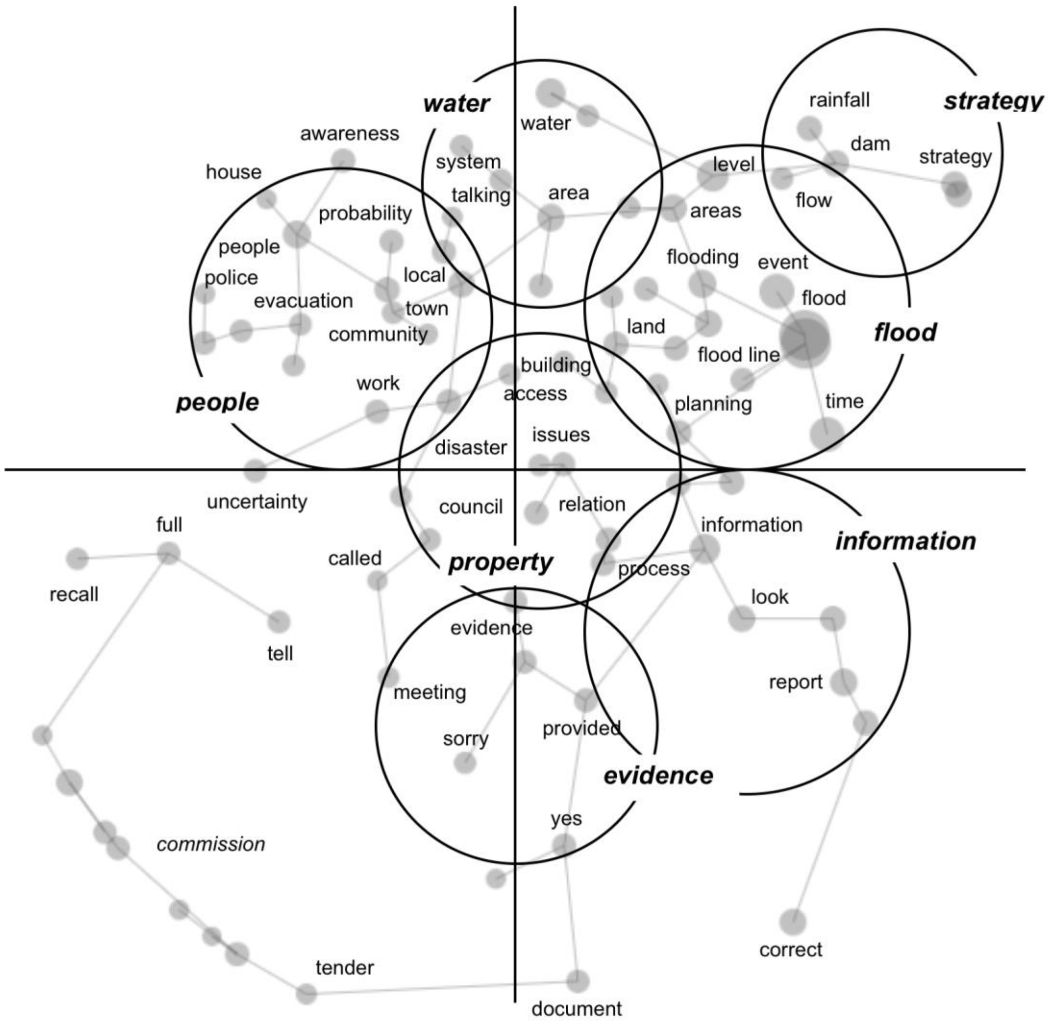


Figure 4.3 **Brisbane Flood Crisis Concepts and Concept Clusters**

Table 4.3 Weights and Frequencies of Concepts

Concept	*Count*	*Weight*	*Concept*	*Count*	*Weight*	*Concept*	*Count*	*Weight*
flood	8073	34745	dam	2516	8992	system	1452	5212
information	3945	12742	look	2935	8964	talking	1517	5207
water	3629	12225	rainfall	2238	7354	river	1150	4882
people	3029	10488	planning	1710	7318	tell	1598	4875
strategy	2354	8861	relation	1836	7051	evacuation	1215	4719
evidence	1657	5832	events	1572	6958	flow	1165	4693
property	1087	4026	process	2110	6956	community	1098	4605
event	4743	18010	disaster	1598	6781	sorry	1634	4276
time	6064	17609	aware	2227	6429	recall	1832	4094
level	3969	14557	commission	5491	6427	access	850	3730
flooding	2360	10419	work	1878	6299	building	889	3622
Areas–	2443	10231	line	1688	6258	land	733	3476
area	2543	9940	council	1744	6180	meeting	1162	3455
report	3681	9832	probably	1732	6057	tender	1713	3026
terms	2563	9631	issues	1531	6034	town	665	2885
correct	4796	9299	full	1862	5684	police	771	2689
local	2375	9034	sure	1755	5407	house	663	2077

Overall, the results suggest that the development of strategy in this instance is significantly complex. Close examination of engineers interviews show that the kind of strategy used was not a planned, design-based approach traditional or Cybernetic organisational theory may suggest (D. A. Plowman & Duchon, 2008). Although treated as a separate issue in discussion, 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; prediction; execution of strategy; strategy labelling; back to environmental assessment; etc. Such a conceptualisation 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; Brown & Eisenhardt, 1997; Chiles et al., 2004). An example in this case is the avoidance of relatively minor risks (e.g. deliberately flooding low lying bridges and roads) in favour of additional information, which in turn results in reinforcement of risk avoidance – or inertia, and the gradual erosion of strategic choices.

4.2.8 Concept Cluster Network Analysis

Concept analysis and mapping reveals two distinct and separate concept networks – strategy and flood information clusters. The strength of the relationship between the strategy and flood, information cluster is surprisingly weak. Figure 4.4 illustrates the loose coupling between the 'strategy' and 'information' clusters – connected by a single network path. In the image, the 'strategy' cluster is bordered, with the concept cluster path highlighted in black and labelled. The limited connection between these two cluster groups is suggestive of a relatively separate treatment of the flood and information related concepts, and strategy concepts.

The implications of this finding are significant. Firstly, the greater separation of strategy from information implies that a practice of emergent strategy formation is considered risky in the mitigation of flood impacts. Flood engineers are unable to enact forward-looking strategy without adequate feedback loops and accurate forecast data. Secondly, it is possible the discussion of strategy and causes for the flood were given unique treatment due to perceived ramifications of this part of the inquiry. Interviews with engineers highlighted the pervasive element of uncertainty in the entire process of decision-making, an element that is impossible to completely remove. Thus, it would suggest that further operationalisation and refinement is needed in this area to cater for emergent strategic outcomes in an environment characterised by unpredictable and rapid change.

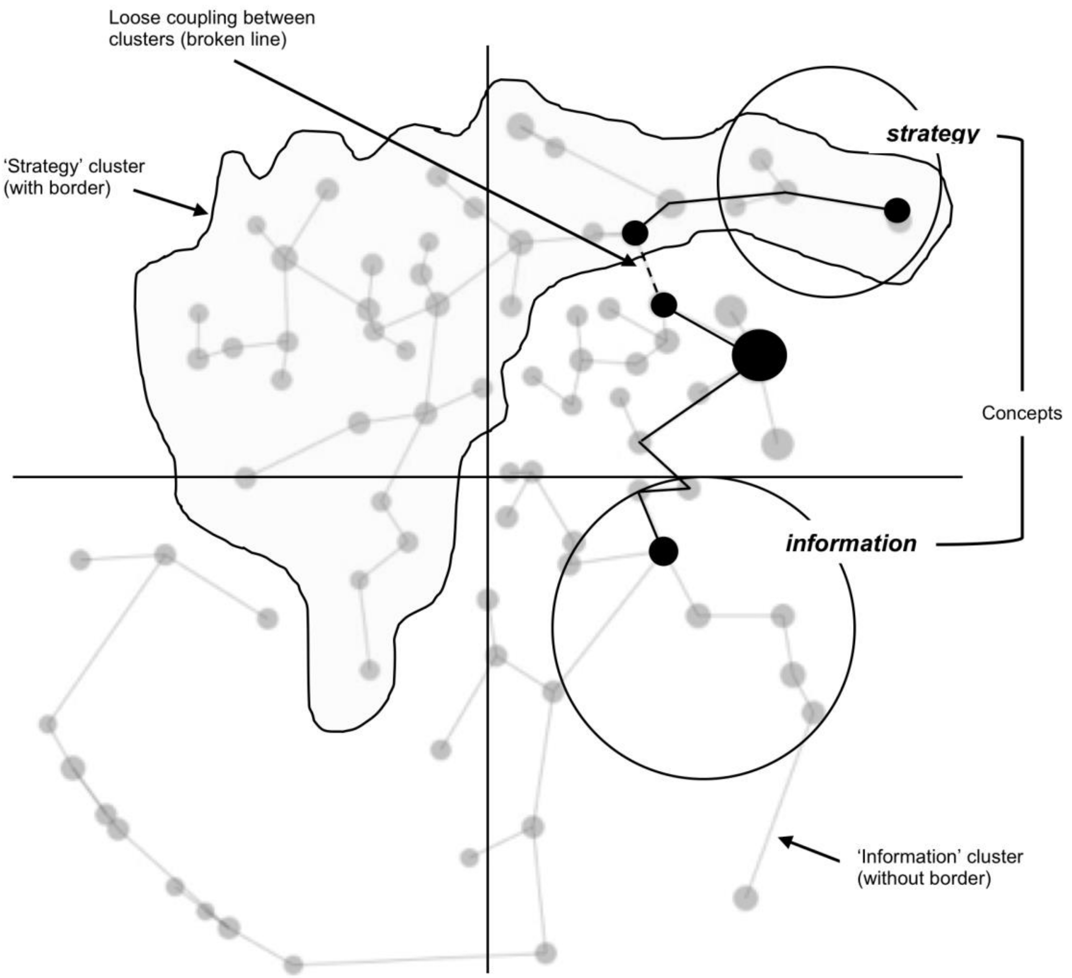


Figure 4.4 Weak Coupling between Concept Clusters

Although the flood operation manual requires a 'conscious adoption of, and operation within' its strategies (QFCI, 2012a) – the reality of emergent strategy, 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 realised strategy, emergent strategies occur simultaneously in a self-constructing community of practice, a concept developed in much more detail by (Wenger, 1988). Findings of this study support Mintzberg and Waters (1985) idea that deliberate and emergent strategy is not necessarily a sharp dichotomy. Rather, emergent strategy formation involves interplay at several organisational levels, nested personal strategy choices, while not explicit to overarching objectives, are connected and potent. Results in this study suggest that a convergence takes place between emergent and intended strategies – the nature of which is dynamic and unplanned.

4.2.9 Thematic Analysis

Given the water levels of the catchment were dangerously low just two years prior to the flood event, the combined objectives of management to: (a) protect the supply of drinking water; while (b) mitigating flood impacts, are in certain conditions conflicting objectives. For this reason, a clear operating protocol is necessary. After very low rainfall probabilities and an extended period of drought, releasing a quarter of the city's water supply would be a significantly proactive step, for a crisis event that may have never eventuated. This is exacerbated by the fact that at the time of the event, the Wivenhoe Dam flood mitigation manual had multiple working interpretations and was sufficiently vague to rely heavily on subjective judgement, risk aversion tactics, and is silent on some of the proactive choices open to engineers. In short, the codified knowledge of the manual is unable to replicate the practical and experiential knowledge acquired and put into action at the time of the event. Emergent strategy and recursive decision cycles were not a consideration in operating practices for Wivenhoe.

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 its flood mitigation capacity. Engineers' statements indicated that if earlier releases had been made from Wivenhoe, this might 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 the Wivenhoe catchment, and the volume of releases, were instrumental factors in the magnitude and prolonged impact of the floods. For this reason, it is emphasised that the accuracy of 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. (Q. Transcript, 2017).

A range of situational factors clouded the operation of the dam, including unpredictable weather patterns, localised risk minimising objectives, poor communication and a rapidly changing environment of massive catchment inflows.

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

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 may be useful to refer to the Wivenhoe Dam Hydrology Data presented earlier in the Visual Diary. 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 (see Visual Diary). Far more strategy choices were made during the crisis than that which is reflected in the chronology of strategy changes. To further understand these strategy choices and the exercise of judgement, the following sections explore in detail concepts and themes arising from the interview transcripts.

Through successive analysis of interviews, three central themes emerged in relation to the decision making mechanisms employed by engineers in their operation of Wivenhoe Dam: (1) *emergent strategy formation*, (2) *subjective judgement in decision making*, and (3) *transient primary objectives*.

An emergent process of strategy formation characterised much of the activities and decisions that governed the operation of Wivenhoe Dam throughout the flood period. Earlier interpretations of the operation manual for Wivenhoe assumed that strategy could be chosen and applied in a cause and effect manner. However, as discussion unfolded, this interpretation proved incorrect, as outlined by engineers during interviews.

> The volume of the flood upstream, the release rate that you adopt once you've hit gate trigger will determine the resultant lake 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. (Q. Transcript, 2017).

All engineers indicated that there was no clear separation between strategy choice and its execution; rather they are intertwined as an emergent strategy 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 lake release options that involved road closures, urban inundation and infrastructure damage – the presence of early risk factors means the discretion exercised in subjective judgement had significant ramifications, signalling 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.(Q. Transcript, 2017).

Although the lake operating manual was provided to engineers to:

> Govern the exercise of the discretion involved in that judgment call (Q. Transcript, 2017),

Engineers claimed they were often not explicitly aware of their strategy choice and instead used ad hoc tools to calculate risk and weigh-up alternatives. The choice of strategy would then be labelled after the fact in one of the applicable risk categories – dependent on earlier release decisions. The question remaining – how and why are release choices made? In terms of emergent strategy and choice, there was some level of discrepancy between engineers recollection of events as highlighted during interviews. 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 (Q. Transcript, 2017);

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 (Q. Transcript, 2017).

Despite the differences in language used during interviews and varying levels of ownership over decision-making, indications for the existence of emergent strategy formation remain. 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 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 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. (Q. Transcript, 2017).

In an attempt to react to changing situational factors, engineers adopted strategies that minimised the risk of local urban inundation, including the low bridges and roads near the spillway. In retrospect, although it is clear that earlier lake 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 (Q. Transcript, 2017);

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 (Q. Transcript, 2017).

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.

4.2.10 Decision Cycles

Drawing from the themes above, two versions of the decision-making process emerged from the analysis of qualitative data: (a) Version 1 - Strategy Choice Based on Predictions [Figure 4.5]; and (b) Version 2 – Unconscious Choice with Post Hoc Strategy Labelling [Figure 4.6]. The first of these is couched in the Wivenhoe operating manual, the second applies a post hoc strategy label and implies ‘unconscious’ choice in actions and decisions. Transcripts reported the simultaneous existence of both decision cycles, which would be feasible.

Version 1 – Strategy Choice Based on Predictions

As highlighted previously, organisational actors used predictions and subjective judgement to make a call about what levels of incoming rainfall were likely, based on their educated understanding of weather patterns and conditions across a 7,020 square kilometre catchment area. These predictions were then applied into a codified manual with finite choices leading to strategy choice, execution and continuous monitoring of inflows and outflows.

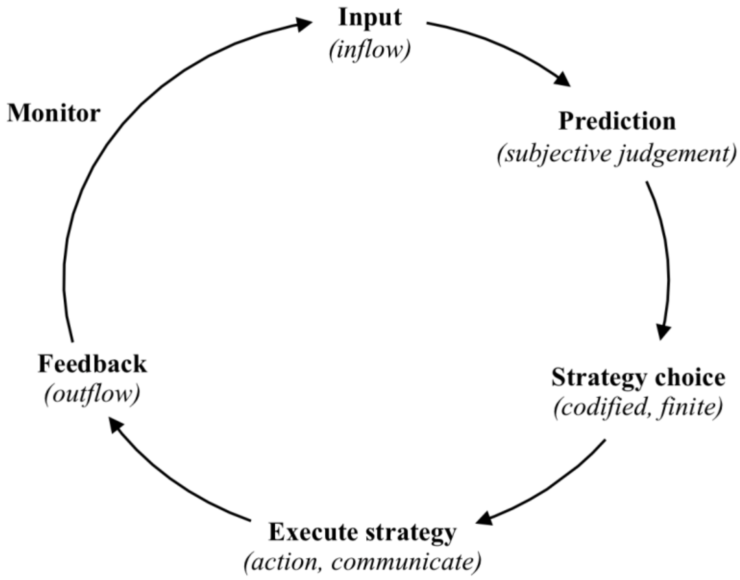


Figure 4.5 Version 1 – Strategy Choice Based on Predictions and Subjective Judgement

Version 2 – Unconscious Choice with Post Hoc Strategy Labelling

The second version of recursive decision making suggests a shortcut of the subjective judgement process as an ad hoc observation tool, used while operating within the strict parameters of an operating procedure. In this model, inflows are observed and strategy is forced (or unconsciously made), actioned, then labelled after the fact. The unconscious strategy choice version provides far less culpability for decision makers, implying choices are finite, to that extent a given situation allows only a mechanical interpretation on the consequences of information input. However, the amplification and irreversibility of this version is found to be far more acute than the conscious choice model, as it does not apply any potential for system-level cognition and corrective action with the identification of potenital system failtures.

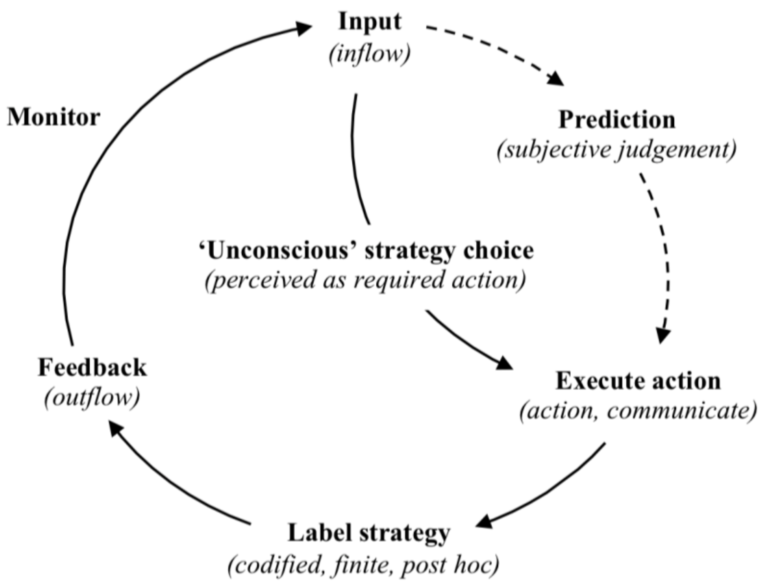


Figure 4.6 Version 2 – Unconscious Choice with Post Hoc Strategy Labelling

In neither case did the operating manual treat the decision making process as a recursive cycle, but rather a linear process where strategies were arrived at and managed. The reality of the situation was that each cycle created an initially small and magnifying cascade of decisions, contributing to the conditions being observed. There was no ability to see the entire system from a distant and objective standpoint with the potential consequences of unlikely scenarios that did actually eventuate. In either version, the sum of small choices is an emergent outcome generating a pattern of behaviour. Further exemplary quotations, conditions and context are outlined at Table 4.4 to assist the reader to gain an understanding of the qualitative data with reference to given conditions and context that are present in this case.

Table 4.4 Evidence of Situational Factors and Emergent Nature of Decisions and Actions

Conditions and Context	*Exemplary Quotation*
Complex and uncertain situational factors – weather predictions	As soon as that rain starts coming you need to really assess what you're doing, like immediately. Obviously if the rain doesn't come and the lake level falls, well, that type of assessment isn't needed, but if the rain does come you certainly need to think, well, do we need to transition into a situation where we're - you know, increasing our outflows. [Engineer]
Interdependency of factors	Whether you'll reach 68.5 depends on two things: the volume of the flood that you're managing and the release rate that you adopt. [Engineer]

Limitations of 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. [Engineer]
Nature of Decisions and Actions	*Exemplary Quotation*
Implicit strategy selection	The volume of the flood upstream, the release rate that you adopt once you've hit gate trigger will determine the resultant lake 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. [Engineer] And the decision to move out of the W1 strategy is determined solely by the lake level. [Counsel] -- Yes. [Engineer]
Unconscious strategy selection	I don't choose strategy; it is imposed upon you. [Engineer]
Question of subjectivity in decision making	The manual is there to govern the exercise of the discretion involved in that judgment call. [Counsel]
Many possible strategy alternatives	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. [Counsel]
Take action first, apply strategy later	The gate release rate informs the choice of strategy rather than the strategy informing the choice of gate release rates. [Counsel summarising Engineer]
Post-fact strategy labelling	You said in paragraph 28 that strategy labels are generally only attributed after the event as part of the reporting process? [Counsel] -- Yes. [Engineer]
Risk minimisation	[Local] urban damage was in the forefront of our minds [in transitioning between objectives]. [Engineer].
Transient primary objectives	The volume of the flood if it exceeds the 20 per cent, so that is the flood is no longer a small flood, it becomes a larger flood, my interpretation of the manual says, ‘This is a flag, you should start now looking at your primary objective as being protection of urban areas.’ And obviously that threshold between W1 and W2 and 3 is a flag to indicate that there is a change of focus. This event is now getting bigger, and so you will need to start making releases with other objectives in mind. [Engineer]
Operating Procedures	*Exemplary Quotation*
Doing things by the book	And up until this week I'd suggest to you every statement you have made, every piece of evidence you have given has been calculated to give that impression. [Counsel – in relation to Engineers’ giving the impression of doing things ‘by the book’]
Poor communication on strategy choices and situational factors	No actual strategy change was documented; at best, it can be said that the actions taken were consistent with strategy W3. [QFCI Final Report]

Engineers breaching the Wivenhoe Dam Operating Manual	You knew that report was a careful reconstruction contrived to give the impression that everything was done by the book; The manual was not used contemporaneously with the flood event, as it ought to have been. [Counsel]
Inadequate reporting on the operation of the dam and concerns over public ridicule	I'd suggest to you that you knew that if the lack of information about how the dam was actually operated became widespread knowledge that it would be regarded as absolutely unacceptable. [Counsel].

Source: QFCI 2012, *Transcript of Proceedings*, 3 February 2012, Day 60, Brisbane, (pp. 5,130-5,237).

4.2.11 Summary of Findings

It has been concluded that engineers at Wivenhoe Dam breached the operating manual from 8.00 am on 8 January 2011 until the evening of 9 January 2011. This finding is in agreement with the Commission's results (QFCI, 2012b). It may provide additional context to reflect on other major disasters, such as the 9/11 Commission 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' (Government, 2006). While these statements are appeasing, what then are the rules that govern emergent behaviours in such circumstances? And, how is the unplanned part of the plan – what is the operating principle for emergent behaviours and unexpected patterns of choice.

The events of Brisbane were neither the scale nor ferociousness of Katrina or 9/11, this notwithstanding, findings share a similar focus: inertia, planning, control, communication, information, coordination and forward thinking are all factors in the successful/unsuccessful management of each crisis. Findings in this study confirm the importance of information transfer between agents and the importance of patterns of behaviour in determining the outcome of major crisis events. Self-organisation exists as latent potential in most firms, and is particularly acute in times of disequilibrium, when operating conditions are well outside the normal range.

Despite claims of a failure of planning, communication or control, the behaviours that led to a lack of mitigation strategies to protect Brisbane from further flooding would have required an adventurous, risk-acquiring approach that although engineers performed a kind of bricolage in their strategy formation – were unwilling or uncompelled to adopt. The existence of more prescriptive plans may not sufficiently reduce levels of structural inertia toward risk acquisition either. The absence of positive (reinforcing) feedback on decision making processes to avoid larger scale inundations changed the frame of reference to one of incalculable risk, and a reactive, gradual decision making process where small incremental decisions were favoured without foresight of their collective impact on irreversible, catastrophic flooding outcomes.

A number of key findings were observed through the case study analysis and are summarised as follows. These findings provide confirmation that the principles and dynamics that underlie a theory of emergence apply well to this case.

Finding 1: *The existence of plans does not eliminate the potential for emergent strategy.*

This study demonstrates the potential for emergent strategy to occur despite the existence of detailed plans, even when those plans are mandated and legislated – where strict adherence would be a natural expectation. Despite the existence of plans, in this case strategy choices were heavily predicated on subjective judgement and were open to interpretation and individual perceptions of risk and probabilities. While the subjective dimension to decision-making is a cause for emergent behaviours, it is also an essential part of informed judgement – in such a way that avoids unconscious and negligent choices that have larger consequences later on. If subjective (and educated) decision-making is essential and deeply coupled with potential for emergent outcomes, a better understanding of emergent strategy in crisis, despite the existence of plans is beneficial. Further research is required to more comprehensively understand the relationship between the existence of different types of plans and their scale of embeddedness, combined with the character of emergent behaviours.

Finding 2: *Small decisions early on in crisis have magnifying ramifications and irreversibility. This occurs in parallel with an erosion of strategic choices.*

Seemingly insignificant or less significant decisions early in the anatomy of crises have magnifying ramifications and pass a threshold of irreversibility. Understanding and defining the exact point of the threshold state and points of irreversibility would be of practical use, particularly where many small decisions are required in an operational context. 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. This observation was accompanied by a gradual and silent erosion of strategic choice, as options narrow with the passage of time. Further understanding of the cognition of emergence and risk of erosion of choice would be of interest for a research extension from this finding.

Finding 3: *New (simple) 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. Simple rules and practices emerge either with or without the existence of plans and explicit instruction. However, strategy emergence occurs more readily when there is a perceived absence of both, combined with an enabling culture. It is noted the existence of plans is a matter of perspective and organisational culture – for those plans can be potentially impotent if not adopted by the actors within the organisation. The potential benefits of ambiguity by reviewing example plans would benefit from further exploration. Deliberately maintaining levels of ambiguity may also be a management or leadership strategy in itself, to condition emergence by disrupting existing patterns then allowing new forms to emerge.

Finding 4: *The presence of positive feedback improves the functioning of emergent strategy.*

Emergent strategy is possible in the absence of feedback, however this diminishes the probability of emergent strategy having positive results. The lack of feedback can trigger a cascading chain of events where small decisions have amplifying results. The existence of feedback in this case is an essential component of the decision making cycle, and is one of the primary drivers behind amplification of small change. The potential issues caused are exacerbated by the fact that many small decisions and predictions are made without a complete and long-term view of the entire system. While the actors interviewed made many attempts to ‘see’ the behaviour of the entire system, the Darkness Principle (Skyttner, 1996) is evident in these results.

Finding 5: *Emergent strategy may be risk averse, structural inertia intensifies risk.*

This study identifies the potential for structural inertia to intensify and create additional risk. The existence of plans may increase risk by inertia, therefore increasing rather than reducing crisis risks. While it may appear counterintuitive, the absence of plans and strict operating procedures can potentially reduce risks in certain circumstances, as demonstrated by this case. An example of risk by inertia from this case is the reluctance to change a course of action to a higher risk strategy because it is outside usual practice, even though that altered course reduces exposure to larger downstream risks. This is due to the reduced effects of structural inertia and the inclination to act differently in changed conditions, to respond to events as they arise and when the pre-existing plans prove ineffective. 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 may include contingency for failure of the plan it seeks to enact.

Finding 6: *The escalation of crisis may be rapid, non-linear and exponential.*

Escalation of crisis risks and impacts may be increasingly rapid, non-linear and exponential as a result of endogenous factors, despite these factors being seen as beyond internal influence. The case provides a compelling example of rapid escalation in what was a prevailing scenario of drought. A recursive perspective on decision cycles demonstrates the reinforcing dimension of prior behaviours, rather than a linear process as defined by pre-existing plans and manuals.

Table 4.5 illustrates the findings within the context of decisive mechanisms employed by engineers (agents) operating within the system, and actions / behaviours exhibited. The following section provides concluding remarks, notes on analytic generalisability and broad reference to areas for further research, which is outlined in further detail at the discussion chapter.

Table 4.5 Decisive Mechanisms Employed by Engineers and Research Implications

Decisive mechanisms employed by agents (themes)	*Actions / behaviours*	*Findings*
Emergent strategy formation	• Unconscious or implicit strategy selection • Post hoc strategy labelling • Strategy choices not communicated between agents • Lack of ownership over implicit decisions	1. The existence of plans does not eliminate the potential for emergent strategy 2. Small decisions early on in crisis have magnifying ramifications and irreversibility
Subjective judgment in decision making	• Unpredictable environmental factors • Judgments drawn from inconclusive data • Ad hoc and non-mandated decision making tools • Incalculable risk probabilities	3. New (simple) rules emerge in the absence of explicit instruction 4. The presence of positive feedback improves the functioning of emergent strategy
Transient primary objectives	• Strategies adopted contingent on changing situation – magnitude of flood risks • Strategies adopted contingent on changing predictions of rainfall	5. Emergent strategy may be risk averse, structural inertia intensifies risk 6. The escalation of crisis may rapid, non-linear and exponential

4.2.12 Concluding Remarks

It is noted case study analysis is undertaken within unique conditions of the case itself, which exists as a real world scenario. Results are not generalisable to all organisations and at all times. To assist in examining and interpreting the case results, attention has been given to describing the situational factors and environmental conditions present prior to and during the unfolding events.

While it may be unlikely the exact conditions would be repeated (weather patterns, individual behaviours), similar conditions do exist in a range of settings, which make the results broadly relevant. For instance, the threshold state criteria are used to evaluate the conditions of the entity under study, should these criteria apply in a similar operational environment and setting the results may be generalisable.

4.3 Case Study Two – US Subprime Mortgage Crisis

4.3.1 Introduction

Almost a decade after the Global Financial Crisis (GFC), there remains much to learn from the events that precipitated and characterised the worst financial crisis since the Great Depression in the 1930s; and in particular, the US subprime crisis that gave rise to the GFC. In the US, as a result of the GFC, US $11 Trillion was wiped from household wealth, four million families lost their homes to foreclosure, followed by a deep recession, high unemployment and a shattered housing market, not to mention the global ramifications. In late 2008, the US Government had two choices: face the potential collapse of the entire US economy or invest trillions in tax payer funded aid to several large and economically crucial Wall Street financial institutions. History recalls the story of anguish and distress caused by a systemic failure of the world's largest free market economy, and the ensuing search for its root causes.

In the months and years following the crisis, the US Government's own commission of inquiry searched to identify the main causes of the disaster. In hindsight, many warning signs are evident with participation in high-risk investment structures pervading all the major financial institutions in the country, and many overseas. Favourable government policy on subprime lending, and a wide berth for institutions to invent products and repackage value were drivers in a growing appetite for high returns from Wall Street in the preceding years. However, the lack of acuity in regulatory oversight does not translate to a lack of salience between organisational actors and competitors regarding market strategy. The close replication of strategy across firms within timescales illustrates information travels very effectively across the marketplace.

In this analysis, a deeper exploration is taken into the salience of market practice across the financial sector, hence the probability for increments of influence to transmit between agents operating in a tightly coupled operating environment. Several findings are made that underscore the importance of influence, information transfer and complexity dynamics as to their impact on market and industry behaviours. Analysis is provided through concept analysis and mapping, thematic analysis and an exploration of the link between perception, awareness and understanding of conditions. Attention is given to describe the situational factors and conditions that present in each case.

Case One (Floods Crisis) and Case Two (Subprime Mortgage Crisis) have one important property in common – both place a material value on the art of *prediction*. As we have observed in Case One, emergent strategy formation led to systemic behaviours in a cascade of small decisions, with an erosion of strategic choice and irreversibility. Structural inertia amplified risk, objectives were transient with changing conditions, all of which was driven by a process of subjective judgement in decision making. There are several obvious differences in the two cases, one group are undoubtedly profit maximisers, both are risk minimisers, but with unique models of risk tolerance and operational dynamics. One is financially incentivised to 'see' system level pattern, the other is penalised for not seeing pattern. Here, we benefit from the diversity of these case examples as the research questions are applied.

4.3.2 Case Notes

The focus in this study is not on the global consequences and complete economic impact of the GFC, rather the focal point is on the precipitating US Subprime Mortgage Crisis that gave rise to the conditions for risk contagion causing the ensuing GFC. An examination of qualitative data provides a rich source on the intra and inter-organisational workings of the organisations and organisational actors involved in the operation of financial instruments and products that were at the core of the Subprime crisis. Hence, the focus is on the operation of high risk subprime loan markets, mortgage-backed securities and associated derivatives, the practice of trade decision making, system-level cognition, information transfer, and emergence of norms that led to the eventual culmination of sector-wide illiquidity.
This study is not an investigation into the causes of the crisis *per se*, rather the role of emergent self-organisation in adapting to acute pressures, and the levels of salience among actors to see the unfolding pattern.

In 2009, the US Government established the Financial Crisis Inquiry Commission (FCIC) to investigate the causes of the financial and economic crisis in the United States that reached global proportions in late 2008. The Commission was overseen by Phil Angelides, Chairman (former California State Treasurer); supported by Hon Bill Thomas, Vice Chairman (politician); eight Commissioners and a number of federal investigators. The inquiry panel was comprised largely of experts in law, investment fraud and regulatory compliance.

The inquiry lasted around 12 months, consisting of 356 interviews with key people across major firms on Wall Street and experts witnesses. Interview transcripts with experts have been consulted, including those from New York University, Standard & Poors, University of Missouri, Columbia University, Council of State Governments, Moodys Corporation, US Treasury, University of Iowa, Princeton University, University of California Berkeley, Harvard University and Stanford University. The focus of this study is on the epicentre of the crisis – that is, the seven firms that were major players in financial markets and carried the bulk of market risk in the form of troubled collateralised debt obligations, derived of mortgage related securities. While expert interviews provide rich context, it is the seven firms and their actors operating within the market that is used for concept analysis and mapping, to enable themes to emerge without influence of external speculation.

Identifying the seven firms is achieved using the US Government's targeting of financial assistance through the Troubled Asset Relief Program (TARP). TARP was created to stabilise the financial system during the financial crisis of 2008, and authorised with resources of US $700 billion during the Presidency of George W. Bush, and enshrined in the *Emergency Economic Stabilization Act of 2008* (EESA) [United States of America] (Treasury, 2017). Within the TARP, the Bank Investment Program has five sub-categories, among which is the Capital Purchase Program (CPP) – aimed at providing capital to viable financial institutions that meet certain criteria, including *limits on executive compensation* in the form of 'golden parachutes', *equity stakes and recoupment* (they are healthy enough to survive), *disclosure and transparency* (we can learn what happened, making this study possible), and *judicial review* (regulatory control and oversight to enhance accountability) ("Emergency Economic Stabilisation Act," 2008). As illustrated at Table 4.6, the vast majority (79%) of TARP/CPP funds were invested in seven of the largest financial institutions with a combined asset value of US $9.57 trillion.

Table 4.6 Amount of Capital Investment and Characteristics of Qualified Financial Institutions as of 25 November 2008 (in US $ millions)

Financial Institution	*TARP/CPP Funds*	*Total Company Assets as of September 2008*	*Proportion of Total TARP/CPP Funds*
Bank of America	$15,000	$1,831,000	9.9%
Citigroup	$25,000	$2,050,000	16.5%
Goldman Sachs	$10,000	$1,082,000	6.6%
JP Morgan Chase	$25,000	$2,251,000	16.5%
Merrill Lynch	$10,000	-	6.6%
Morgan Stanley	$10,000	$987,000	6.6%
Wells Fargo	$25,000	$1,371,000	16.5%
Subtotal	*$120,000*	*$9,572,000*	*79.2%*
US Bancorp	$6,599	$247,055	4.4%
Capital One Financial	$3,555	$154,803	2.3%
Regions Financial	$3,500	$144,292	2.3%
SunTrust Banks	$3,500	$174,777	2.3%
Bank of New York	$3,000	$268,000	2.0%
KeyCorp	$2,500	$101,290	1.7%
Comerica	$2,250	$65,153	1.5%
All others (n=39)	$6,568	$721,487	4.3%
Grand Total	**$151,472**	**$11,448,857**	**100%**

Notes: Total company assets were note reported for Merrill Lynch in 2008 due to a pending acquisition by Bank of America.

Rather than seek to identify and invest TARP funds directly into the troubled mortgage securities, in a midnight-hour change of direction, the US Government channelled its investment to firms with the greatest potential for survival, then reflected in the criteria for potential repayment.

Another reason for the last minute change, was the realisation of similar lessons from a financial intervention model in the UK (Treasury, 2017). The criteria for the allocation of TARP apply to firms where a great deal of impact and risk is concentrated, created by participation in subprime markets. For the purposes of this study, TARP is used as a mechanism of focus, and to that end is a good approximation of the locus of major market activity, using Treasury's own criteria. This is not however, an evaluation of the federal assistance in itself. General comment is made in concluding remarks on the work of the Commission and their report.

In total, 43 interviews from seven firms were used in concept analysis and mapping, and thematic analysis for the purposes of this case (see Table 4.7). The volume and breadth of qualitative data is significant, comprised of 65 audio hours and 561,761 transcribed words.

Table 4.7 List of Interviews and Transcript Volume

Financial Institution	*Interviews*	*Transcript Volume (words)*
Bank of America	3	28,463
Citigroup	9	132,553
Goldman Sachs	10	137,812
JP Morgan Chase	7	96,381
Merrill Lynch	6	94,345
Morgan Stanley	1	12,412
Wells Fargo	7	59,795
Total	43	561,761

4.3.3 Threshold State Criteria

Similar to Case One, threshold state criteria are applied to the Subprime Mortgage Crisis case. The Subprime Mortgage Crisis confirms the presence of the six threshold state criteria (or critical values) at the time events unfolded. The criteria define conditions when an organisation is faced with significant disequilibrium from internal and / or external pressures, which are beyond the normal range (Anderson, 1999; Osborn et al., 2002). As outlined in Chapter 3, threshold-states have been used to inform criteria upon which case conditions are evaluated (see Table 4.8).

Table 4.8 Threshold State Criteria – Subprime Mortgage Crisis

Threshold State Criteria	*Subprime Mortgage Crisis – Initial Assessment*	*Notes and Confirmed Assessment*
(a) Changing market expectations	HIGH – increasing expectations on market returns, normalisation of risky behaviour and increasing complexity in securitisation methods	Confirmed – HIGH. The demand for high returns and appetite for synthetic CDOs increased, risky investments permeated the industry, consumer market expectations for loan approvals and refinancing access increased over a sustained period
(b) Critical and immediate pressures to adapt	HIGH – sudden realisation of vulnerability and risk exposure in collateralised debt	Confirmed – HIGH. The critical and immediate need to adapt with system-wide risk exposure led to the crisis, with early warning signs observed by some
(c) Shifting definitions of success	HIGH – from profitability to survival in a new landscape of competition	Confirmed – HIGH. After an initial and slight market return in attempts to curb the free fall, the definition of success shifted from profitability to survival
(d) Uncertain future performance capabilities	HIGH – rapid change from status quo to insolvency risk	Confirmed – HIGH. Viability of the entire sector at risk, even relatively healthy firms with an uncertain future outlook due to erosion of market confidence
(e) Diversification of schema, networks and competitive forces	HIGH – highly interconnected market with decentralised controls	Confirmed – HIGH. The velocity of change, resulting in massively heightened network activity as the market comes to grips with a new reality
(f) Characteristics of apparent structural inertia	MODERATE – tendency to break norms, but with questionable risk tolerance and limited regard for systemic failure	Confirmed, redefined – MODERATE. A new definition of structural inertia is required for inter-organisational characteristics, where risk and volatility is the norm

Source: threshold state criteria formed through an amalgam of work by Anderson (1999); M. Hannan and Freeman (1984); Lichtenstein and Plowman (2009a); Osborn et al. (2002).

4.3.4 Situation Factors and Conditions

The Subprime Mortgage Crisis of 2008 that eventually spread across the globe is a significantly complex matter. The beginning of the Subprime crisis occurred in late 2007 with a gradual realisation of a housing bubble and aggressive uptake of risky loans during the previous six years. As a result of an increasing number of loan defaults and a realisation of massively overvalued mortgage related securities that had saturated the market, a number of significant financial institutions failed. These included Countrywide Financial, Bear Stearns, IndyMac; and the two government established corporations that traded in low-end mortgages: known as *Fannie Mae* (Federal National Mortgage Association), and *Freddie Mac* (Federal Home Loan Mortgage Corporation). The US Treasury had been engaged in closed-door meetings and asset guarantee strategies to secure Wall Street (SIG, 2015) when finally, on 15 September 2008 the 158 year-old and fourth largest investment bank in the US, Lehman Brothers, filed for bankruptcy.

The day after the Lehman collapse, the US stock market dropped 500 points bringing the entire financial system to its knees (Treasury, 2017). American International Group (AIG), one of the largest firms in the world was on the brink of failure.

> Beginning in 2007, the Treasury Department, the Federal Reserve, the Federal Deposit Insurance Corporation (FDIC), and other federal government agencies undertook a series of emergency actions to prevent a collapse of the country's financial system and the dangers that would pose to consumers, businesses, and the broader economy. However, the severe conditions our nation faced required additional resources and authorities. Therefore, in late September, the Bush Administration proposed EESA [*Emergency Economic Stabilisation Act 2008*], and with bi-partisan support in Congress, it was enacted into law on 3 October 2008. (Treasury, 2017).

As panic spread through Wall Street, confidence in the financial and banking sector evaporated. Financing for credit cards, student loans, mortgage loans, auto loans, small business loans and other types of financing stopped functioning.
From these circumstances, the TARP was formed to restore the stability and confidence in the banking sector, credit markets, housing (regarding foreclosure), the car industry and controversially, AIG.

In the months and years leading to the crisis a range of market factors converged that appear to reflect a financial market operating without proper supervision, inadequate risk controls, and with a deep exploitation of policy settings designed to enable Americans to purchase their own homes. In hindsight, a range of warning signals were evident, such as small pre-shocks, in an already volatile marketplace with unparalleled access to information, resources and the ability for flexible responses in product and service delivery. Despite this, the depth of the crisis came as a surprise to most.

> There was an unwillingness to lend on repo [collateralised borrowing] even on treasuries and the concern really became more of the counter party than the collateral. (F. Transcript, 2017).

A point of interest is the differing perspective and conclusions drawn by operators in the market to those that supervise, including in relation to the underlying causes for the crisis. Risky behaviour appears to have been normalised across much of the industry, with firms actively looking out for signposts for risk, but with a general sense that the entire system is self-correcting.

> Now you may not know this but money funds have broken the buck before. I would say not. If I remember correctly 60 times. 58 Of them, someone fixed it. (F. Transcript, 2017).

Contrary to the view of the US Treasury, informants suggest Lehman itself was symptomatic of a deeper systemic risk and in some ways unlucky, rather than a cause unto itself.

> The markets were like fickle and nervous and right, right before Lehman, the month before Lehman. It wasn't just Lehman. Lehman was just kind of like that hole in the dyke that burst. (F. Transcript, 2017). [In reference to the book *Hans Brinker, or the Silver Skates* by Mary Mapes Dodge, published in 1865].

Furthermore, the nature of the market itself and asset valuation operates in an intangible and contestable space. Within audited accounting practice, informants suggest there is room for subjectivity and optimism, on what is reflected in the general practice of mark-to-market 'fair value' accounting, in particular, used by Goldman Sachs. The value of the asset reflects its current market price. 'There is a significant benefit of fair market value accounting … if properly applied' (F. Transcript, 2017).

> I would be very careful about the word over-valuation, because you know, everyone. You know you get ten people who have ten opinions … On a liquid thing and also of the opinion of what it's worth tomorrow as opposed to what it was worth yesterday. (F. Transcript, 2017).

From the example narrative above, it is clear the perception on situational factors and conditions are inseparable from the perceptions of the anatomy of the crisis itself. The concept of value and over/under-value is speculative and at all times is being exploited through arbitrage. Assets are worth what others will pay, but subjectively embed a *price on risk* – assuming markets are operating efficiently. For this reason, in many ways, financial markets are simply a market of information transfer. Over the last 20 years, a growing variety of technology and tools are used to extrapolate and distribute information – in aid to the art of prediction.

The situational factors and conditions that preceded the crisis are commented on extensively in the FCIC reports, dissenting statements and a range of popular press publications (FCIC, 2011; F. Transcript, 2017; Treasury, 2017). Despite their lack of consensus, three main conclusions that can be reached which all reports agree on: a) *human action and risk management* – financial markets operated with a significantly wide berth that gave rise to aggressive risk taking, often within the false security of a guaranteed securities market; b) *government policy* – while the commission was split on whether regulation itself was a cause for the crisis, regulatory and policy settings were a contributing factor in creating the conditions for market exploitation, potentially emboldened in parts by a laissez-faire approach to supervision and regulatory compliance; and finally, c) *amplification* – the stacking of risky securities into tranches and AAA-rated (high quality) products which were in fact toxic. The interconnectedness of markets is known, but became significantly apparent on the realisation of the extent of saturation in high-risk assets across the sector that gripped the entire economy and shortly after, the world.

4.3.5 Industry Dynamics and Cultural Factors

Much has been written and inferred about the dynamics and culture of fast moving Wall Street financial institutions – especially investment banks; 'Wall Street has always been a dangerous place' (Cohan, 2011). Surprisingly, organisational culture is not a focus of either the inquiry or any of the dissenting statements – yet culture is the focus of almost all its narrative in popular press, small screen and cinema; *The Wolf of Wall Street, Money and Power, The Big Short, Arbitrage, Money Never Sleeps, Margin Call, Inside Job, Capitalism: A Love Story, Company Men, Billions* – to name a few, with storylines further popularised by the financial crisis (Belfort, 2007; Cohan, 2011). While these articles are not considered empirical, the focus on culture is compelling. Moreover, culture plays a role in interview transcripts, and in many ways could be considered the fabric that normalised a tapestry of organisational behaviour, in complexity terms – an attractor for 'stable equilibrium' (Stacey, 1995).

Naturally, there is no single culture that defines all seven firms within the scope of this study; each has its own history, norms and specialisations. Culture has been given consideration in each interview, noting its definition is seen through the lens of each informant. On aggregation, industry dynamics can be observed through behaviours taken, decisions made and patterns that follow – reflective of cultural practices within each participating firm. This is a similar projection found in studies of dynamic social psychology, discussed earlier, thereby making use of individual and group *actions* to understand pattern, not only in individual or isolated component causations (Vallacher & Nowak, 2008). To this we add the dimension of salience to assist with the cognition of emergence (Friedkin, 1998).

4.3.6 Structure and Operation of Subprime Markets

In the two decades that preceded the Subprime Mortgage Crisis, sustained and significant growth in housing prices was evident across the United States, combined with a spread of increasing leverage [loan to value ratio] (Ellis, 2009). Growth in values across the housing market were fuelled by market speculation, optimism, credit was cheap and easy to come by. Additionally, home owners may not have fully understood the terms of their mortgages and risks of foreclosure (Hennessey, Holtz-Eakin, & Thomas, 2011). Within financial markets, credit agencies were the cogs of misinformation, rating mortgage-backed security tranches and their derivatives as 'AAA' investments, further exacerbating the issue. From this point, risks were amplified as financial institutions amassed huge amounts of mortgage-backed securities, collateralised debt obligations and other correlated investments – while at the same time not holding enough capital on balance sheets to maintain liquidity should the underlying assets fail through mortgage default (Hennessey et al., 2011).

In 2006, US $600 billion in subprime loans had been created [referred to as 'originations'] (FCIC, 2011). At that time, subprime mortgages accounted for almost a quarter (23.5%) of all home loans in the US – quickly becoming an epidemic, as shown at Figure 4.7. Subprime mortgages are a type of loan offered to individuals with low or deficient credit ratings, where a conventional mortgage in inaccessible for these reasons. Subprime loans are characterised by low quality collateral and higher credit risks. Fuelling the rapid growth was also a redistribution of subprime loans from Fannie Mae and Freddie Mac to private firms, while maintaining the use of collateralisation through government sponsorship (Simkovic, 2013).

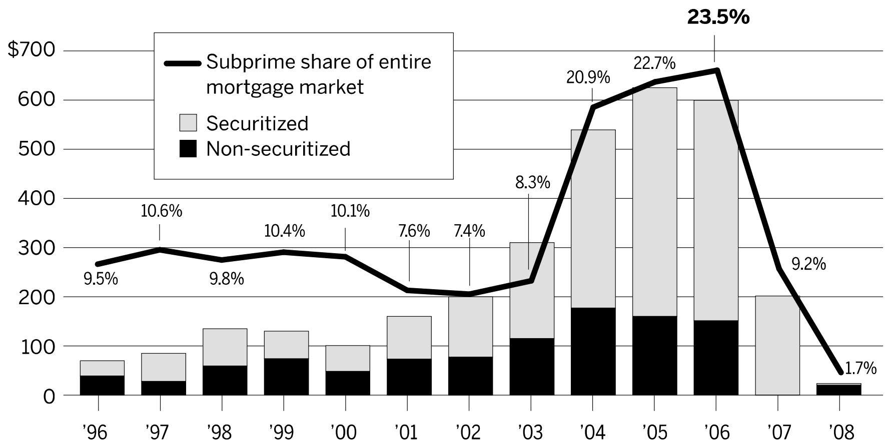


Figure 4.7 Subprime Mortgage Originations

Note: Amounts in in US $ billions. Per cent securitised is defined as subprime securities issues divided by originations in a given year. In 2007, securities issued exceeded originations. Source: Inside Mortgage Finance. (FCIC, 2011).

Subprime mortgages failed across the US and in great numbers, as illustrated at Figure 4.8. Serious delinquencies were higher among adjustable rate mortgages, which also started to default earlier. As housing prices declined, interest rates increased, refinance options became unavailable, and delinquencies soared.

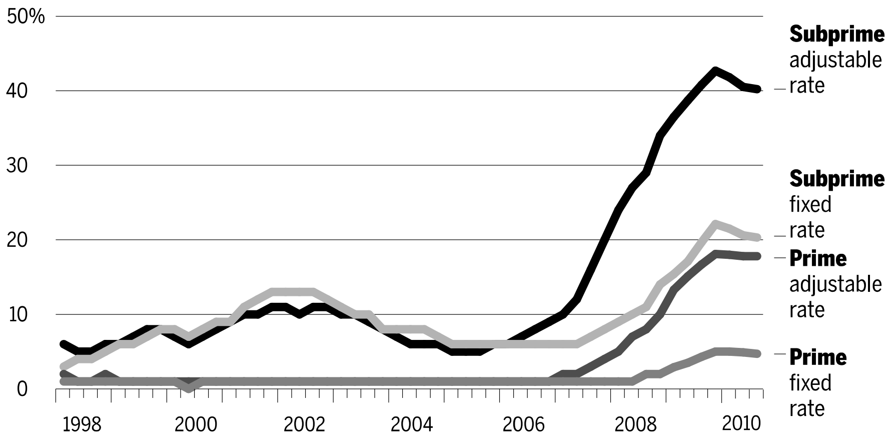


Figure 4.8 Mortgage Delinquencies by Loan Type

Note: Serious delinquencies include mortgages 90 days or more past due and those in foreclosure. Source: Mortgage Bankers Association National Delinquency Survey. (FCIC, 2011).

For several of the preceding years, subprime loans were pooled into mortgage-backed securities then sold to investors. The theory of how the financial system created AAA assets from high-risk subprime mortgages is further illustrated at Figure 4.9. With the growth of subprime mortgages, demand increased for this kind of risk / return investment. Mortgages were grouped into hundreds of mortgage-backed securities. These securities were sold in tranches, with lower and mezzanine tranches often used for collateralised debt obligations (CDOs). Payments against mortgages would be distributed according to the risk rating of tranches, AAA first, AA second, and so on. CDOs (and synthetic CDOs, which use a credit default swap) are a structured security, using the asset backing from risky mortgage-backed securities. CDOs were also used to form new bundles [put simply: bundles of bundles of bundles], known as CDO-squared. While CDO^2 were ‘tiny relative to the whole volume’ of mortgage-backed securities, in the two years prior to 2008, Goldman alone had crafted a US $900 million synthetic CDO² known as ‘Abacus’, which also involved a credit default swap (Cohan, 2011; F. Transcript, 2017).

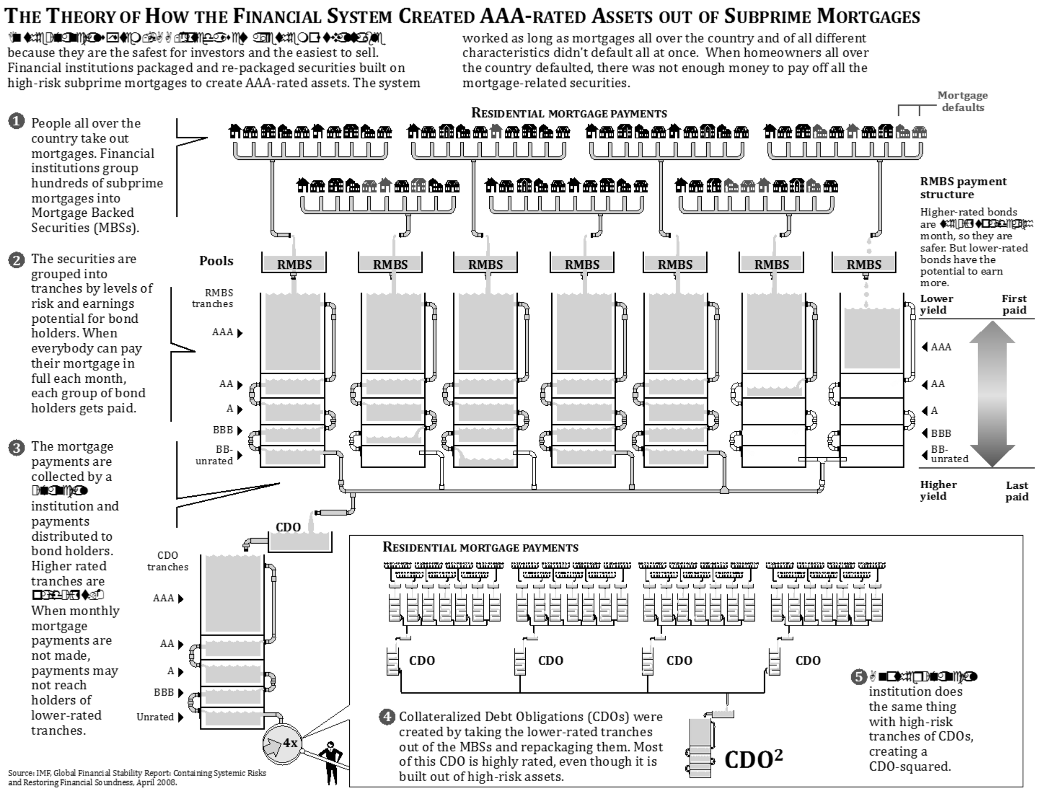


Figure 4.9 How the Financial System Created AAA-rated Assets from Subprime Mortgages

Source: (FCIC, 2011).

The Subprime Mortgage Crisis was the catalyst for financial unease across the globe as the risk of contagion, shock, panic and interdependencies within and beyond the financial sector were realised (Hennessey et al., 2011). As housing prices fell, defaults increased and correlated securities rapidly shed value. A large number of firms faced liquidity crisis on the realisation they held swathes of toxic assets that were massively overvalued. As a result, credit markets and their firms ceased to function, impacting the entire economy. The underlying actions and behaviours precipitating the crisis reveal a number of key concepts that explain the nature and characteristics of activity during this important period. Concept analysis and mapping, cluster analysis and thematic analysis are used to unpack these findings in detail.

4.3.7 Concept Analysis and Mapping

Results of the analysis reveal five key concept clusters that emerge through interview transcripts: *time, risk, market, people, business* and *credit*; within five concept clusters which add: *loans, financial* and *deal* – as illustrated at Figure 4.10. Individual weights and concepts, frequency counts and relevance scores are provided at Table 4.9.

Concept analysis shows the prominence of risk as a major factor in connection with a view of the market, securitisation structures and the methods of trading practice. Informants demonstrated a commanding knowledge of the financial industry and fluent comprehension of the function and components of complex and structured financial products. Transcripts demonstrate the financial sector operates with its own quasi-dialect, a language that employs conceptual device, and deals in subtlety and layered meaning – which would be difficult to penetrate in direct conversation, without careful review or a glossary at hand.

> If I think about a professional football team, you know the blind side which people see. That position prices higher than virtually anything else on the field. And that... and so, if you're the wide receiver, does that mean you now want to be the left guard? I'm sorry, but the build of the wide receiver has no hope. So you know if you can sing and dance like Madonna, then sing and dance like Madonna, if that's what you want to do. (F. Transcript, 2017).

A level of mystery permeates the hypercompetitive financial market where good intelligence, strategy, and pre-emptive choice produce value of almost 'infinite multiplication' (F. Transcript, 2017). In the case of Goldman Sachs, mystery is marketing ammunition (Cohan, 2011). It is the case for studied firms that risk management is a core function of the business – however, it is also a common view that 'risk is simply too complex to handle all in one place' (F. Transcript, 2017), despite having a chief risk officer or direct information flow to a functioning board. While a distributed model of risk management is understandable, the consequent reliance on information flows and a culture of openness is all the more important. This is of use in executing a core ambition that is shared across all firms – to make money.

In addition to being a source for information on risk, a common factor is the nature of deal-making within the firm – conceptualised, planned and executed through 'groups', an informal and formal decussate that coalesce around critical strategies (deals), key information sources and at particular times, e.g. during major acquisitions. Time is the pivotal link between investment choice and structure, risk, people and all that awaits in the external world (see Figure 4.10). Salience on activity within these groups is high. However, depending on the internal culture there appear to be many areas where neighbouring teams and groups are locked out. Despite a fluent understanding of the complexity of markets, structured products, risk and prevailing warning signals, it is possible that due to an inhibited information flow within firms, no single actor was capable of piecing together all the moving parts to identify the pattern of crisis that had emerged: ‘there are all sort of limits we impose on sharing information’ (F. Transcript, 2017). Hence, the lack of an information sharing culture is of interest.

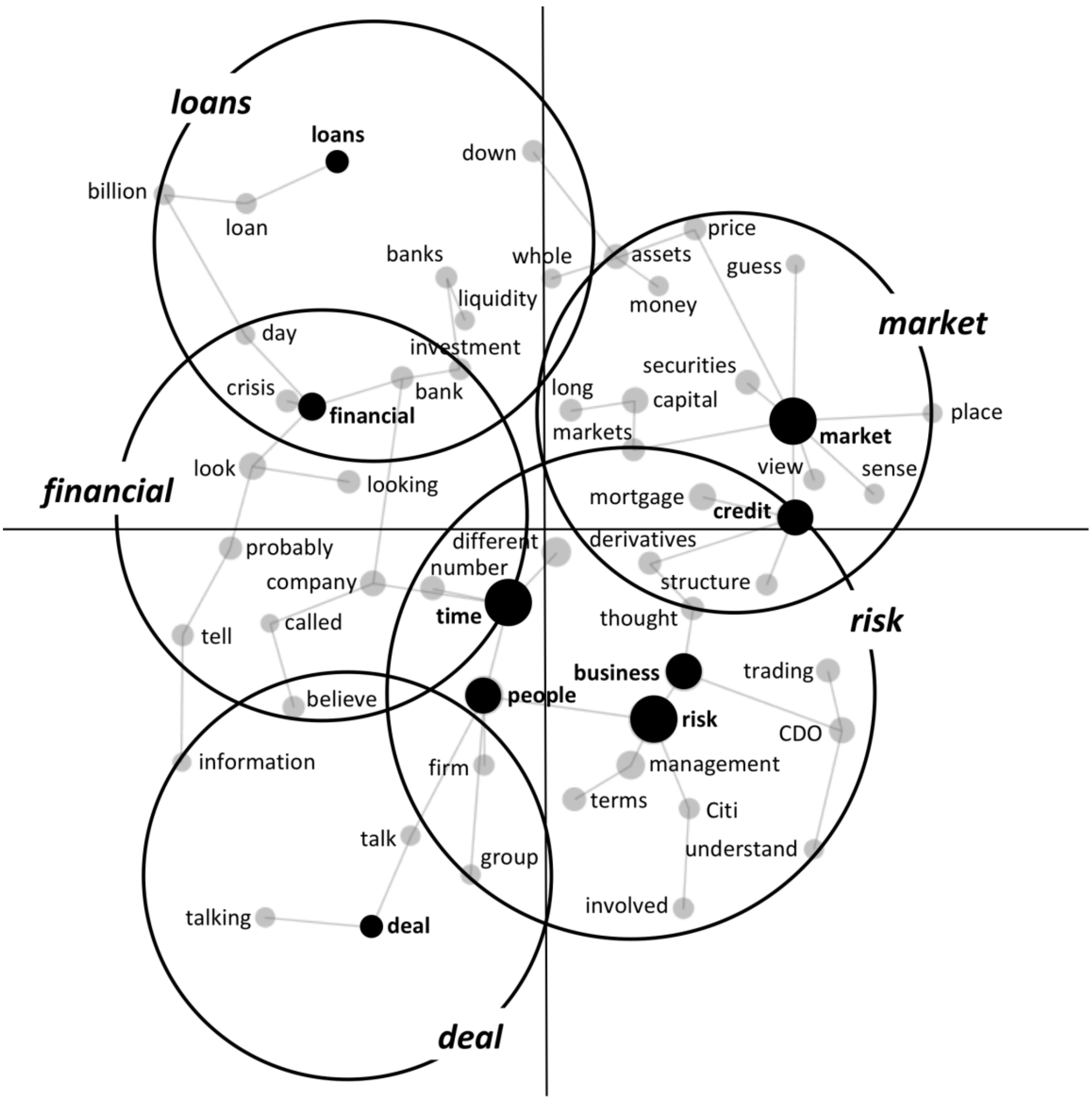


Figure 4.10 Subprime Mortgage Crisis Concepts and Themes

Table 4.9 Count and Relevance of Concepts

Concept	*Count*	*Rel.*	*Concept*	*Count*	*Rel.*	*Concept*	*Count*	*Rel.*
time	699	100%	probably	208	30%	view	155	22%
risk	659	94%	number	205	29%	money	151	22%
market	589	84%	down	202	29%	markets	150	21%
people	510	73%	capital	201	29%	group	149	21%
business	443	63%	believe	201	29%	investment	148	21%
credit	421	60%	tell	201	29%	firm	148	21%
different	299	43%	trading	195	28%	banks	143	20%
look	292	42%	thought	195	28%	structure	140	20%
financial	253	36%	looking	189	27%	place	139	20%
company	241	34%	price	189	27%	day	138	20%
loans	237	34%	talking	184	26%	sense	135	19%
mortgage	233	33%	long	183	26%	guess	135	19%
assets	232	33%	involved	178	25%	crisis	133	19%
deal	227	32%	loan	173	25%	whole	127	18%
terms	220	31%	understand	164	23%	information	125	18%
billion	217	31%	bank	162	23%	liquidity	107	15%
management	211	30%	derivatives	160	23%	called	107	15%
securities	208	30%	talk	157	22%			

Note: Relevance (Rel). Concept clusters are highlighted, 50%+ relevance concepts are boxed. The relevance score is the equivalent of *weight,* calculated over the sum of concept counts per cluster.

Many factors were at play in the lead up and during the Subprime crisis. Despite which, it is the expressed view of most informants 'the crisis could not have been foreseen or avoided' (FCIC, 2011). The inability to see the coming crisis opens a number of lines of analysis; included in which is the notion that effective transmission of information is essential to the creation of emergent pattern. Furthermore, on the link between culture and risk: in this study, culture is a frame that binds collective behaviour and entrenches structural inertia – including the lack of willingness to alter an existing course of action. Therein, risk culture is an emergent property of a complex human social system. With so many alarm bells in place, limits on information flow are a risk magnifier.

The crisis itself is not seen by informants as a single chain of events, but rather a cascade of many decisions, widely spread, repeated and amplified over the course of several years; and this was perpetuated by the many, rather than the few – in response to market demand and an appetite for equity growth.

4.3.8 Concept Cluster Network Analysis

Concept cluster network analysis is provided below, highlighting the centrality of time and the interconnectedness of risk within the network of concept terms, at Figure 4.11 (accompanied by Table 4.10). The cluster analysis has led to many useful insights, the main themes of which are highlighted as follows.

4.3.8.1 Time – an uncertain variable

It is the shared recollection of most informants that the crisis was not foreseen. However, there are certain parameters around this assertion. For instance, two years prior to the crisis, early research was being conducted by several firms on 'the [potential decline of] home prices and its effects on the performance of these securities' (F. Transcript, 2017). Potential macro-economic factors that influence house prices include unemployment, particularly if concentrated in a geographic area. The potential for high-risk mortgages to default and spread risk to correlated assets was likely identified, and is a reason for collateralisation and insurance. While this risk is reasonably likely and with high impact – the timing of such events would be a tremendous feat to make a sharp prediction on. (Also see Figure 4.11).

> During that time period the securities performed quite well, there was one factor that many people, or virtually almost everybody in the market did not factor in, which was a severe downward price move in home prices. And during that time period securities performed quite well, because you had a rising home price market. So, that indirectly resulted in curves that were more optimistic than what actually happened with those pools. (F. Transcript, 2017).

Furthermore, a principle of operation for the free market is for the forces of demand and supply to determine price. In which case, 'price … varies based on the market's view of how likely it is that they will default' (F. Transcript, 2017). This is the case for subprime mortgages in addition to the correlated products that were stacked on this underlying risk. It is the same principle of 'mark-to-market' valuation – an asset is worth what the market is willing to pay (F. Transcript, 2017).

4.3.8.2 Rapid emergence of new products

The financial sector is unique from many others in that physical constraints on product creation do not exist. Furthermore, it is not uncommon for both operators and clients in the financial sector to not completely understand the products and markets they are actually dealing with.

> Playing in a league where you [firms] understand things that a whole bunch of people that may be qualified investors, whatever that means, may not understand (F. Transcript, 2017).

Without any physical limitations and a wide berth within the regulatory system, financial institutions put their smarts into creating bespoke products to meet demand and deliver value, 'We didn't create the problems … we created the product to facilitate client need.' (F. Transcript, 2017).

> Well I don't recall making a conscious decision that we will now do synthetic CDOs. What we did we definitely entered the CDO business and we also entered the correlation trading business which really was trading trust synthetic baskets of assets. Which I think you could refer to as some people might call that synthetic CDOs but I

> would have called it tranche synthetics. What synthetics did for the first business I mentioned CDOs they allowed more CDOs to be created. And they allowed more tailored risk to be created for investors that they described. With the Tranche synthetic business which a lot of the ABACUS transactions were that allowed you to create these baskets of investments. (F. Transcript, 2017).

Following a boom in refinancing mortgages for consumers, financiers needed more products, leading to the growth in subprime mortgages, complex derivatives and slightly less risky Alt-A loans, most (70%) of which were adjustable rate mortgages. Simultaneously, debt was bundled and new products emerged in the financial sector, with a boom in synthetic CDOs [complex derivative security that uses CDSs].

4.3.9 Thematic Analysis

Thematic analysis presents five interrelated themes that cut across qualitative data and are informed by further analysis: *risk, market, financial, loan* and *deal* (see Figure 4.11). Each theme has an associated cluster of concepts, frequency count and underlying qualitative data. This method of analysis provides an accurate picture of patterns in qualitative data to assist in the search for meaning. Thematic derivations describe the main topics of discussion that are associated with themes, each explained in further detail at Table 4.10. Concept linkages are derived by examining rank, cluster and frequency count, also expressed at Table 4.10.

Table 4.10 Ranked Themes, Concepts and Derivations

Ranked Theme	*Clustered Concepts*	*Frequency Count*	*Thematic Derivations*
Risk	risk, time, people, business, different, management	2,216	Emergent risk culture
Market	market, credit, mortgage, capital	1,278	The art of prediction and value of knowledge
Financial	financial, look	521	Amplification, interconnectedness and contagion
Loan	loans	237	Autonomy of pattern and downward causation

Deal	deal	227	Information and people in groups

Source: (F. Transcript, 2017).

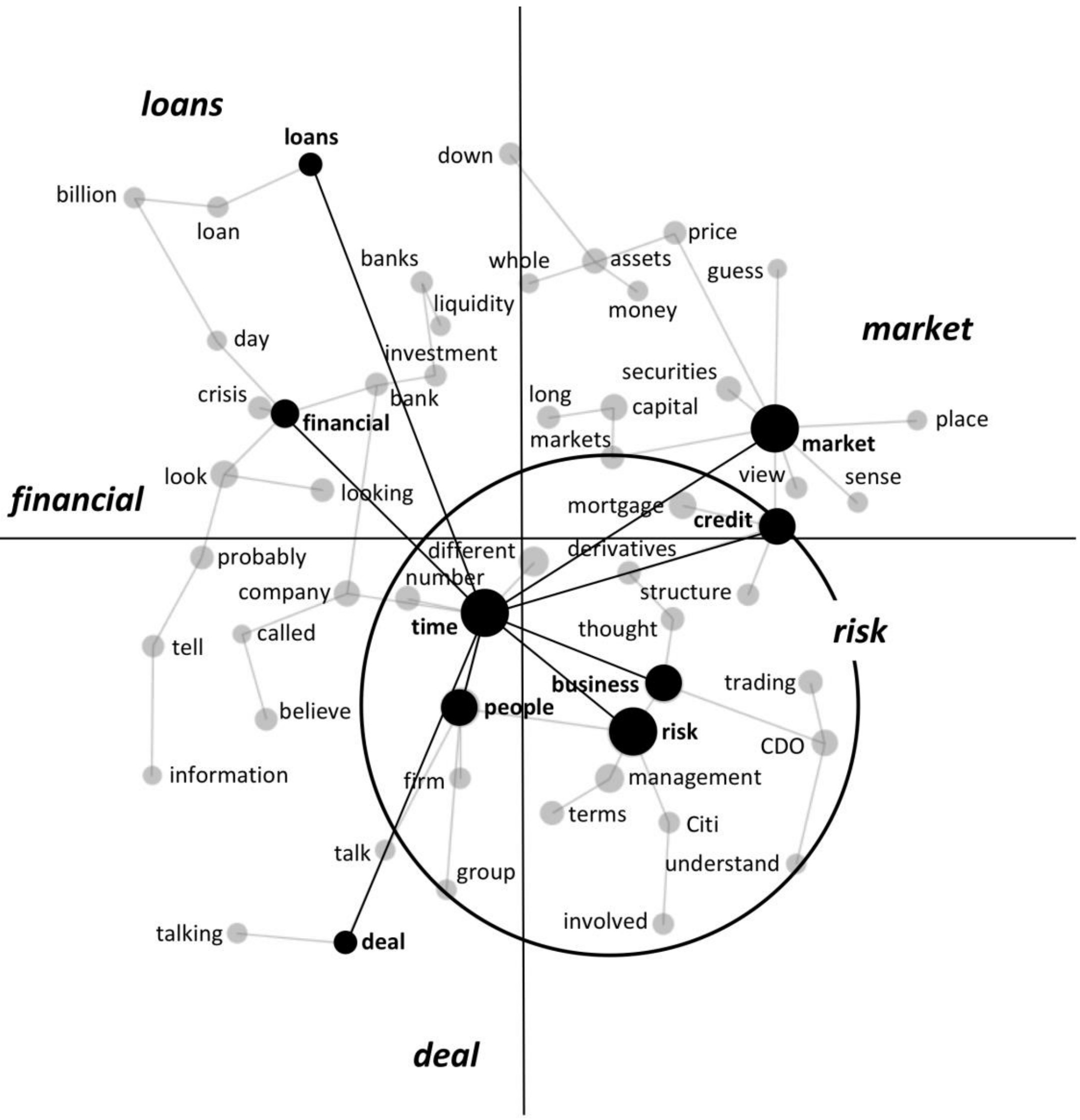


Figure 4.11 Centrality of Time and Interconnectedness of Risk

4.3.9.1 Emergent risk culture

Risk management is at the core of each firm's ability to achieve its objectives, and a dimension of every transaction. All seven firms in this study have a natural and shared desire to minimise losses, and in this way are to a certain extent risk averse. For this reason, risk management is a prime function of each business. On this basis, principles of regulatory oversight and market supervision endow significant trust in the market –

on the basis each firm has a natural interest in self-preservation, to avoid excessive risk taking that compromise their own existence, and which are found by the market itself to be unacceptable (FCIC, 2011).
While the FCIC findings report ‘stunning instances of governance breakdowns and irresponsibility’ (FCIC, 2011), there are few non-compliant actions singled out. Rather, a plethora of investment choice, newly created and complex products and aggressive acquisition of high risk securities spread widely across firms and across the sector.

The patterns of behaviour are indicative of the emergence of practice, borrowed and replicated across firms, accruing into shared norms and a framework of beliefs in the ways and means to structure and execute transactions on Wall Street.

> What it really came down to was culture risk capital. (F. Transcript, 2017).

In addition, within a partnership, private and publicly listed company structure, employees of the firm are often personally vested in each firm’s success. For example, all employees at Goldman Sachs are equity partners; individual net worth is tied to the net worth of the company. While risk culture is acknowledged as a major factor in the operation of each firm, perspectives differ on the most effective manner to achieve this. An approach is to concentrate the expertise of risk into a chief risk officer structure that report to the CEO and the board, ‘I have several chief risk officers by region that are under my direct reports’ (F. Transcript, 2017).

> I have chief risk officers for each of the major regions, so for Asia, LatAm [Latin America] and Europe. And the people who are in... Who are the chief risk officers for those regions, their responsibility is to understand all the risks in their region regardless of the business unit it’s in. (F. Transcript, 2017).

An alternative view highlighted earlier in the concept analysis and mapping is that business is simply too complex to have risk all in one place, i.e. under a chief risk officer.

> And some of them [transactions] are so complex that we don't know how a single Risk Committee could really do a competent job of that. (F. Transcript, 2017).

Hence, the chief risk officer role/s are to an extent a function of formal oversight and transparency to the board, and often not involved in day-to-day transactions. Firms without a chief risk officer appear to place greater emphasis on risk culture.

> I think that that risk culture allows an organisation to go for some period of time when there isn't an individual that may be called the chief risk officer of corporate. But throughout that whole period of time, there were still chief risk officers at each of the lines of business, the same risk infrastructure of risk committees, separation of church and state etc. (F. Transcript, 2017).

The latter reference in the quotation refers to the ability for risk management to be exercised freely and ingrained into operating practice, as the informant continues after this statement. Risk culture and culture in general is a latent factor identified by informants. The set of ideas, values and shared norms in an organisation, and consensus about what things mean and how things get done (Schein, 2004) is commonly referred to as a matter of practice and the pursuit of organisational objectives, while it is not always referred to explicitly as ‘culture’.

> I think that it's very important that organisations, speaking for J.P. Morgan Chase now, continue to constantly re-evaluate, remake, rebuild those risk cultures through the type of dialogue that we've talked about, starting with the board all the way down through the organisation.

While the practices of risk are spread throughout the organisation and entwined with culture – risk culture in itself is seen to start with executive direction, or ‘tone at the top’. It is worth noting that across the world, these seven firms employ a combined 1.04 million people – many of whom have little or no interaction with those at the strategic apex. Further, this is not merely a view of risk cultures, but of practical measures to optimise performance with known and anticipated uncertainties that may give rise to undesirable consequences.

> A strong risk culture starts with the tone at the top of the organisation and percolates through the organisation. Not just through a risk organisation, but through both a risk organisation and a revenue generating organisation.

The *silent room theorem*, referred to earlier in the thesis [and again at Chapter 5] is relevant here with regard to the function of influence and leadership. While it may be the view from the strategic apex of each firm that risk culture is set at the top; in all cases followership is required to enact such behaviours. As explored earlier in the review of literature, even in C2 [military, command and control] organisations, self-synchronisation takes time and this is increased with the greater 'tacitness' of knowledge (Manso & Moffat, 2011). Furthermore, the exchange of influence [and leadership] is an emergent event that occurs in the 'spaces between' agents, during a relational process (Lichtenstein et al., 2006). Therefore, regardless of the potency of leader influences, risk culture remains an emergent property of a complex system – albeit conditioned by leadership.

> But there's no question in my mind that one of the strengths of the risk culture at J.P. Morgan is the fact that everybody understands that risk has 51% of the votes.

On these accounts, this study finds that risk is both an emergent property housed within the broader frame of corporate culture, and that it is conditioned by leadership and management, in the principles and codes that are espoused and become shared. Risk is critical to the continued viability of each firm. For this reason, it is surprising to find significant divergence in that:

> One of the things I think is critical to the risk culture at J.P. Morgan Chase is that fluidity of communication and the lack of hierarchical shielding of information. (F. Transcript, 2017).

This assertion exists in company with a diametrically opposed view, for the purposes of making strategic trades and complex products:

> Just as you might understand, there are all sorts of limits we impose on sharing information so that, you know, you do make a bespoke trade for some client, which you've called opaque or whatever. (F. Transcript, 2017).

Without the adequate transfer of knowledge and information, risk culture would likely be a patchwork, rather than a unified norm. It is also likely those operating within specified 'groups' would have a different view of risk, based on their own experience, access to the strategic apex and the nature of each major play being executed.

4.3.9.2 The art of prediction and value of knowledge

When Lorenz (1963) first published his article on deterministic non-periodic flows, his initial ambition was to develop a model to predict patterns in atmospheric science. On the unfolding of natural phenomenon however, appeared chaotic systems, highly sensitive to initial conditions, exhibiting unstable and non-linear behaviour. In the same manner, financial markets are chaotic, unpredictable systems. Financial markets are deterministic [non-random] and employ the extensive use of knowledge, there is a high level of sensitivity to initial conditions where the variable of time is of major significance, products and markets are subject to amplification of small change. While markets are not subject to the laws of gravity in the same way physical systems are, there are limits to choice and potential eventualities. Those potential trajectories however, are extremely broad; and, operate in an environment where typical constraints of buyer / seller relationships are altered with increasingly complex product structures.

Informants have a high level of awareness and understanding of the behaviour of complex products in financial markets. However, rather than complexity itself being a cause for an inability to foresee eventualities, structured products are seen as a vehicle to transmit risk. Hence, a bundled product would be exposed to the same risks as the underlying asset.

> I think that the better characterisation is a propagating mechanism, they transmitted rather than caused. So to be specific, in the case we've been discussing, if you buy a credit derivative to an underlying portfolio of mortgage securities. That is inherently

> going to behave similarly under certain economic conditions, then that weakness in the underlying mortgage securities will be transmitted by the valuation of the derivatives. In this case the house price declines, you know, etc. because of our economy led to that occurring. (F. Transcript, 2017).

In the 1970s, Wall Street expanded its use of technical analysts known colloquially as 'quants', with advanced knowledge of mathematics and computers (FCIC, 2011). 'Wall Street is essentially floating on a sea of mathematics and computer power' (Patterson, 2010). The growing use of quants enabled the cultivation of increasingly complex product structures to emerge using calculated probabilities on likely changes in price, risk and value. Simply put, it is not a fiction that the best and brightest minds in the US have been drawn to Wall Street in great numbers (Patterson, 2010). Similar to Wivenhoe Dam, there is a high premium on the ability to see what is on the horizon, quantitatively. For Wivenhoe it is rainfall across a 7,022 square kilometre catchment; on Wall Street it is price, demand, risk and value.

According to transcripts, there was not a complete visibility on system level pattern, rather a cognition on system level components, causing and giving rise to three main issues: (a) a lack of visibility on correlated and underlying risks due to the treatment of investment bundles as an entity in itself; (b) combined with a lack of universal knowledge and understanding among investors of complex, structured products; and, (c) an underestimation of risk velocity, reliance on market efficiency and uncertainty of timing.

> It's like it when Warren Buffett came in. He said, I don't know, I didn't see it. People say that's why you have a bubble. But the people that are being cited to prove that... to me, it proves the opposite. There were a few guys that were seeing things a little... in a little bit of an off-beat way, and they got it right, so right, because so many people didn't see it. (F. Transcript, 2017).

The ability for a system to observe itself is a foundation for Second Order Cybernetics, and principle for the application of autopoietic systems to human social systems. Luhmann (1986) attempted to place human social systems into a new class of 'living systems', which then applies to complex systems such as economies and financial markets. While markets are 'alive' metaphorically, they do not have the capacity to observe themselves, arising from a distinct cognitive capability. That cognition (of system level behaviour and pattern) at an individual component level also appears to be limited for the same reasons, as per the *Darkness Principle* and *Law of Requisite Variety* (Ashby, 1958; Skyttner, 1996).

On this understanding, it is not possible for an individual to 'see' the entire marketplace from moment to moment. The system itself hides in plain sight by virtue of its incomprehensible mass and complexity. There are however, alternate views – and these are the main subject of popular press articles concerning the financial crisis and Wall Street.

> Although it underwrote billions of dollars of mortgage securities, Goldman Sachs avoided the worst of the crisis, thanks largely to a fully authorised, well-timed proprietary bet by a small group of Goldman traders – led by Dan Sparks, Josh Birnbaum, and Michael Swenson – beginning in December 2006, that the housing bubble would collapse and that the securities ties to home mortgages would rapidly lose value. They were right.
>
> In July 2007, David Viniar, Goldmans's long-time chief financial officer, referred to this proprietary bet as 'the big short' in an email he wrote to Blankfein and others. During 2007, as other firms lost billions of dollars writing down the value of mortgage-related securities on their balance sheets, Goldman was able to offset its own mortgage-related losses with huge gains – of some $4 billion – from its bet the housing market would fall. (Cohan, 2011).

Cohan claims that Goldman used its precision in mark-to-market accounting practices to achieve a pre-emptive lowering in the value of its mortgage securities, while setting up 'the big short' – a strategy to bet on a sharp fall in the housing market using credit default swaps [insurance on a CDO]. However, the reality of the situation is less glamorous and awash in ethical dilemmas that have led to legal action against the firm. Further, FCIC argues the benefits from proprietary trades were enabled by TARP money.

> Goldman also argued that the $14 billion of CDS protection that it purchased from AIG was part of Goldman's 'matched book,' meaning that Goldman sold $14 billion in offsetting protection to its own clients; it provided information to the FCIC indicating that the $14 billion received from Maiden Lane III was entirely paid to its clients.

> Without the federal assistance, Goldman would have had to find the $14 billion some other way.
>
> Goldman also produced documents to the FCIC that showed it received $3.4 billion from AIG related to credit default swaps on CDOs that were not part of Maiden Lane III. Of that $3.4 billion, $1.9 billion was received after, and thus made possible by, the federal bailout of AIG. And most— $2.9 billion—of the total was for proprietary trades (that is, trades made solely for Goldman's benefit rather than on behalf of a client) largely relating to Goldman's Abacus CDOs. Thus, unlike the $14 billion received from AIG on trades in which Goldman owed the money to its own counterparties, this $2.9 billion was retained by Goldman. (FCIC, 2011).

Interview transcripts, are less than clear on the methods of prediction used, and salience in relation to credit default swaps or insurance against falls in the market that also expose clients. This is an important matter for several reasons. An ability to see patterns in the market has a material value as an operator, and is also related to amplification and volatility in the operation of markets. This is referred to again with regard to downward causation. It is inferred by Cohan that Goldman Sachs pushed the other firms 'off the cliff' by offsetting profits, absorbing a write-down (Cohan, 2011), but in what the Goldman CEO refers to as 'a decision to neutralise the book' (F. Transcript, 2017). Further, the main reliance is claimed to be on ready access to good information.

> We have good technologies and systems ... you know, because the information is forthcoming and this is the only way you can run a business like that, is you have ... you know, your systems work so they can aggregate stuff so you can run your business on a macro basis, and also so you can get the details quickly if you need them. And that's all systems and technology and operations and how they're putting in. That's why we have ... we have more people in this firm in operations and technology, I believe, than we do in the producing side of the firm. (F. Transcript, 2017).

Returning to the subject of new products, there is a connection between the use of groups, client interaction and a view of the market through the lens of risk, timing and product structures. While invention of some products, for instance the credit default swap is attributed to Blythe Masters of JP Morgan in 1994 (Cohan, 2011), the creation of bespoke and trade-specific strategies is performed by the collective of small groups.

The transfer of information within these groups is a key part of the rapid emergence of new products.

> Many publications have credited me with inventing them [credit derivatives]. It's not actually true and I couldn't tell you who did, but I was involved in the early stages of helping to define the products, helping to educate people about their structure, the concept. (F. Transcript, 2017).

With the use of significant expertise, and small groups with high information access, firms were able to create products capable of amplifying value, employing increasingly complex structures, which masked the transmission of underlying risk.

4.3.9.3 Amplification, interconnectedness and contagion

Amplification is a topic embedded across qualitative data. The idea of amplification [or multiplication] operates in surprising ways, particularly for complex financial products. For example, synthetic CDOs create 'multiple gains … so for every multiplied lost dollar there was a multiplied gain dollar', therefore this is seen as a zero-sum game from a macro-economic perspective (F. Transcript, 2017).

> Remember when you create a synthetic, by the mere nature of being a synthetic there'd have to be a buyer and a seller. So at the end of the day, to the net economy, for the net disposable income it's zero. (F. Transcript, 2017).

In essence, the stacking of synthetic and structured products that are comprised of underlying mortgage-backed securities takes the original value of the underlying securities and amplifies it. Three examples using the AAA tranche method outlined earlier are provided at Table 4.11 - Amplification of Mortgage-Backed Securities to illustrate. The table details how the 'original value' [e.g. $15 m] is refactored to have an 'amplified value' [e.g. $85 m] through bundling of assets under linked CDOs. Bundled assets were then given a rating that also reclassified assets from low to high quality.

Table 4.11 Amplification of Mortgage-Backed Securities (in US $ millions)

Tranche	*Original rating*	*Original value*	*Linked CDOs*	*Amplified value*
Glacier Funding CDO 2006-4A C tranche	A2	$15	1. 888 Tactical Fund, Ltd. 2. Cairn High Grade ABS CDO II Limited 3. Diversey Harbor ABS CDO, Ltd. 4. Grand Avenue CDO I Ltd 5. Kleros Preferred Funding IV, Ltd. 6. Kleros Preferred Funding VI, Ltd. 7. Lancer Funding II, Ltd. 8. Palmer ABS CDO 2007-1, Ltd. 9. Rockbound CDO I, Ltd. 10. Tahoma CDO, Ltd. 11. Tricadia CDO 2006-7, Ltd. 12. Timberwolf 2007-1A 13. Point Pleasant 2007-1A 14. Lochsong 2006-1A 15. GSC ABS CDO 2006-3GA 16. Abacus 2006-HG1A 17. Abacus 2006-15A	$85
Soundview Home Equity Loan Trust 2006-EQ1 M5 tranche	A2	$28	1. Brooklyn Structured Finance CDO, Ltd. 2. Cairn Mezz ABS CDO I PLC 3. Cairn Mezz ABS CDO III Limited 4. GSC ABS CDO 2005-1, Ltd. 5. GSC ABS CDO 2006-1c, Ltd. 6. Kleros Preferred Funding III, Ltd. 7. Kleros Preferred Funding IV, Ltd. 8. Kleros Preferred Funding VI, Ltd. 9. Kleros Real Estate CDO III, Ltd. 10. Libertas Preferred Funding III, Ltd. 11. Maxim High Grade CDO I, Ltd. 12. McKinley Funding III, Ltd. 13. Montrose Harbor CDO I, Ltd. 14. Singa Funding, Ltd.	$79
Soundview Home Equity Loan Trust 2006-EQ1 M8 tranche	Baa2	$13	1. Aventine Hill CDO I, Ltd. 2. Ischus Mezzanine CDO IV, Ltd. 3. Kleros Real Estate CDO III, Ltd. 4. Libertas Preferred Funding III, Ltd. 5. Neptune CDO IV, Ltd. 6. Sagittarius CDO I Ltd. 7. TABS 2005-3, Ltd. 8. Vertical ABS CDO 2007-2, Ltd.	$49

Note: Using Standard & Poor's rating system. Source: (FCIC, 2011).

While the amplification method provides for multiplied gains, and as a result led to a rapid expansion of synthetic CDOs, risk and potential losses are also multiplied and distributed across correlated [linked] CDOs.

> I think the role that derivatives played was in transferring risk that did exist from one party to the next. (F. Transcript, 2017).

Using the earlier description of CDOs as a vehicle to transmit value (and risk), complex structured products are a novel challenge in the application of a theory for emergence and the amplification of small change. Briefly revisiting case one, amplification occurred through many small decisions that led to irreversibility and the gradual erosion of strategic choices. In the case of the subprime crisis, this study finds that the erosion of choice also occurred once a certain threshold of available time elapsed. A practical mechanism to apply here would be to apply a measure of risk velocity against the potential erosion of strategic choices that would come about due to fluctuations in price or exposure to underlying risks. This threshold could be quantified. Clearly, timing is critical to such events – the remaining question being what specific patterns would be observable that could be used to forewarn or sharply predict an arising pattern before it takes hold.

> So the panic again definitely related to the interconnectedness of institutions and or processions thereof. And one mechanism that created this interconnectedness was definitely derivatives along with lending, tri-party repo, you know, consolidated debt, so on and so forth. The interconnectedness would've been less problematic if it was more transparent than it was. (F. Transcript, 2017).

A further macro-level observation is that the more amplification tools are used, the more volatility should be expected in markets, based on the complexity dynamics of an interdependent system. Once again using the earlier finding that structured products are a ‘propagating mechanism’ used to transmit and ‘infinitely multiply’ value (F. Transcript, 2017), the changed characteristic of these components would then give rise to changed patterns on the market overall. The emergent layer is autonomous within a threshold state, and not impervious to underlying defaults.

4.3.9.4 Autonomy of pattern and downward causation

The idea of emergent order is found in classical economics, in the 'invisible hand' that guides the free market economy (A. Smith, 1776). The operation of Wall Street is a prime example of this invisible guidance, in the form of market efficiency. The efficient market hypothesis refers to the ability for price to reflect all available information – hence, even with the temporary potential to exploit price differentials through arbitrage, markets are assumed to be the knowers of all things of interest to them, eventually (Edgar, 1996). For financial institutions that 'trust' market forces, the same hypothesis gives rise to systemic failure when the flow of information breaks down, is false or misleading. This leads to a possible conclusion that ratings agencies (such as Moody's, Standard & Poor's) potentially damage the efficient market hypothesis – if they get it wrong and that information is used in putting a price on risk.

> We used all three of Moody's, S&P and Fitch and the majority that I recall was Moody's, S&P and some others it was S&P Fitch, I think there was a couple that were like that. The process would be to send to the rating agency the description of a portfolio including the line items as well as term sheet on the transaction. (F. Transcript, 2017).

Transcripts suggest optimisation of product structure to maximise rating values. This study finds that emergent systems, structures and patterns of behaviour in the market are autonomous from their substrate, and sustainable beyond a single component. Emergents are a product of underlying knowledge and behaviours – for example, prices can be assumed to be accurate to all salient information without any need to delve into the reasons why, or to wield expertise in all things. Price is a universally understood currency reflective of market intelligence. This study finds the actors that comprise the emergent are deeply conscious of pattern fragments (price at time x), and in effect, this casts significant downward causation. This topic is revisited again at Chapter 5.

In addition to indicating autonomy of emergent phenomena, findings also confirm that emergent phenomena are error prone. Contrary to fitness landscapes and axiomatic assumptions, emergent phenomena suffer the same imperfections as their underlying components, or worse – their exacerbation. It follows that autonomy does not ameliorate the emergent from the imperfections of its substrate. While collective behaviours are often assumed to be an aggregation of the best knowledge and information (Anderson, 1999; Hazy, 2008b; S. Johnson, 2001; S Johnson, 2004; McKelvey, 2008; Surowiecki, 2005), an alternative view, considering downward causation, is that emergent layers can exhibit significant imperfections – as an aggregation of the ill health of those components of which they are constituted. If a threshold is passed where ‘good’ parts outweigh imperfections, the emergent will appear healthy, but in fact can remain toxic, correlated and sensitive to amplification.

An earlier limitation discussed in the literature review concerns the question of autonomy of emergent phenomena from their underlying substrate. Culture for instance, could be considered an emergent property constituted by the agents that give rise to its affect. This transmits casual power in the form of ‘downward causation’, having an effect on the behaviour and characteristic of its emergent base (Bedau, 2008). This study finds that causation is a factor within and down an emergent structure, where there are high levels of correlation. A further example from this study is the emergent pattern of behaviour to use high-risk securities that spread across the industry and was based on relatively simple schema. The ongoing observations of price and return reinforced those behaviours via downward causation.

> I would say that the growth of the ABS [asset-backed security] CDO market had an impact on the underlying mortgage market. There's no question that that was... You know, ABS CDOs became an important factor in terms of purchasing the underlying credits, so they were highly correlated. The two markets were not working in isolation, there was... You know the ABS CDOs became... I don’t know what the numbers are, but became a large buyer of the underlying BBB [mid/low credit rating] assets. (F. Transcript, 2017).

The high levels of interconnectedness across the sector and between products, including their underlying components implies not only topside risks, but also an impact on the underlying assets. As stated earlier, while it may be a view that financial institutions didn’t create the problems; the framework of collateralised debt and securitisation is certainly related to the attractiveness of underlying products, and ultimately for consumers – accumulating debts that they couldn't possibly repay.

> But, certainly, by creating a demand, there were tonnes of mortgage bankers and others who were quite willing to originate, package and sell, and so the demand did come out of the Wall Street houses. (F. Transcript, 2017).

The interlock between structures and layers of investment was the main concern in the risk of contagion that enabled the crisis to spread from one firm to another and across the economy. This finding has several elements, which then require a determination to be made on what the emergent layer is and the components of which it is comprised. In this study, the pattern of behaviour is the pervasive use of high risk and structured mortgage-backed security products that spread across the industry and were based on relatively simple schema.

4.3.9.5 Information and people in groups

Despite the reporting of strong risk culture and capabilities in each firm, the transmission of information within firms appears limited in many cases, particularly in relation to major transactions and strategic plays. Knowledge and insights are gathered using experts, but are not widely communicated across the organisational structure. The role of groups, formed around a business objective, is strong but temporal, bringing together required expertise and maintaining limits on the further distribution of information (see prior Figure 4.11 and Table 4.10). The boundary conditions for information transfer between firms are permeable, but strategy contingent.

> Just as you might understand, there are all sorts of limits we impose on sharing information so that, you know, you do make a bespoke trade for some client, which you've called opaque or whatever. That information wouldn't be shared, you know, in the sense that, you know, share it the way you're describing. So if there's someone else in the firm who's trying do something they wouldn't get it. Plus there's this whole concept which we've tried to figure out what the boundary is, you know, like trade information generally. (F. Transcript, 2017).

The competitive, market sensitive nature of transactions and huge magnitude of investment provides explanation of the desire to contain strategic information. The distinction arises however, for two parallel streams of information to exist: one for strategic plays and another for risk and compliance. While it is less likely strategic groups formed in a completely organic manner within organisations, the industry is tightly coupled with broad intelligence transfer from one firm to the next – via formal channels (joint ventures, partnerships, cooperation) informal channels (social networks and groups), and markets (visibility on price, ratings, news, balance sheets and many other sources). Within the firm, expertise is called on as it's required and practice is structured around business objectives. Underlying social networks would potentially reveal further insights on the informal transmission of information beyond these groups, which would be of value for future research.

> Basically it was similar kinds of groups melded together, co-management with me and the Bear guys, and then we worked through to try figure out who should stay. (F. Transcript, 2017).

The degree of involvement in major decisions, scenario planning, structuring products or making strategic plays is a key dimension to the flow and use of information within firms. People involved, consideration of risk and engagement with senior management were all aspects of the temporal formation of groups. Time and people are tightly coupled concepts in the cluster analysis, providing a lens for risk, looking to markets and structuring deals.

> I was in the group that was looking for the solution to fund. Not the asset valuation group. So I guess the third one was, would be the, Holy Christ, what do we do now, group. (F. Transcript, 2017).

While the formation of groups and use of information is clear, the actual process of decision-making is opaque and appears unstructured. Similar to Wivenhoe decision cycles, actors sought input, used predictive models, applied strategy and in doing so crafted new products/deals, executed them, gathered feedback, adjusted the course of action, and repeated the cycle. While a cycle can be extrapolated, informants are coy on the capabilities of their models for prediction and exact methods for structuring products for specific clients and how these deals take place.

Informants provide limited clarity on the guiding hand of management and leadership to set the direction for the general character of investment decisions. Rather, a broad network of subject matter expertise appears to be deployed in finding solutions, active market participation, bespoke and major strategic plays – often formed through semi-formal groups. Given the importance of knowledge and information to executing these deals, and the large number of technical analysts and strategists employed, an emergent base appears to underlie part of the semi-formal group formation and definition of boundaries.

> I made that decision as I often did in the past. So what I used to do is... I'm a market guy or I was a market guy back then and I tend to read a lot of different things and try to best guesstimate which way the market would go and I would send out blast emails, you know, just sharing my views on the market with the rest of the population in fixed income and equities. And I wasn't always right, you know? I don't think I ever asked a trader to put on a position because I had strong views. Where at the time I felt that the marked conditions were such that given our increasing risk in the credit products in general, I wanted to be conservative and reduce the spread risk. So that's how it initially started. (F. Transcript, 2017).

Large decisions appear to be concentrated in a select number of company executives, with smaller investment choices executed within semi-formal parameters. As the quotation above highlights and continues for some time in text, much thought was given to the reduction of credit risk prior to the culmination of the subprime collapse. However, decision makers have in some cases only vague recollection of how they came to possess information that formed the basis of their judgement and when it was consciously part of a strategy selection process. As is the case for all other firms identified in the literature review, each firm has the capacity for emergent self-organising behaviour. On the basis of those general conditions, the transmission of information and influence is a necessary instrument through which behaviours and knowledge can coalesce and arise to form an emergent pattern.

The study finds that a reliance on concentrated influence from designated authority for decision-making is a potential source for strategic risk and weakness. While some aspects of group formation and evidence base resemble a Delphi-like technique, they lack structure, facilitation, feedback and the limiting of concentrated authority. On the other hand, internal prediction markets could be stifled by the strict parameters put around the flow of information for strategic plays and major risks.

As discussed earlier in review of literature, at first glance, the presence of antecedent conditions can be seen as counterproductive or divergent within an organisation. The practical implication however, is that in almost all cases these antecedent conditions exist and are as a consequence latent potential. Of the four conditions: disequilibrium, amplifying actions, self-organisation and stabilising feedback; the free transmission of information and its coupling with influence is a primary moderating factor for emergent characteristics within firms. Additionally, emergent behaviours exist and are pervasive, but are not always recognised by senior management.

In light of the findings discussed on this case, Table 4.12 provides further exemplary quotations on various conditions and context arising through analysis of the text, to further elucidate qualitative data for the reader.

Table 4.12 Further Exemplary Quotations on Various Conditions and Context

Conditions and Context	*Exemplary Quotation*
Market supervision and credit ratings	The rating agencies rated things, and the risk people really were looking at lower rated instruments as risk of leverage in LBO's [leveraged buy-out] as risk but really when something was rated Triple A, or Super Senior, they thought that that was okay and they didn't look at that was something which really pervaded the thing.

	Which let them feel too comfortable about an asset class which turned out to be somewhat toxic. And you look also at the financial industry, and you look at the leverage that they had on the balance sheet, there really was no transparency that was visible to regulators or others, as to what was off the balance sheet, and the ease with which financial companies were able to move financial assets off the balance sheet which increased the leverage substantially more than what was reported. I think all those elements contributed to the problem.
Timescales	This was a… This is a pretty odd time period and I think that a lot of people missed the scale of what could happen. In synthetics and CDOs, overall in notional terms were much smaller than in cash terms. And that's because synthetic was, you know, was a market which was a new market.
Interdependency of factors	Corporate credit is highly correlated. Credit correlation is highly correlated to trading of single-name credit default swaps. But yes, I think that they... I mean it's right there in the thing. Much more correlated. Much lower diversity score than a corporate CDO. The real difference in the correlation probably is that the sort of commercial versus consumer difference… they were highly correlated both from a business standpoint and from a revenue standpoint…
Cognition on systemic risks	You know, the ability to identify systemic risk in advance is not very good. I mean forget about the Fed, anybody, because if you could identify it in advance, it then typically doesn't become a systemic risk. So, the whole problem of systemic risk is that there are... You don't see them in advance. But, the risk position's not the same as inventory. Inventory is one number, and another is a measure of risk inherent in that inventory. That's the first thing. But another thing is, this was a, in my mind, it was a danger to the business, so I believed that we were originating and selling what we originated. And we weren't actually even originating, we were buying in the secondary origination point. We were buying from originators, up until we bought First Franklin. But even then, as I recall, most of the mortgages that we packaged with third party originated, the vast majority of them. So we were buying, packaging and reselling it, so inherently there was warehouse risk and there was some lag risk, but it should not have been all that significant. And if the standards for the quality of the papers we were buying were upheld, the risk would have been contained by that as well. That turned out not to be the case, but there was no evidence, no reason for me, day to day, to know that that was true.
Transparency	I think the market is connected, and I think if you were to ask a number of us we would tell you that the biggest and most troubling inner connection, which I know policy makers are thinking about, is how to deal with the derivatives markets. Because, you know, the over the counter derivatives markets are not hugely transparent, there are a number of inner connections which are not as visible to people as I think one would hope. And you look also at the financial industry, and you look at the leverage that they had

	on the balance sheet, there really was no transparency that was visible to regulators or others… Something's off balance like things like SIV's [structured investment vehicle]. They just created more leverage in the system that was not visible to people. And in reality the responsibility for the SIV's came back on the banks, some of the banks' balance sheets. So I would. They also became depositories for mortgages, other things. So I think we know that area just added to the leverage.
Consumer factors	And a lot of them... There was a whole lot of refinancing going on, even refinancing of old equity lines. So you would see, not only the same loan officer again and again, but you would see the same customer refinancing over and over again. And they would keep on until the refinancing was where there was no more equity.
Structure and systems	They structure that in the form of CDOs but they protect themselves in some cases on some of the more challenging tranches by getting CDSs from the marketplace. Those CDSs get provided by market participants who in fact are not held to in market standards... Because they’re not on exchange, you don’t see the margin, you don’t see the quantity. CDOs provided was an ability for investors that needed to buy higher rated securities, to buy like triple-A securities, that would be formed out of a pool of triple-B subprime mortgage securities. And the excess returns that those investors would pay to buy those triple-A securities backed by CDOs or investment grade securities, I’m just using triple-A for this example, became very attractive to those investors. The underlying securities performed quite well during the 2003 to 2005 period, and investors were attracted to the extra returns that they were getting, they were approximately getting 20 to 25 basis points more in spread, than the comparable rated triple-A, RMBS security [residential mortgage-backed security] at that time.
The nature of CDOs	And the objective is not to issue anymore tranches of that, it’s not a fully distributed structure, but it’s more of a trading business in the sense that that single tranche which is issued then is risk managed by the ABS correlation desk. Now the risk management would have lots of technicalities and all that, but even before going into that, that’s how I would kind of look at the two business models, that’s how I would distinguish a CDO business to a correlation business. It was a demand driven, phenomena from the investor's side of CDOs that helped meet the demand from a macro-community that wanted to buy protection on subprime securities, to reflect their views of the housing market. And we stood in between, in the middle of all of that, as a market maker in facilitating those flows. So, in the 2006-time period, we generally were facing... We were selling protection to investors who wanted to express or hedge... Express a negative view on the housing market, also who wanted to hedge their portfolios, whether it was home loans, whether they wanted to play capital structure arbitrage for cash securities they owned, and bought protection on higher parts of the capital structure. But I do think

	the genesis and the ... was not CDO related. The genesis was just the macro economic factors. Or the technical factors affecting the underlying collateral.
Amplification	They could easily have simply standardized and guaranteed mortgages, they don't have to own giant portfolios that they finance at government subsidized rates. So, the GSEs [government sponsored entity] certainly contributed to the problem because they continued to provide mortgages to lower and lower credit quality borrowers, at higher and higher LTVs, and whether they were the purchasers of the securities or not, you know, they were basically fuelling the mortgage market and driving housing prices higher. And similarly the first loss the riskiest layer would maybe only be you know I'll make up a number 50 million but it could be equivalent to 400 million again to make up a number of mark-to-market risk. Again the sum of the parts has to add up to three billion. So the problem is if you hedge your hundred million of tranche protection 300 million of long that would maybe be the correct hedge for assuming your correlation is correct and assuming that the market moves are not large. But if you have a sudden huge shock to the market you'd be long 300 million ultimately you know if everything got wiped out you'd lose $200 million you see the amount.
Risk appetite	That demand drove the demand for more CDOs and there was limited supply of cash securities, triple-B cash securities to create CDOs. So, at that time investors started to become more and more comfortable with purchasing, initially, hybrid CDOs, those were CDOs that were backed by cash and synthetic securities. Ultimately, investors became more comfortable purchasing 100% synthetic CDOs, to meet that demand for assets. All the different subsets of risk management, but generically, it was poor risk management, because they could have done the same thing without going to the derivatives market. If you called it a failure of colossal proportions in risk management and all that that implies, you get to it. So it all implies all the different categories of risk management and the testing of risk management and the supervision of risk management by a competent regulator. And I do not believe that bankers have a good track record at anticipating risk before the fact. And, therefore, all this risk adjustment and so forth and so on, I just think that it's wishful thinking. I learned the hard way that the guys running the business are the last guys in the world who are going to have a reasonable assessment of the risk. We have a full series of risk limits. We have limits for risks in a whole variety of ways. So we will have the, you know, just balance sheet limits is one, they'll have floor limits. We have, back to our credit spread widening that I was talking about, we give all of our desks credit widening limits as well so that's at least three limits that desks would have.

Reputational risk	I think there's a clear view here of everybody from the top, on down throughout the whole organisation, that reputational risk is the most damaging risk that we have to manage. That I think we constantly try to get people to understand that it takes us years to build our reputation and it can be lost over night. That sometimes the best transactions are the transactions that we don't do, all of which are meant to reinforce the importance of reputational risk.
Subjectivity in decision making	And so I… and so the pro-cyclicality of some of the accounting policies and I'm sure you've seen a lot of the stuff about where Spain supposedly has an accounting treatment that allowed less pro-cyclicality, what that really comes down to thought is you… The management judgement where you say I'm really nervous about the credit environment, so I'm going to build my reserves a little bit, the flip side of that is people worry that. You are in fact using… Having too much management discretion, so they want it more mathematically.

Source: (F. Transcript, 2017).

4.3.10 Summary of Findings

A number of key findings are made through the analysis undertaken in this study that shed light on the structure and operation of complex financial markets. The study finds that a number of challenging capabilities would need to be in place in order to avoid such a crisis occurring again in future, should similar conditions present themselves. In the main, the crisis ensued after a period of significant growth in risky lending and investment practices, and the interplay of a range of corporate governance, accountability, policy, ethical, and macro-economic factors. Key learnings in relation to these prevailing conditions, patterns of behaviour and mechanics that reached a tipping point have been observed and reported in detail. The domain of complexity is well equipped to explore the terrain of systemic risk – with a focus on emergent pattern and multi-layered analysis. Findings shed further light on the condition and emergence of risk culture in complex systems; the practical treatment of aggregated products; the link between product complexity and market volatility; red flags; autonomy; downward causation; information imperfection; and the role of information and groups.

Analysis of qualitative data has been extremely fruitful in delivering many insights on the Subprime Mortgage Crisis – and, ensuing risk contagion. From this study it is clear the application of complexity principles and a theory of emergence is a practical and novel lens to view events of such magnitude, of importance to both the economy and society. The context of crisis gives a new dimension to literature on emergence, in addition to avenues for further exploration and confirmations on earlier literature.

Detailed observations are made in earlier sections, which also include an explanation of key findings in text. These are supported by direct quotations and in some cases quantitative explanatory data on the structure and operation of complex products and markets. The wealth of insights available through qualitative data are not limited to the findings below, hence, suggestions for further research are included in the discussion chapter. Findings provide confirmation that the principles and dynamics that underlie a theory of emergence apply well to this case. Note: the numbering of findings continues from the list at Case One.

Finding 7: *Risk culture is an emergent system and conditioned property that shapes behaviour, and is contingent on information transfer.*

Risk culture is an emergent system of beliefs, codes and shared norms; and, a conditioned property housed within the broader frame of corporate culture, influenced significantly by leadership and management. Risk is critical to the continued viability of each firm. Informants share the view that fluidity of information transfer is essential to forming a strong risk culture. However, each firm also confirms the existence of many limits on the sharing of information, particularly for major strategic plays and the development of bespoke or complex, structured products. Without the adequate transfer of knowledge and information, the emergence of a unified risk culture would be unlikely, and rather exist as a patchwork. It is also likely those operating within information / strategy 'groups' would have a different view of risk, based on their own experience, access to the strategic apex and the nature of each major play being executed.

Finding 8: *The treatment of emergents (pattern, aggregated products or strategies) as distinct or whole entities can exacerbate exposure to underlying risks.*

The study confirms financial markets are deterministic [non-random] and employ the extensive use of knowledge; there is a high level of sensitivity to initial conditions where the variable of timing is of major significance; products and markets are subject to amplification of small change. What is more likely than a total lack of foresight on the inherent risks of default on underlying securities is the intersection of three explanatory factors: (a) a lack of visibility on correlated and underlying risks due to the treatment of investment bundles as an entity in itself, rather than a vehicle that transmits the content of underlying components; (b) this is combined with a lack of detailed understanding among investors of complex, structured products; and, (c) an underestimation of risk velocity, a reliance on market efficiency and uncertainty of timing.

Finding 9: *The more aggregated products are used, the more volatility should be expected in markets.*

A further macro-level observation is that the more amplification products are used, the more volatility should be expected in markets. Using the earlier theorem that structured products are a ‘propagating mechanism’ used to transmit and ‘infinitely multiply’ (F. Transcript, 2017), the changed characteristic of these components would then give rise to changed patterns on the market overall. Further research to use historical data to model specific patterns that could be used to forewarn or sharply predict an arising pattern, would be of practical value and use. This finding is combined with effects of downward causation.

Finding 10: *Risk velocity and the erosion of strategic choice can be used as early warning signs.*

The stacking of synthetic and structured products comprised of underlying mortgage-backed securities takes the original value of the underlying securities and amplifies it. Potential losses and gains are amplified with the use of structured products – the same products are also vehicles for the transmission of risk and in times of crisis, risk contagion in the form of the widespread erosion of confidence. The study suggests a practical mechanism to apply is a measure of risk velocity against the potential erosion of strategic choices that would come about due to fluctuations in price or exposure to underlying risks.

Finding 11: *Emergents are autonomous from their substrate, sustainable beyond a single component, but within a threshold state.*

Emergent systems, structures and patterns of behaviour are autonomous from their substrate, and sustainable beyond a single component. In themselves, they are an emergent product of underlying behaviours. Furthermore, in addition to indicating autonomy of emergent phenomena, findings also confirm that emergent phenomena are error prone. Contrary to fitness landscapes and axiomatic assumptions, emergent phenomena suffer the same imperfections as their underlying components, or worse – their exacerbation.

Finding 12: *Financial markets are a practical demonstration of the 'problem' of downward causation.*

This study finds the actors that comprise the emergent are deeply conscious of the arising pattern, and in effect, this casts significant downward causation via salience and the probability of influence. Causation is a factor within and down an emergent structure, particularly where there are high levels of correlation. Culture for instance, is a potent source for downward causation, having an effect on the behaviour and characteristic of its emergent base. This finding has several elements, which then require a determination to be made on what the emergent layer is and the components by which it is comprised. Other matters to be discussed are the potential for downward causation to amplify volatility and the potency of reinforcing feedback.

Finding 13: *Autonomy does not ameliorate the emergent from imperfections of the substrate.*

Findings also confirm that emergent phenomena are error prone, to the sum of their underlying constituents. Contrary to fitness landscapes and axiomatic assumptions, emergent phenomena suffer the same imperfections as their underlying components, or their potential exacerbation. Emergent layers can exhibit significant imperfections – as an aggregation of the ill health of those components of which they are constituted. The ill health of a component is not entirely rebalanced by the good health of others. Autonomy does not ameliorate the emergent from the imperfections of its substrate, and in some cases can give a false reading if the health of the emergent is considered autonomous from a toxic substrate, especially where components are sensitive to amplification. A further matter of discussion is the nature of markets as entropic systems, with low energy demands to transmit information (efficiency), hence their accuracy is tightly coupled to collective intelligence. Finding 13 is related to Finding 11, as amelioration follows the observation / application of emergent autonomy.

Finding 14: *Restrained information transfer isolates emergent forms and is a potential source for strategic risk.*

The study finds that a reliance on concentrated influence from designated authority for decision-making is a potential source for strategic risk and weakness. Internal predictive capabilities are stifled by the strict parameters put around the flow of information for strategic plays and major risks. The free transmission of information appears to be the main inhibitor of emergent characteristics within firms.

Table 4.13 provides a complete list of the themes, actions/behaviours and findings from the study, in summary format, to assist the reader to link themes, actions/behaviours and results.

Table 4.13 Summary of Themes, Actions/Behaviours and Findings

Themes	*Actions / behaviours*	*Findings*
Emergent risk culture	• Risk culture is an espoused system of beliefs, codes and shared norms, emerging through a community of practitioners	7. Risk culture is an emergent system and conditioned property that shapes behaviour, and is contingent on information transfer

	• Corporate culture is conditioned by leadership and management, balancing risk with company objectives • Multiple perspectives on risk exist in parallel, attributed in part to involvement in and access to information groups	
	• Emergent patterns and collections of products when treated as whole entities suffer three main issues: lack of transparency, comprehensive understanding, and the uncertain velocity and timing of underlying risks	8. The treatment of emergents (pattern, aggregated products or strategies) as distinct or whole entities can exacerbate exposure to underlying risks
The art of prediction and value of knowledge	• Complex structured financial products can be used as a 'propagating mechanism' to transmit and 'infinitely multiply' gains and losses	9. The more structured amplification products are used, the more volatility should be expected in markets
Amplification, interconnectedness and contagion	• The changed characteristic of amplifying and highly correlated components give rise to changed patterns for the market overall	10. Risk velocity and the erosion of strategic choice can be used as early warning signs
Autonomy of pattern and downward causation	• Emergent systems, structures and patterns of behaviours are sustainable beyond individual components	11. Emergents are autonomous from their substrate, sustainable beyond a single component, but within a threshold state
	• Causation is a factor within and down an emergent structure, where high levels of correlation exist	12. Financial markets are a practical demonstration of the 'problem' of downward causation
	• The pervasive use of high risk products and their spread, with reinforced behaviours using market knowledge creates downward causation	
	• Emergent phenomena are error prone, to the sum of their underlying constituents	13. Autonomy does not ameliorate the emergent from imperfections of the substrate

Information and people in groups	• Reliance on concentrated influence from designated authority for decision-making is a source for strategic risk and weakness, when information flow is restricted • Information limits and the use of temporal groups to develop and execute strategic plays and major deals	14. Restrained information transfer isolates emergent forms and is a potential source for strategic risk

4.3.11 Concluding Remarks

This case exists in its natural setting and is a study of actual events. Hence, the case is rich with context, meaning and information that relate directly and indirectly to the questions at hand. Qualitative data has revealed a range of matters relevant from a pragmatic standpoint and to theory building in the social sciences. It is noted however, results are not generalisable to all organisations or at all times. To assist in placing parameters around analytic generalisability, substantial attention is given to describe situational factors, environmental conditions and the structure and operation of markets in the lead up to and during events under study. Similar conditions exist today and prevail, making the generalisation of results widely relevant and useful. Threshold state criteria are applied, which may also be of use in future studies or for the purpose of generalisability.

Furthermore, in reviewing a very large quantum of data, several observations were made on matters that relate to the conclusions of the Commission of Inquiry, which it is felt are worthy of mention at least in summary.

Despite amassing an extremely rich source of data, there are several shortcomings of the Commission’s report, including: uneven weight on third-party sources; a lack of multilateral discourse; limited qualitative depth in narrative analysis; knowledge asymmetry; and a limited focus on risk culture and ethics. To contextualise, the following is a key passage reproduced from the FCIC report.

> Despite the expressed view of many on Wall Street and in Washington that the crisis could not have been foreseen or avoided, there were warning signs. The tragedy was

> that they were ignored or discounted. There was an explosion in risky subprime lending and securitisation, an unsustainable rise in housing prices, widespread re- ports of egregious and predatory lending practices, dramatic increases in household mortgage debt, and exponential growth in financial firms' trading activities, unregulated derivatives, and short-term 'repo' lending markets, among many other red flags. Yet there was pervasive permissiveness; little meaningful action was taken to quell the threats in a timely manner. (FCIC, 2011).

In light of the qualitative analysis undertaken in this study, the following observations are noted with regard to the FCIC reports and dissenting statements:

- Access to industry leaders and representatives is without parallel and in itself a major success of the inquiry. Qualitative data is deserved of multiple turns of analysis.

However;

- Significant gravitas is placed in third-party expertise, yet are not recursively tested with practitioner counterparties. Combined with this, the report omits multilateral discourse encompassing alternate and competing views.

- The Commission itself sought principally to engage with 'captains of industry' rather than a deep cross section of key players throughout the sector. To that end, it is also unclear if or how the Commission weighted qualitative input from informants with particular insight and knowledge, or if all information was considered of equal measure.

- The work of the Commission initially appears clouded by a relatively narrow objective to find stand-alone factors of universal truth. Two dissenting statements were issued by half of the ten member Commission, both of which are published in the FCIC report, suggesting causal factors are a matter of perspective and to a certain extent, subjective.

- The Commission is comprised largely of experts in law, investment fraud, regulatory compliance – rather than including a panel of market practitioners, for example the panel of engineers used in the QFCI. It is evident in transcripts that operators have a different perspective and insight on the operation of the market, risk management practice and how money is made (and lost). This also transpires as an asymmetry in knowledge, exposing the Commission to the risk of subjectively inferred causations; this is demonstrated in several instances where deeper investigation is stymied by the lack of an equivalently commanding knowledge of markets.

- While a 'systemic breakdown in accountability and ethics…' is referred to as a primary cause of the crisis, transcripts under examination in this study are largely absent of any meaningful discussion on ethics. In all 43 interviews examined here, only one question is raised regarding ethics, concerning the existence of a 'national ethics line' at Wells Fargo. How the Commission arrived at the conclusion there was a complete erosion of ethics, but provide no examination of corporate culture remains unexplained.

- The dimension of risk culture within a frame of corporate governance is absent from the Commission's report. The original report takes a view that 'widespread failures in financial regulation and supervision proved devastating', whereas the dissenting view of Hennessey et al. (2011) is in stark contrast.

> No regulator could force these firms to strengthen their capital or liquidity buffers. There was agreement among Commissioners that this was a contributing factor to the failure of these firms. The Commission split, however, on whether the relatively weaker regulation of investment banks was an essential cause of the crisis.
> Institutional structure and differential regulation of various types of financial institutions were less important in causing the crisis than common factors that spanned different firm structures and regulatory regimes. Investment banks failed in the United States, and so did many commercial banks, large and small, despite a stronger regulatory and supervisory regime. (Hennessey et al., 2011).

Neither the dissenting statement or original report address the dimension of corporate culture which is both a reflection of organisational ethos, and a known characteristic of good corporate governance (ASX, 2014). The Australian case of HIH Insurance is used to illustrate: HIH was considered the largest corporate collapse in Australia's history, with liquidators estimating that HIH's losses totalled up to $5.3 billion (‘chump change’ in the context of any of the seven firms in this case). These are the judgements of the presiding Hon Justice Owen, which underscored Australia’s CLERP9 Reform:

> There was a clear causal link between poor corporate governance and mismanagement. Viewed in this light, corporate governance is much more than compliance with an arid set of guidelines just for the sake of appearing to comply ... I am not so much concerned with the content of a corporate governance model as with the culture of the organisation to which it attaches. For me, the key to good corporate governance lies in substance, not form. (Owen, 2003).

- On a technical matter, the Commission gives only limited attention to the systemic properties of risk amplification. It would be instructive from a policy and regulatory standpoint to quantitatively understand the impact of complex, aggregate products when their use expands rapidly and is pervasive beyond a certain threshold. Also, the spread and use of market practices that aggravate volatility. While the fundamental structure and use of multiplication (of gains, losses and risk) is explained, the systemic link to the crisis is not examined in detail.

- The Commission lacks a focus on the creation of new products and complex structures that few understand, including investors. How these products come about and the issues that are caused when transparency is constrained by a lack of technical knowledge. Informants to the Commission appeared indifferent to the lack of understanding among both investors and clients on complex investment products. The proper functioning of the market is in jeopardy if large and small investors do not understand what they are purchasing and the underlying risks. In particular, if these products are not well understood by ratings agencies, the problem is exacerbated.

- Interviews are a rich and unique source of data, deserving of multiple turns of analysis. Returning to the matter of unprecedented access to industry leaders, there is a sense that while the interviews are a rich source of information, extended and open-ended, the chance to ask more qualitative and probing questions is an opportunity lost.

- Finally, while this study is immensely grateful for the release of qualitative data by Stanford University, it is surprising the length of time it has taken to produce. The Commission delivered its final report in January 2011, six years elapsing before its release. Furthermore, the Commission did not produce all interviews in transcript, rather as audio files – which have been transcribed under this study. Without any disclosure on the analysis methodology, it is unclear how the Commission conducted a systematic examination of such breadth of data – overall, more than 700 hours of interview tape. Further information on the Commission's methodology in this regard may be instructive for future researchers.

4.4 Cross-Case Synthesis and Summary of Findings

In total, 14 findings are observed through analysis of two case studies within the scope of this research. Each of the 14 findings has been reviewed in light of the situational factors, threshold state criteria and conditions of its parallel case, summarised at table 4.13. Each case presents a unique real world setting with observations embedded within the described environmental conditions. Cross-case synthesis confirms generalisability for most findings across cases – provided the situational factors and threshold states are considered. This is not to suggest decision making, culture factors or organisational behaviours are identical, rather that the patterning of behaviour and conceptual modelling shares many similar characteristics at common levels of analysis. This is compelling evidence of the existence of general propositions that can be broadly applied.

4.4.1 Cross-Case Synthesis

Results of each case have been triangulated and examined in detail according to all observations and main findings, as highlighted in the previous section. Behind these results are also a number of parallels at a conceptual and thematic level. Table 4.14 illustrates concepts and weights shared across both cases. Despite the two cases being of a significantly different origin, both share a number of parallels. The concepts of: *time, people, look (observing, salience)* and *information* are all of significant weight.

The triangulation of concepts and the clusters derived of them demonstrates a consistency in the root causes and meaning in arriving at a consensus on the manner in which decisions were made and actions taken for each case. It is noted that each case has its own setting, hence the concepts at Table 4.14 are explored within their own context rather than only on an aggregated basis. These concepts underpin findings and cross case generalisability. The table demonstrates the relevance / weight of each concept as it apples to each case. With the exception of *information,* most other concepts fall into a similar order in their relative weight for each case. Case one has a significantly higher weight placed on information, second only to *time.* The relationship between *time* and *people* is evidence in both cases.

Table 4.14 Triangulation of Parallel Concepts

Case One (Floods) *Relevance / Weight*	*Concept name*	*Case Two (Subprime)* *Relevance / Weight*
29.1%	time	27.3%
14.5%	people	19.9%
14.1%	look	11.4%
8.3%	probably	8.1%
7.7%	tell	7.8%
-	looking	7.4%

7.3%	talking	7.2%
-	talk	6.1%
18.9%	information	4.9%

Notes: concepts are discussed and explained within each case analysis.

4.4.2 Summary of Findings and Analytic Generalisability

The generalisability of findings is limited to human social systems in similar conditions to those under study. Therein, findings 1, 3, 4 and 6 (case one) are generalisable to case two and have only ‘general’ limits on their broader application, see Table 4.15 and accompanying definitions. It has been found that situational factors and the nature of phenomena place few limits on the application of these findings to a variety of organisations. The emergence of strategy and simple rules occurs despite the existence of plans and explicit instruction, in tacit or codified form. Positive, reinforcing feedback and rapid, non-linear escalation are known factors in prior literature and are confirmed here in a real world setting. Findings 2 and 5 are considered ‘situational’, and are contingent on specific situational factors and context present in the case under study. For instance: small decisions are generalisable to case two, but may be contingent on levels of agent interaction and threshold states during the erosion of strategic choices; in this way Finding 10 and Finding 2 are closely related, a practical use of which may be instructive for industry application in both settings.

Findings 8 and 9 (case two) are seen as only partially generalisable to case one, related to the definition and nature of the phenomena under observation – hence they are generalisable only at the level of the ‘phenomena’ (see Table 4.15). While Finding 8 is conceptually linked to Findings 1, 2, 3 and 6, the treatment of ‘emergents’ or aggregated products as distinct entities is more pronounced and widespread in case two. The equivalent strategy choices of case one are an emergent pattern, but are characteristically different to an aggregated product or strategy with multiple system layers in financial markets. In case two, a focus on aggregated strategy exacerbated risk, in case one a choice-by-choice approach magnified risk. What is missing in both cases is a clear and simultaneous view of both the substrate and the emergent form.

Finding 9 is relatively specific to financial markets or other industries that have the flexibility to create complex, structured products that are free from physical constraints and give rise to the benefits and risks of amplification – hence, the generalisability of the finding is contingent on the nature of the phenomena.

Autonomy, downward causation and amelioration (Findings 11, 12 and 13) are conceptual matters that will be discussed in more detail during the next chapter. Finding 12 is contingent on levels of potential salience and cognition within nested systems and therefore depends on the nature of the phenomena. Findings 11 and 13 deal with significant theoretical matters that have been observed in this study, within a pragmatic frame for use in future research or practice. The 'problems' of autonomy and downward causation are conceptual issues within the theory of emergence and complexity that have limited confirmation and refinement in real world case studies of human social systems. The first of these (Finding 11) applies threshold state criteria to parameterise and define the boundary point of autonomy from a substrate. The latter (Finding 13), also observes a significant matter that is rarely addressed in the downside of complex systems, which is: can emergent patterns be trusted? This finding is also found to amplify volatility, due to the nature of reinforcing feedback, also a matter to be further discussed at Chapter 5. The summary of findings and analytic generalisability limits are detailed at Table 4.15, and followed by discussion on the limitations of this study.

Table 4.15 Summary of Findings and Analytic Generalisability

	Findings	*Generalisable to Case One (Floods)*	*Generalisable to Case Two (Subprime)*	*Analytic Generalisability Limits*
Case One	1. The existence of plans does not eliminate the potential for emergent strategy	-	Yes	General
	2. Small decisions early on in crisis have magnifying ramifications and irreversibility	-	Yes	Situational
	3. New (simple) rules emerge in the absence of explicit instruction	-	Yes	General
	4. The presence of positive feedback improves the functioning of emergent strategy	-	Yes	General

	5. Emergent strategy may be risk averse, structural inertia intensifies risk	-	Yes	Situational
	6. The escalation of crisis may rapid, non-linear and exponential	-	Yes	General
	7. Risk culture is an emergent system and conditioned property that shapes behaviour, and is contingent on information transfer	Yes	-	Situational
	8. The treatment of emergents (pattern, aggregated products or strategies) as distinct or whole entities can exacerbate exposure to underlying risks	Partial	-	Phenomena
	9. The more structured amplification products are used, the more volatility should be expected in markets	Partial	-	Phenomena
	10. Risk velocity and the erosion of strategic choice can be used as early warning signs	Yes	-	Situational
	11. Emergents are autonomous from their substrate, sustainable beyond a single component, but within a threshold state	Yes	-	General
	12. Financial markets are a practical demonstration of the 'problem' of downward causation	Yes	-	Phenomena
	13. Autonomy does not ameliorate the emergent from imperfections of the substrate	Yes	-	General
Case Two	14. Restrained information transfer isolates emergent forms and is a potential source for strategic risk	Yes	-	General

Notes: the table lists generalisability limits according to the following definitions: '*phenomena*' = application of the finding is limited to the phenomena and is not generalisable; '*situational*' = contingent on specific situational factors and context present in the case under study; '*general*' = the finding is broadly generalisable, within threshold state criteria.

4.5 Limitations

The findings in this study are not without limitations. Both cases present significantly complex situational factors and conditions that are attached to a real world setting. Given the study is outside the laboratory setting, factors cannot simply be removed or conditions synthesised and administered. Threshold state criteria are used to explain the external conditions and draw reference between each case, in addition to identifying the antecedent sequences of emergence: far from equilibrium state; sensitivity to initial conditions; amplification of small change and emergent self-organisation. Due to the dynamic complexity of each case, multiple perspectives may exist on causal factors, macro-economic or environmental probabilities and the cognitive states of decision making in light of moderating factors. The researcher is objectively placed outside the phenomena under study, hence does not have the direct experience of working within each firm. Although informants are transparent, they are also reluctant to discuss matters they consider trade secrets. The aggregation of more than 3.2 million words of qualitative data and 47 interviews, and the use of several validation and analysis tools is substantial to alleviate these issues, combined with diversity in the informant group, and on the balance of converging narrative (K. Eisenhardt, 1989). Points of difference are noted throughout.

In both cases, methods were used to target research on the core narrative in direct relevance to matters of interest. As discussed, case one (floods) is a single firm study, focusing on interviews with employees on duty immediately prior, during and after the crisis – these are primarily senior engineers of Seqwater. Case two (subprime) is a multi-firm study, and using the TARP CPP model identifies seven firms: Bank of America, Merrill Lynch, Citigroup, Goldman Sachs, JP Morgan Chase, Wells Fargo and Morgan Stanley. While these seven firms represent the vast majority of net value under the TARP and key players, it is noted they do not represent the entire market. As noted earlier, with literature clearly lacking in application and refinement, it has been of significant empirical value to take a nascent theory of emergent forward into the real world of practice. Further developments, tied to a recursive process of testing and refinement would be of great benefit to further research. This and an interpretation of findings are discussed in detail in the following chapter.

5 Discussion

This chapter aims to critically examine research findings in the context of current literature, what can be understood from findings as they apply to theory and practice, and challenges and opportunities relevant for further research. Conceptual models, research implications, and an evaluation of the research process are discussed. Reviews of literature, collection of data, analysis and findings have provided many empirical insights into case studies examined as part of this research project. While the discussion below provides a deep exploration of the results, many avenues for further research remain, including through the reuse of data and analysis.

5.1 Explanation of Results

The aim of this study is to explore how complex organisations adapt through emergent self-organisation, with a focus on the role of influence between agents. As outlined in detail at Chapter 3 (Methodology), an interview-driven, multiple-case study approach has been taken, yielding a rich analysis of how emergent self-organisation occurs in a real world human social context, and its relationship to organisational adaptability.

For this purpose, there are two primary research questions in scope, concerning: (1) the *function*, and (2) the *process* of emergence in human social systems, within the context of complex organisations:

1. What role does emergent self-organisation play in adapting to new or acute internal/external pressures?

2. How do (emergent) patterns of behaviour coalesce in complex organisational systems, can a conceptual model for the theory of emergence be applied to this process?

Both questions are revisited in light of the findings of the study. Question (2) is discussed in detail at the following section via the application of conceptual modelling techniques.

5.1.1 Understanding the Function of Emergence

This section discusses five important questions that describe the function of emergent self-organisation in complex organisations. Firstly, the role of emergence in adapting to acute pressures; the potential for making reliable observations and predictions on emergent patterns; the nature of emergent forms as informed by literature and findings; and finally, comments on the universal features of emergent patterns in complex organisations that are supported by findings and propositions of this study.

What role does emergent self-organisation play in adapting to new or acute internal/external pressures?

Both the review of literature and findings of this study indicate emergent self-organisation is a potent force at play in human organisations, markets and economies. The potential for emergence is at its most acute during times of turbulence, disequilibrium, uncertainty and where the necessary ingredients are present that underlie the mechanics of an emergent process. Whether adopted as a strategy, cultural practice or organisational ethos – the potential for emergence exists, regardless of management directive. As found in the transmission of influence and information, conditioning can be used to temper the character of an emergent outcome, however, it is not essential to generate system level behaviour. Keeping in mind while emergent potential is pervasive, those behaviours may not be in line with deliberate plans or authorised strategies.

While the existence of emergence within and between organisations is observed, there are many limitations in literature to properly define emergence from a process and systems perspective. The literature review has identified and explained 41 of these key limitations, the resolution of which are well beyond a single study. Findings of this research contribute to addressing many of these limitations, and in doing so identify specific areas that would benefit from further research.
It is found that many of the limitations are either methodologically or ontologically related, in part stemming from a lack of clear principles and definitions upon which a theory can use as its foundation. Without a solid base, the advancement of a theory of emergence is significantly hampered. This study finds that a pragmatic application of theory to real world cases provides rich and useful insights into the refinement and maturity of theory, using information and data that is enriched by its real world application. Both the application of a complexity lens and the use of pragmatic, case study driven data collection have provided a rich source of information to advance the body of knowledge toward a theory of emergence. Therein, the domain of complexity is well equipped to deal in matters of systemic risk, disequilibrium and uncertainty.

Can emergent self-organisation be reliably observed?

Literature review and findings support the notion that emergent self-organisation can be reliably observed, within acceptable limitations. A large number of conceptual, theoretical, simulation and case study approaches are cited throughout this research, providing a wealth of knowledge on the systems and processes of emergence in its various forms. What is lacking from several of these studies however, is a conceptual bridge that joins the common attributes of a theory of emergence to form general principles. Despite the obvious difference between human social systems and those of the natural sciences, there is not a general classification system that frames the application of complexity principles and puts the endless variety of systems and components on a spectrum of predictability. What is needed to support further research in applied social science research is a handbook to guide study in the area of complexity theory and emergence. Such a tool may provide working definitions that bring research closer to a general classification. The consistent use of terms, concepts and definitions would be of great value in supporting the reliable observation of emergent behaviours in a research and real world application.

Are emergents predictable?

Predictability is a question of central importance to the practical application of a theory of emergence in human social systems, as demonstrated through both cases under study. Despite complex systems being defined by their nature of unpredictability, if one can understand systems and processes deeply enough to make sharp predictions – what impact does this have in practice and does this fact redefine the meaning of complexity? In this study, both Case One (Floods) and Case Two (Subprime) place a material value on the art of prediction for the purposes of risk management and resource mobilisation. Particularly in case two, the ability to predict systemic outcomes is be of almost unlimited financial value. In both cases, it is found that restricted information transfer hampers adaptability and the capacity for human agents to 'see' system level cues.

Neither case provides evidence that sharp predictions can be made on specific system level outcomes. However, cases do present many practical applications that indicate emergent processes are at work and the ramifications of complexity dynamics – such as amplification.

Case Two suggests there are pockets of intuition where those with finely attuned antenna coalesce around the detection of emerging patterns. However, sharp predictions are cautionary as they may be a product of luck or retrospective bias – generalisations on the reliability of human precognition on a matter of such complexity is fraught with danger. Furthermore, while training sharp predictions on actual outcomes appear to be remotely achievable, there are several process observations that predictably amplify results, and where the conditions for emergent pattern are probable. This also extends to recursive decision cycles and downward causation.

Findings within the context of this study reaffirm the Darkness Principle and Law of Requisite Variety with two subtle distinctions. Firstly, uncertainty is found to be on a spectrum of probability, not an on/off model. With sufficient information input and powers of observation over emergent layers, it is possible to progressively eliminate unlikely eventualities; therein a by-product of irreversibility (and the erosion of choice) is a narrowing of potential outcomes, and a warning signal for systemic failure or risk. As time elapses, choices erode and small decisions amplify, new systemic order (or disorder) moves from being possible to imminent – unless corrective action is taken. Beyond a certain threshold, corrective action becomes futile. Second, multi-layer system cognition is a weak link of sharp prediction. But, is constrained by the same laws as those cited within the Law of Requisite Variety – to exhaustively understand and therefore enable predictability over the whole system, multiple system layers must be simultaneously comprehensible.

An additional observation within the review of literature is the application of Chaos Theory to human systems in the form of dynamical social psychology (Nowak & Vallacher, 1998). What is known from the Poincare (1892) 'fortuitous phenomenon' is the radical alteration of trajectories caused by a sensitivity to initial conditions and amplification of small change. Chaotic systems are non-random (deterministic) as each iteration abides by shared rules (Simon, 2008). The isomorphism of an attractor model in phase space could be applied to human social systems, using influence as an attractor – an emergent property of a chaotic non-linear system. The research of Vallacher and Nowak (2008) attach a fixed point to this attractor – a human agent, thereby exerting the force of influence over system behaviour and generating predictability.

The findings of this study challenge Vallacher and Nowak (2008) in asserting that influence (irrespective of the actor/s to which it is attached) is an emergent property of a human social system. The effect of influence may be considered an attractor in a chaotic system; however, influence is diffused and not 'owned' by any individual as it occurs as a relational event that equally requires followership in proportion to the exertion of influence. The reader may wish to return to Chapter 2.4 (Influence Processes), Chapter 2.6 (Limitations of Existing Literature) and Chapter 4.3.9 (Case Two: Thematic Analysis) for explanations on the nature of influence as it applies in this study. Furthermore, an attractor is generally an emergent property in abstract space, whereas an individual actor is not, therefore the attractor is autonomous from the components of which it is comprised. In other words, human beings (as physical entities) do not form as a result of the complex processes of an organisation.

Behaviours, interactions and in particular – influence, are not the equivalent of turning gas knobs on the stove. They require the interaction of two or more parties and [on a larger scale] are a product of, and constituent part of system dynamics. While an attractor model has some analytical use to apply a mathematical lens to human influence, it requires a transactional understanding of human interaction and is therefore limited in its practical application.

What does the literature tell us about the nature of emergent-self organisation in the context of the modern firm?

The comprehensive review of literature delivered through this study has revealed much about the nature of emergent self-organisation and its practical application. Building on the conceptual foundations for the study of complex systems, considerations from literature are grouped into three main parts: (a) the organisation and behaviour of whole systems; (b) the functioning and properties of the parts; and (c) the anchor-point phenomenon of emergent self-organisation. Greater understanding of emergent self-organisation in human social systems and in organisations has yielded significant insights in both cases under study.

Contributions to the body of knowledge are a small part of the superstructure that underpins a more comprehensive understanding and making sense of perpetual novelty, longevity and flourishing of societies, cultures and economies. As addressed throughout the review of literature, human social systems are not the equivalent of electrons or chemicals, a source for much ongoing critique and limitation on the generalisation of results across fields and disciplines. Current literature does not redefine the principles of complexity into the field of social science research, rather adopts a practice of interdisciplinary borrowing using a direct *theory-phenomena* link, referred to here as the ‘organisation-science problem’, to be discussed at Section 4.2. This issue is a root cause for many of the 41 limitations referred to earlier.

Despite the ideas of emergent self-organisation having long been associated with human social systems, either intentionally or not, mechanisms for the creation of order remain principally derived of the chemistry lab. There currently exists no universal process or general theory for emergence in complex human social systems. Such an outcome would be a field-defining endeavour, to which this study contributes, but which is well beyond any single piece of research. As stated previously, without such a definitive general process and definitions, there is little reason to believe a theory of emergence exists, beyond the constructs and ideas that are proposed and applied for individual systems or individual cases. In light of findings in this study, a model-centred approach and several conceptual models are applied at the following section. Furthermore, a comprehensive research agenda is proposed to better understand the theoretical space occupied by current theories and what remains necessary to operationalise, apply, confirm/disconfirm and refine. It is the assessment of this study that a theory of emergence is in a state of transition – from conceptualisation to application and refinement, thus it is in a nascent stage of development and is not yet confirmed. Therefore, a general theory of emergence does not yet exist. The rich and diverse origins of complexity resemble a tapestry of ideas that weave a number of common properties into a general understanding of the process of self-organisation, these are: sensitivity to initial conditions, amplification of small change, reinforcing feedback, disequilibrium, and information (or energy) transfer.

What universal features, if any, identify the pattern of emergence in complex organisations?

A general theory for emergence would perhaps be the greatest achievement for complexity sciences this century. While the principles and foundations continue to gain traction and spread in their application to an ever-widening variety of settings, it is the social sciences where these foundations are often the most subtle and challenging. Both cases in this study find similar properties in the arising patterns of emergence that bring about novel results. For instance: (a) a threshold state at significant disequilibrium, (b) the amplification of small change in cascading decisions for managing infrastructure in crisis, and the tools for amplification used in financial markets; (c) the role of reinforcing feedback that generates small decision cycles which later comprise a larger system risk; (d) sensitivity to initial conditions and the cultures that act as a precursor to behavioural dynamics and the psychological dimensions of structural inertia; and (e) the causal relationships within, across and down each complex system and the impact this has on system level behaviours.

The five consistencies identified above and in the previous cross-case synthesis agree with earlier literature which identify the sequences of emergence: disequilibrium, sensitivity to initial conditions, amplification of small change, reinforcing feedback and emergent self-organisation. However, there are additional confirmations that provide a more contextualised application of Kauffman's (1993) 'ingredients' for emergent self-organisation, each are discussed as follows.

Agents with schemata – to – *informed participation:* Anderson's (1999) elaboration on the Kauffman (1993) approach to apply 'simple rules' to complex systems that parameterise agent behaviours required significant reconceptualisation for the social sciences. Human agents are distinct from chemical agents in their normative capacity for free choice. Rather than an arid set of laws or operating principles, schemata are a malleable set of rules applied by those individuals enacting them. However, it has long been a principle of self-organising systems that these rules emerge 'automatically, from the division of labour' (Durkheim, 1997). Therefore, if the rules are emergent and hence tied to the system in which agents are participating – both are inseparable. Findings in this study demonstrate the difficulty in locating simple rules, as they are often not consciously applied (e.g. case one unconscious strategy choice). In the two cases explored, rules are far from simple, but are a complex of ideas, norms, formal rules, plans, strategies and ad hoc opportunities. With this in mind, agents require no rules or schemata above those that naturally occur; they simply *participate* by using information about the behaviours of others within or around the system. Schemata emerge; are often followed, sometimes not, are redefined or redeveloped, and regardless – patterns emerge. For this reason, a pragmatic focus in both research and practice is of significant value in identifying simple rules, emerging patterns and sources for amplification.

Heterogeneity – to – *freedom of choice:* heterogeneity is often considered a prerequisite for the creation of emergent order, based on the thinking of Kauffman (1993) and Marion (1999). Heterogeneity may be required in a chemical system to generate the dynamic interactions that give rise to a complex adaptive system. However, human agents are a qualitatively different entity. The decision making of human agents are simultaneously heterogeneous and homogenous, depending on influencing factors, context, culture and the heat of the moment.

Furthermore, human agents possess an unparalleled faculty of decision making which occasions a view to system level behaviour, thereby enhancing the potential for downward causation through self-consciousness. Findings of this study suggest potential heterogeneity is an inherent predisposition of any two human agents and is therefore not a unique attribute of any human social system. Despite some networks being considered more heterogeneous than others, both are capable of emergent order, provided they are imbued with *freedom of choice* over their decisions and actions. Where greater levels of apparent heterogeneity do exist, the simpler solution is then to apply the propositions of *autonomy* and *amelioration,* which are discussed shortly.

Motive to connect – to – *interrelatedness:* earlier literature argues that complex human systems are generally comprised of numerous autonomous agents with motive to connect, sensitivity to feedback, and malleable schemata (Stacey, 1995). The two points above have provided an alternative view on schemata and heterogeneity. The final point regards motive to connect. Motivation to engage with other agents is a unique characteristic of human systems that is partially derived of the dissipative structures theory and attractors model for complexity. Findings of this study support the proposition that a focus on motive to connect is conditional on situational factors, culture and context, which are neither static nor readily generalisable. Beyond motive to connect is the dependency on system and agent interrelatedness. Regardless of motive, if the actions of an individual are interrelated to others and salient, those behaviours are sufficient for emergent order. Motive and motivation are intrinsic dynamics that form part of the character of agents and agent interaction, which then constitute systemic properties. Motive can emerge during system disequilibrium, in which case it is interdependency between agents that is the 'real' ingredient.

5.1.2 Understanding the Process of Emergence

This section aims to discuss research questions that describe the *process* of emergent self-organisation in complex organisations. Firstly, how do these behavioural patterns emerge; what is the role of social influence; and what are the implications, applications and challenges for organisations and management.

How do (emergent) patterns of behaviour coalesce in complex organisational systems, can a conceptual model for the theory of emergence be applied to this process?

A significantly detailed review of literature has been provided, outlining how patterns of behaviour are understood to emerge in complex systems. To briefly recap, emergent self-organisation is a process whereby system level order spontaneously arises as a result of individual agents interacting with only local knowledge, reinforcing feedback and no central point of control (Anderson, 1999; Chiles et al., 2004). At critical threshold states, a system of complexly interacting agents can re-combine into new patterns of interaction that tend to improve system functioning, but can also lead to system collapse (Lichtenstein et al., 2006). The emergent pattern of behaviour exhibits qualities that are not merely a sum of underlying components and are, to a degree, autonomous from the substrate.

The cohesion among groups and formation of patterned behaviours comes about as a result of an aggregation of individual responses to environmental stimuli, intrinsic motivations and cognitive process. The approach of dynamic social psychology applies a method of conceptualising organisational actors as moving parts within a complex system whose complementary behaviour can be visualised using an attractor model

(Vallacher & Nowak, 2008). Similar methods are also used in C2 organisations, described as self-synchronisation, in which a group of agents achieve patterned decision making without central coordination or authority (Manso & Moffat, 2011). The model of self-synchronisation also opens to the idea of cognitive entropy, to be discussed. While the two models (dynamic social psychology and self-synchronisation) provide a quantitative understanding at the level of the pattern, both lack an explanation at the level of agent interaction, where 'energy' dissipation is a primary vehicle for system adaptation and novel order.

What is 'energy' dissipation in the context of human social systems?

The process of emergent self-organisation in chemical systems is well explained within the dissipative structures theory of Nicolis and Prigogine (1977), as a function of several sequences and conditions which exhibit disequilibrium, feedback, sensitivity and recombination. A key finding of the dissipative structures model was to quantitatively observe the dissipation (rather than accumulation) of energy as a mechanism for the arising of novel and coherent structures. Energy has a physical basis at the level of individual agents. However, the arising of macro level behaviours requires a reconceptualisation of the concept of energy transfer when considering multiple agents at a higher level of analysis. Therefore, while the fundamental sequences and components for a model of self-organisation are largely unchanged across levels, the mechanisms for order require deeper understanding. The logic of this equation is illustrated in Figure 5.1 and can be summarised as follows:

Energy dissipation is tightly coupled with information transfer, which is tightly coupled with influence increment.

Therefore;

Influence is the primary vehicle for emergent self-organisation in human social systems.

As highlighted by Weiner (1954), the transfer of information cannot take place without the expenditure of energy, hence the two are tightly coupled. The transmission of information, however, is the more salient attribute in a human system, where energetic transfer has limited empirical meaning at the level of the individual agent. This is caused because the transfer of energy between human agents occurs at a cognitive not physical level. Then, information potency is coupled with influence increment. Influence does not occur without the transfer of information, measurable through salience (Friedkin, 1998). Therefore, influence is the nucleus of energetic transfer in human social systems, and a conceptual model through which the dissipative structures (or other) theorems can be applied. Conceptual models of emergence are revisited again shortly.

Figure 5.1 illustrates the logical argument above. To recap, using a model for semantic conceptualisation (Yezdani et al., 2015), the concept of energy can be coupled with information and therefore influence through a recursive validation process. No information can be transmitted without an expenditure of energy, therefore energetic and information transfer are coupled. Moreover, influence increment is coupled with information potency. Hence, the relationship between energy and influence can coupled through multiple levels of conceptual modelling.

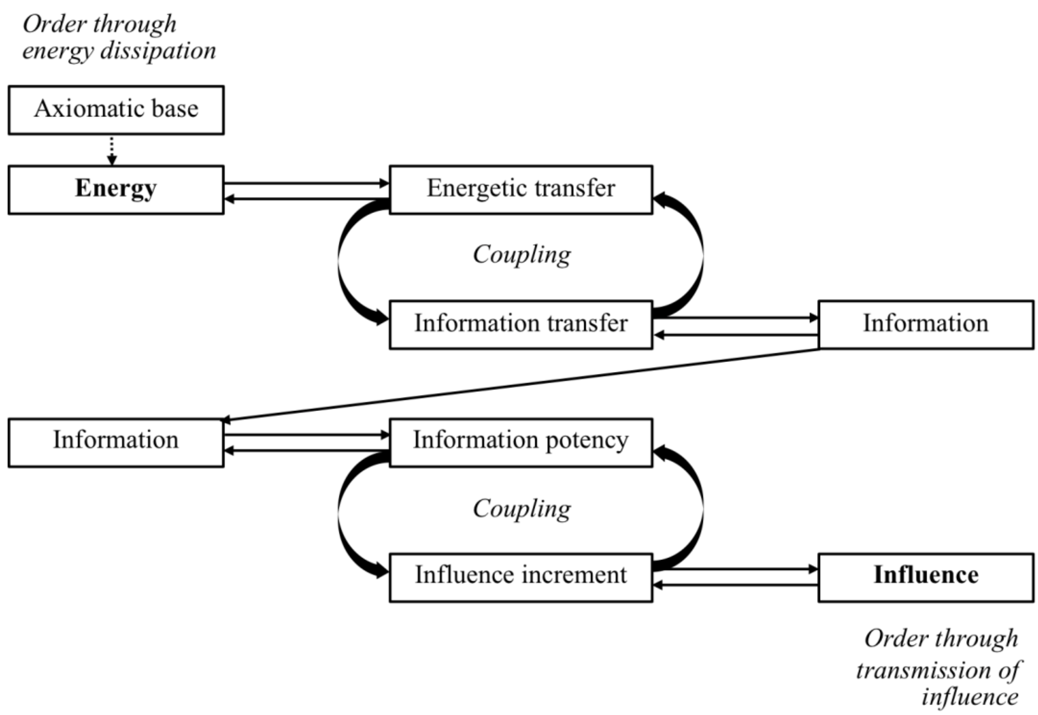


Figure 5.1 Energetic, Informational and Influence Coupling in Human Agents

What is the role of inter-agent (social) influence on the emergence of coherent structure and system level behaviours? How do we define this concept in the context of the social sciences?

Complexity, as it applies to the social sciences is the study of complex human social systems. Therein, a theory of emergence seeks to make sense of the patterns that emerge from the interaction of human agents, and the mechanisms through which system level order arises.

Social influence is at the heart of emergent pattern, because it seeks to explain how individuals give effect to the changed ideas or behaviours of others. For this reason, an indelible link exists between influence and leadership, being one (but not all) of its principal functions.

Vallacher and Nowak (2008) argue that human systems are unlike any other in that 'people have goals and plans, moments of reflection and sudden impulse'; yet, they also possess the fundamental character of non-linear dynamical systems. Social influence is a central feature of the transaction between individuals and groups within the system –

hence, influence holds a pivotal role in understanding the behaviour of complex human social systems. Social influence is a force (or reservoir of potential force) exerted by an agent that results in a change in behaviour of other agent/s, either vertically or horizontally (Porter et al., 2003). While the nature of influence differs from energy in complex chemical systems, its function is similar – influence is diffused throughout the system and results in a cascade of changed behaviours. While the cognitive and interpretive nature of human interaction causes a greater complication to exchanges of influence in a human system, the sum of these dynamical interactions can be observed, as demonstrated in detail within the literature review.

A natural tendency of what has been discussed above is to turn to the role of leadership as the locus of control for influence behaviours within a complex firm. This is demonstrated by existing literature into Complexity Leadership Theory (Marion, 2008). However, there remain several issues with this conclusion. Firstly, the direct isomorphism of concepts from the natural sciences pervades Complexity Leadership Theory, and is a prime contributor to the *organisation-science problem.* Second, a focus on single actors runs counter to the body of knowledge for complexity which is a study of whole systems, not only explained by a reduction to individual parts. Third, the ontological questions of emergence (e.g. downward causation, autonomy, amelioration) go largely unanswered. Fourth, black box assumptions used in dynamical social psychology (discussed in Chapter 2), while useful at a systemic level, are insufficient to define the function of a single actor. And finally, the darkness principle and law of requisite variety imply *luck* is a function of leadership, but are unable to incorporate this as a dimension of individual capability.
In light of the above and in the context of this study, social influence is defined in the following manner:

Social influence is the mechanism through which energy is dissipated within and across a complex human social system, and is therefore tightly coupled with the anchor point phenomenon of emergent self-organisation.

The transmission of influence is found to be an emergent event that occurs in the ‘spaces between’ agents, during a relational process, also supported by (Lichtenstein et al., 2006). Therefore, regardless of the potency of leader influences, phenomena such as *risk culture* remain an emergent property of a complex system – albeit conditioned by leadership. The transmission of influence is a necessary vehicle through which meaning, knowledge, and behaviours coalesce and arise to form an emergent pattern. This is possible without the need to conceptualise individual agents as attractors. Moreover, findings suggest that a reliance on concentrated influence sources are a potential source for strategic risk and weakness, due to constraints that are placed on the transmission of 'good' information, which is necessary for emergent structures to tend toward higher levels of fitness.

Can a conceptual model be applied, measured, and managed in a real world scenario of emergent self-organisation in complex firms?

Conceptual models, as an element of applied social science research and paradigmatic bridging, have an important role in the development and application of theory. Theory building can be described as the 'ongoing process of producing, confirming, applying and adapting theory' (Lynham, 2000). Then, the two important qualities of 'good' theory are validity and utility (Van de Ven, 1989). As surmised by Gioia and Pitre (1990) theory building ought not to be viewed not as a search for universal truths, but as 'a search for comprehensiveness stemming from different worldviews'. A pragmatic test for theory itself is its practical application and the recursive link between the real world and that of research, in this pursuit there is no need for an artificial divide. Theory is imbued with utility value to help practitioners perform with more comprehensive knowledge, and theory is continuously informed by practice (Corbin and Strauss, 2008; Lynham, 2000; Van de Ven, 1989).

There are however, many views of complexity, emergent change and methods to grapple with the challenges of a novel event. The existence of a great number of competing paradigms to explain, predict or define organisations and their actors are likely to produce confusion among practitioners not to mention scholarly fragmentation (Burnes, 2005; Gioia and Pitre, 1990). Given the current status of the nascent theory of emergence that has been discussed in this study, a further research agenda is proposed which includes a strong dimension of real world case studies that would bolster the practical application and refinement of theory, beyond data and information gathered in a simulated or laboratory environment. Tools and supporting methods are suggested in order to support this approach.

5.1.3 Problems, Theorems and Propositions

This section aims to discuss several important problems, theorems and propositions that have arisen in the course of research and are closely related to both the function and process of emergence in complex organisations. This discussion addresses the matters of autonomy, precision and the nature of leadership in a complex human social system.

Can emergents be trusted?

While a major focus of emergent self-organisation is on the fitness of arising patterns within an adaptive landscape, a less attended issue is the precision of emergent patterns and what conditions lead to error-prone outcomes. Findings in this study refer to this phenomenon as autonomy that does not ameliorate underlying imperfection. From a biological, chemical, and mathematical perspective, it is assumed emergent processes bring forth a most suitably adapted form, arising from the combination of attributes and information possessed by its emergent base (Anderson, 1999; Kauffman, 1993). Lichtenstein et al. (2006) demonstrates this assumption, where '… agents/resources in the system re-combine in new patterns of interaction that *tend to improve* system functioning' [emphasis added].

However, a key distinction between *human* and *chemical* agents, when considered at the level of the individual, is the cognitive capability of the former and the lack thereof in the latter. It is generally held that the complexity dynamics and interplay of agents in a natural system will behave in such a way that is adaptive to fitness landscapes and therefore generates a system level pattern that is novel, coherent and improved. Whole systems are able to make use of widely distributed information about the internal and external world and make numerous small adaptations in the pursuit of survival and perpetual novelty. The self-regulation and recombination properties of genes attest to this idea of ideal fitness (Mukherjee, 2016).

Introducing a cognitive dimension and many other complex interpersonal factors into the dynamical equation not only complicates this understanding, but also brings to bear core motives for acting in certain ways. As most significantly demonstrated in Case Two (Subprime), emergent patterns that come about through human interaction are indeed error-prone. While the potential for accuracy in collective behaviours has been popularised and is in everyday practical use in markets, economies and organisations, illustrated well by Surowiecki (2005) – such assertions must be grounded with an attention to the potential for system behaviours to significantly amplify underlying problems. The ‘problem’ of trust and its reading in history is laboriously detailed by Mackay (1841).

> We find that whole communities suddenly fix their minds upon one object, and go mad in its pursuit; that millions of people become simultaneously impressed with one delusion, and run after it, till their attention is caught by some new folly more captivating than the first. (Mackay, 1841).

While the setting for Mackay is in the satirical and profane, the account can be recalled into the modern context of collective behaviour on false assumptions. Empirically, the concept of amelioration has two important and practical implications: (a) emergent patterns should not be trusted simply because they are comprised by the behaviours of many; and, (b) emergent patterns from a complex dynamical substrate are simultaneously a source for perpetual novelty and a vehicle for systemic risk.

Further research on the error-rate of self-organising systems would be of value to a more quantitative understanding. Self-referencing bias and downward causation are factors that amplify the risk of error, due to the lack of accurate, heterogeneous or external information input to the making of choice for behaviours or actions. While the system remains inherently unpredictable, these could serve as warning signals that a system is imbued with risks deeper than those identified at the level of individual components.

What is ‘leadership’ in a complex social system?

As highlighted in the limitations of existing literature, a focus on single points of influence via Complexity Leadership Theory is inconsistent with foundation principles of dissipative structure, darkness, and requisite variety. In a complex human social system, the function of leadership could be seen as a potent source for the transmission of influence across multiple actors – and where there is a significant proximity to a larger number of agents than those lower in the organisational hierarchy. However, if leadership itself belongs not only to those with designated authority – but as a function of influence increment, the concept of what leadership is and where it is located is a very different hypothesis. An opportunity exists to reconceptualise leadership as an emergent property or event, seen in the patterning of follower behaviours and resulting from a *relational process*; in this way, autopoietic leadership is a transient quality that belongs to the system – not the individual. Further research to understand the nature of leadership in a complex social system is required to interpret this new perspective and its application to social science research and management practice.

The 'silent room theorem'

Salience has a structural function in complex human social systems. An actor's ability to exert influence on the behaviour of others depends entirely on transmitted information and knowledge of the first actor's opinions or other influence sources. Then, influence itself is determined by the salience value of the influence source, primarily because unknown factors have no ability to influence others.

A thought experiment to demonstrate this theorem is as follows: if one sits in a room alone and has no communication with the outside world, their opinions will have no influence on others. This is referred to here as 'the silent room theorem'. Conversely, the more widely known one's opinions, or work, the more likely interpersonal influence becomes. The 'probability of interpersonal attachment' is referred to by Friedkin (1998) as a measurable quality within social space. In this way, the structure of influence in social space depends on salience and is nullified in a vacuum of information.

Are emergents autonomous?

A pertinent matter for complexity and emergence is the question of autonomy of an emergent from its underlying base. For this purpose, an 'emergent' is described as any emergent self-organised form arising from the dynamic interplay of individuals in a complex system. As highlighted in the literature, emergents are discussed and treated as an entity that is distinct from individual components, but which are ultimately reliant on an inter-functioning with and between those underlying parts. As stated earlier in the thesis, *there is no form of substance without that substance itself to comprise it*. If an emergent phenomenon can't exist without its constituent parts, how then would it be autonomous from them? This is posed as a continuing ontological problem in philosophical readings of emergence explored by (Bedau, 2008).

The literature review points to the issue that a definition on the autonomy of emergent phenomena is currently unclear. The idea of autopoiesis gives reference to the function of autonomy, for self-making systems, albeit there is an inseparable relationship between component parts and the system. Autopoiesis is 'a network of patterns in which the function of each component is to participate in the production or transformation of other components in the network' (Capra, 1996).

Herein, two conclusions can be reached on the autonomy of emergents from their underlying base. Firstly, autonomy is not a sharp dichotomy with an on/off switch. Autonomy can be simply demonstrated by removing individuals from the system and observing the survival [sustained existence] of the whole.
The emergent is autonomous from individual components, but only to a threshold state – to the extent the removal of those parts cross a threshold of replacement or loss where the emergent layer is decomposed. Secondly, autonomy has a complex relationship with the state of imperfection caused by its constituent parts.

Findings in this study present a useful and evidenced distinction that defines levels of autonomy and their link to what is referred to here as the amelioration from imperfections of the substrate. This contributes to the problem described below by Bedau (2008).

> Emergent phenomena are Janus faced; they depend on more basic phenomena and yet are autonomous from that base. Therefore, if emergence is to be coherent, it must involve different senses of dependence and interdependence. A number of different kinds of autonomy have been discussed in the literature, including the ideas that

> emergent phenomena are irreducible to their bases, inexplicable from them, unpredictable from them, supervenient on them, and multiply realisable in them. In addition emergent phenomena sometimes are thought to involve the introduction of novel concepts or properties, and functionally characterised properties sometimes are thought to be especially associated with emergent phenomena. Another important question about the autonomy of emergent phenomena is whether that autonomy is merely epistemological or whether it has ontological consequences. An extreme version of the merely epistemological interpretation of emergence holds that emergence is simply a sign of our ignorance. (Bedau, 2008).

It is a finding of this study (Finding 11) that emergents are autonomous from individuals within the substrate, sustainable beyond single components, albeit within a threshold state. At the sublevel, components are reducible, and therefore treated as *individual* components, rather than as a collective. The collective is inseparable from the collective, but autonomous from the parts alone; to the extent the removal of those parts cross a threshold of replacement or loss. An example from this study is the arising pattern of behaviours across financial markets: these patterns are sustainable beyond any single component, and therefore are autonomous from them at an individual level. The emergent layer, however, remains mutually tied to its underlying constituents, on an aggregate level – hence, should the number of components decrease beyond a certain threshold – autonomy is lost.

The use of a threshold state opens the potential to quantitatively demonstrate levels of autonomy for complex systems under study. Existing descriptions of threshold states in their respective conditions can also be used to define the point at which this autonomy arises. More simply, autonomy could be cast as a universal characteristic of emergent wholes – on a spectrum of threshold states, rather than a sharp line. While philosophical in nature, it is argued this perspective is a unique proposition, arising through a synthesis of literature, results and analysis. A process of recursive testing is suggested to confirm this proposition.

5.2 Conceptual Models of Emergence

5.2.1 Applying a Model-Centred Approach to Emergent Self-Organisation

The following section references the published paper entitled ‘Theory of Emergence: Introducing a Model-Centred Approach to Applied Social Science Research’ (Yezdani et al., 2015). The development and application of a model-centred approach for a theory of emergent self-organisation is discussed.

> Despite the growing body of research pertaining to a nascent theory of emergence, its central themes are based on a limited theory–model–phenomena conception that does not adequately support those conceptual abstractions. Take, for instance, the direct transfer of microscopic concepts to macroscopic levels of analysis. Strengthening the conceptual link beyond metaphorical device is essential to a robust process of theory building and holds numerous applications, such as underpinning further social science research and theory-building pursuits. Without an effective isomorphism of theory and structures to real-world behaviour, it is an arguable conclusion that a theory of emergence for human organisation does not currently exist. Such is the importance of ontological adequacy and the interchange between conceptual models. It facilitates the practice of interdisciplinary science that characterises much of complexity research. (Yezdani et al., 2015).

The ‘rope at the end of the anchor’

As referenced in the literature review, much is known about the properties of complex systems – at a general level. However, the application of complexity principles in the social sciences is often without clear guideposts that reconceptualise fundamental tenets of complexity into the world of cognition, symbolic interpretation and constructivist realities that are dynamic, subjective and frequently irrational. Case study research into emergent self-organisation via social influence within the lens of complexity are surprisingly few, even less make use of a pragmatic research tradition. Discussed in detail earlier, dynamic social psychology and self-synchronisation come close to this realisation, but seek primarily to explain system-level pattern, rather than underlying process. Moreover, Complexity Leadership Theory adopts a focus on individual actors, and relies on direct theory-phenomena links, the problems of which are elaborated on in the next section.

The question that arises from the above state of play in complexity research is this: if social influence is the link between the observed phenomena at the level of the substrate, and in aggregation the constituent of system-level pattern – why is there not a great deal more interest quantifying large scale social influence processes within the complexity sciences? The anomaly is referred to here in shorthand as *the rope at the end of the anchor*. In other words, if emergence is the anchor-point phenomena, a conceptual link is required to tie the phenomenon to both individual agents and to the system, otherwise the phenomena is not an anchor, but merely an interesting observation in a sea of information. The metaphor is used with the intention of being memorable.

Figure 5.2 illustrates the problem with a hypothetical structure of analysis and complex phenomena that exist at multiple levels of analysis. The model is used to provide an abstraction of levels of analysis, for conceptual purposes. As demonstrated through the findings in this analysis, phenomena exist at multiple scales of analysis. For instance, individual human agents are themselves comprised of a complex neurological system that gives rise to consciousness – then cognitive capability (Blackmore, 2005; Dennett, 1991; Edelman & Tononi, 2001; Searle, 2000); here, this is referred to as the system within agents.
Cognition, for instance, can be treated as a distinct system layer, whose behaviour is understood at a cognitive, not chemical level (Maturana & Varela, 1980). Interactions between agents reflect the dynamic interplay between parts, which form groups of individuals and a complex network. These groups then form larger groups (e.g. organisations) to form whole complex human social systems. Systems of systems (e.g. markets or economies) and macro scales of analysis are formed of the underlying substrate, comprised by many nested systems. With this in mind, the problem of the rope at the end of the anchor refers to the need to embed a conceptual link between these scales of analysis – in order to make sense of whole complex systems, based on a reliable understanding of the behaviour of their underlying components.

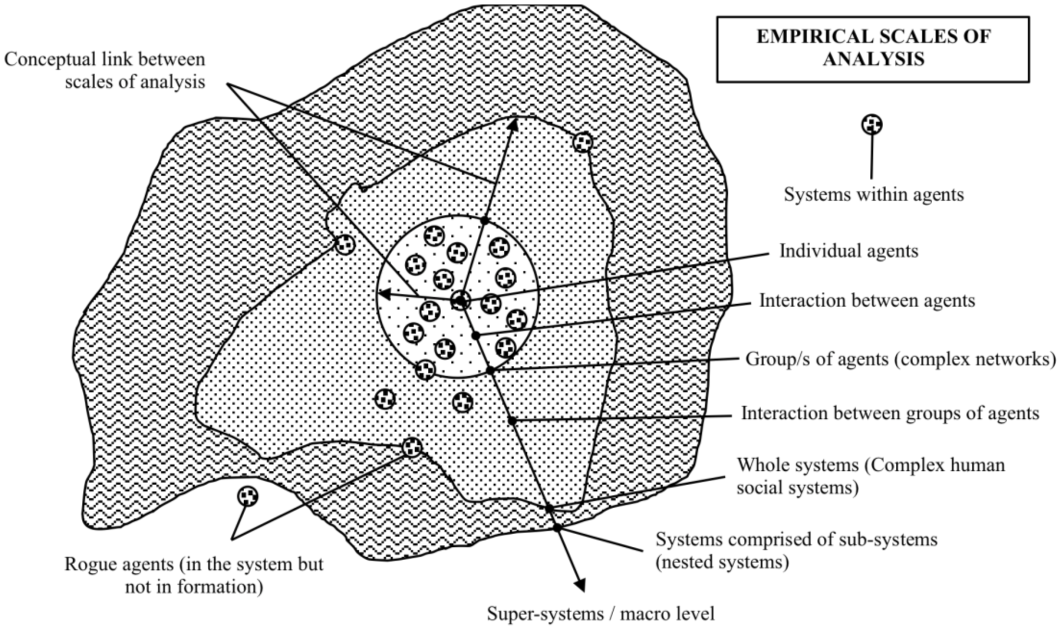


Figure 5.2 Empirical Scales of Analysis

There are two simple reasons why the rope at the end of the anchor problem exists for a theory of emergence. Both are rooted in methodological issues. First, complex social systems are fluid in both structure and form; patterns emerge, dissipate and re-emerge often without quantifiable trace. For example, thoughts emerge and disappear in the minds of actors often without any visible effect. The issue is concerned with the collection of data and information. It is currently not feasible to simultaneously collect data at all levels of the system in ways that would explain the phenomena completely and on all occasions. This matter could be considered a temporary limitation constrained by current technology.

Second, influence exists only in a transitive state; it cannot be easily preserved, reused or redeployed without new effort. Unlike chemical energy and codified information, influence has an uncertain shelf life. Influence is a concoction of human consciousness and exists only via the uneven terrain of symbolic interpretation and interpersonal construction of meaning. In essence, the problem of the rope at the end of the anchor is about explaining in shared terms all processes that occur at all levels of analysis throughout the phenomena, between agents and at the level of the system.

The 'organisation-science problem'

Complexity theory and emergence are rich, diverse and growing fields of study with many remaining research opportunities. Yet, large portions of its central themes rely on direct theory-phenomena applications from origin fields, which have limited validity when translated directly across disciplines. For example, emergent self-organisation relies on an understanding of the laws of thermodynamics for the dissipation of energy to generate system-level order, referred to as dissipative structures. While emergence is the anchor point phenomenon for such systems, the vehicle for dissipation of energy requires substantial abstraction when applied outside a chemical system – in particular, to a human social system. This direct translation of theory to phenomena, without conceptual models, is referred to here as the 'organisation-science problem'. (Yezdani et al., 2015).

> Given the obvious differences between chemicals and humans, a substantial level of abstraction is required to apply the Nicolis and Prigogine (1977) dissipative structures theorem to human social systems, particularly when quantifying the mechanisms by which the importation and dissipation of energy are achieved. (Yezdani et al., 2015).

> The publication of the studies presented by Anderson (1999), Lichtenstein (2000) and Chiles et al. (2004) demonstrate that the method of systematic inquiry based on direct theory–phenomenon conception has been reasonably well accepted into the process of theory building for complexity. Figure 5.3 illustrates the theory– phenomenon ('organisation science') conception discussed here (McKelvey, 1999).

> The direct theory–phenomenon conception applies a recursive cycle of continuous refinement where formalised models are developed in parallel with theory, and ontological adequacy is established through predictions (directly from theory) and confirmation/disconfirmation against sampled, real-world phenomena (McKelvey, 1999). (Yezdani et al., 2015).

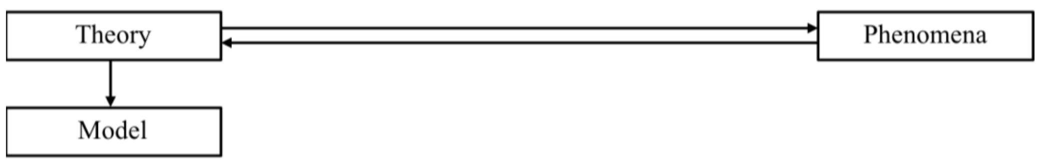


Figure 5.3 **Organisation Science Conception**
Source: (Yezdani et al., 2015).

Among the key limitations of the direct theory–phenomenon link identified by McKelvey (1999) is the need for high instrumental reliability and justification of ontological adequacy that rests on the predictive accuracy of theory to real-world scenarios. Both are areas of concern if there is an absence of ontologically adequate models that are accompanied by appropriate idealised experimentation (i.e. computational models) where instrumental reliability is high enough to formulate prediction, and generalisability within specified parameters. (Yezdani et al., 2015).

Investigations of complexity impose particular challenges on researchers beyond those presented by simpler, hypothetico-deductive research. Figure 5.4 illustrates a model of semantic conception suggested by McKelvey (1999) as the preferred tool for exploring emergent phenomena. According to the model of semantic conception, theory is always linked to and tested via (idealised) models, where theory attempts to explain the behaviour within a model, and models attempt to explain phenomenological behaviour (McKelvey, 1999). From this viewpoint, formalised computational and mathematical models take a central role in theory development. The process of semantic conception posits that theory, models and phenomena are distinctly separate entities. Thus, theory attempts to explain the behaviour of only models (McKelvey, 1999), with ontological adequacy achieved by isomorphism of the model against that portion of real-world phenomena (McKelvey, 1999). (Yezdani et al., 2015).

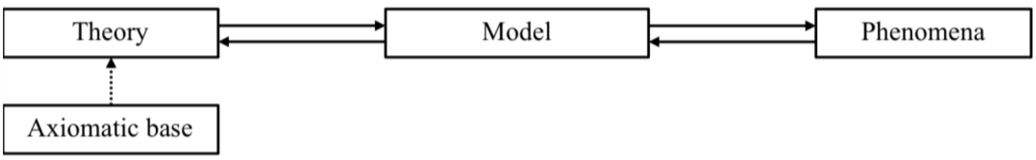


Figure 5.4 **Semantic Conception**

Source: (Yezdani et al., 2015).

McKelvey's semantic conception model can be logically expanded through a discrete process of conceptualisation that supports both the organisation science (theory–phenomenon) conception and semantic (theory–model–phenomena) conception methods, so as not to rule out any particular methodological approach. A novel model of semantic conceptualisation is offered here at Figure 5.5. A more extensive conceptualisation process presents numerous benefits. It tightens the (organisation science) theory–phenomenon conceptual loop through ontologically appropriate conceptualisation (addressing the 'metaphorical device' issue), while simultaneously lending support to formalised computational and mathematical models, expanding and testing semantic conceptualisation between models, as necessary. The 'original' McKelvey semantic conception provides for conceptualisation embedded within theory–model links: what is discussed here is a pragmatic, explicit and broadly applicable process of conceptualisation in support of current and potential empirical works, regardless of their approach. (Yezdani et al., 2015).

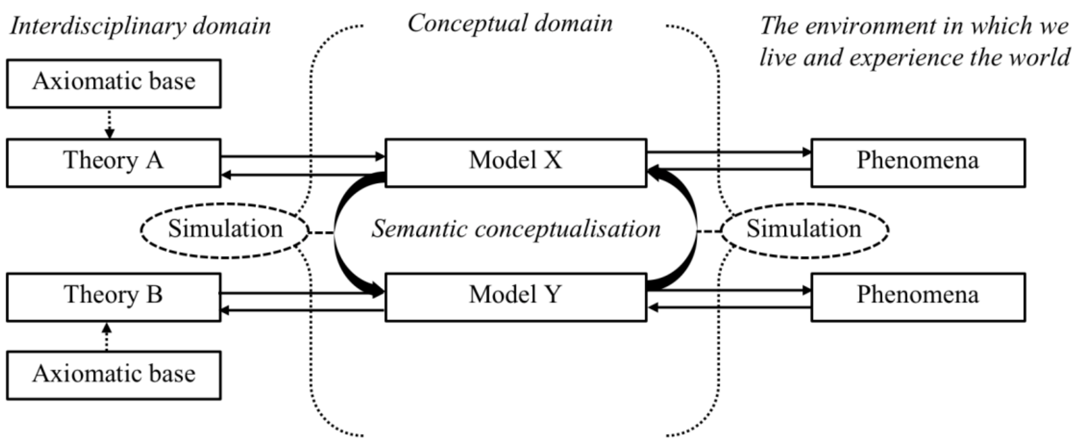


Figure 5.5 Model for Semantic Conceptualisation of Theory and Phenomena
\Source: (Yezdani et al., 2015).

The new model for semantic conceptualisation (Figure 5.5) offers greater variety of empirical method and broad scope for the interdisciplinary application of multiple theories to seemingly disparate phenomena, such as the behaviours of water molecules in human systems. A recursive cycle of conceptualisation to verify the comparability of models enables several pathways from theory, through models to phenomena. (Yezdani et al., 2015).

An example of this process of abstraction is provided at Figure 5.6: theory 'A' linked to model 'X', which is then recursively linked to model 'Y', in turn capable of explaining multiple phenomena, provided those conceptual models are valid and consistent – which continue to be hooked via the theory-model-phenomena link – and provided those interpositions have practical consequences. Simulation-based research may be used to strengthen the semantic conceptualisation process through the interchange of phenomena-based variables. The use of a tool to support

> interdisciplinary importation through conceptual modelling is of enormous use to the nascent theory of emergence, and of importance across the sciences that deal in both reducible and holistic constructs, and the relationship between them, in applied research and theory building. (Yezdani et al., 2015).

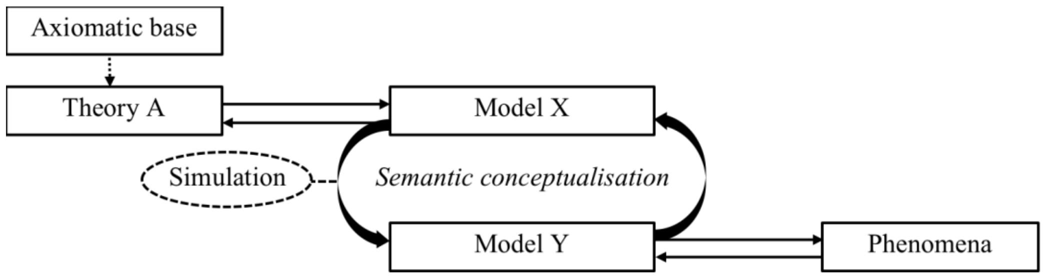


Figure 5.6 Example of semantic conceptualisation of theory, models and phenomena with a simulation

5.2.2 The Idea of Consilience

A further expansion of the model of semantic conceptualisation is the recursive intersection of theories and phenomena through conceptual models. An expansive use of such a method to build theory and link concepts is an avenue through which knowledge can move toward levels of consilience.

The idea of consilience is explained in detail by biologist Wilson (1998), as the basis on which evidence about phenomena converge to form conclusions that apply across multiple disciplines. Wilson (1998) also points to a pragmatic issue that real world problems often exist at the nexus between multiple disciplines and the answers to such large questions are better for traversing the usual disciplinary boundaries of science.

> A range of possibilities remain in exploring novel applications of emergence and the products of dynamic interaction, to extend the existing body of research using formalised computational models and real world case studies that are tied together by a common thread, or conceptual link. (Yezdani et al., 2015).

Figure 5.7 offers a practical tool and visual model to connect the model for semantic conceptualisation developed by Yezdani et al. (2015) with Wilson's (1998) ideas for consilience, on the 'unity of knowledge'. The model suggests that with a wide adoption of the process for semantic conceptualisation, a relationship between observations, e.g. ‘(a)’ and ‘(b)’ can be established via formalised conceptual models in a superstructure of enjoined knowledge of subject matter. The logical equation of new knowledge being enjoined is a convex superstructure that has more attachments within itself than without. For illustrative purposes, Figure 5.7 identifies the circularity of an extreme outcome of enjoined observations, conceptual models, theory and axiomatic bases – in what Wilson’s (1998) theoretically described as ‘consilience’ (the unity of knowledge).

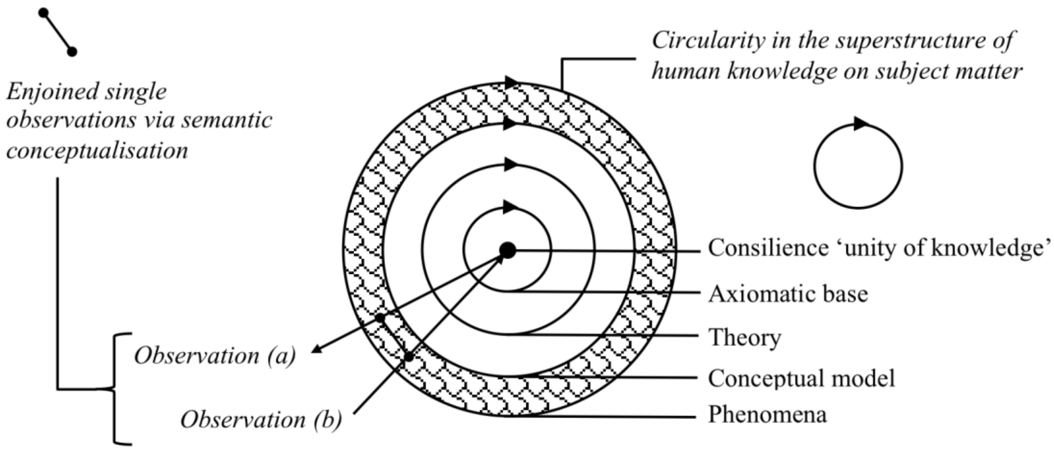


Figure 5.7 Linking of Conceptual Models and Consilience

5.2.3 Downward Causation and Cognitive Entropy

What is the casual relationship between an emergent layer and its underlying base?

Complex systems demonstrate a unique causal relationship between the emergent layer and the underlying base or component parts. The first understanding is that due to the complex and dynamic interactions of individual agents, patterns emerge that give rise to coherent, system level behaviours and form – considered as ‘upward causation’. The relationship between this emergent layer and its underlying component via ‘downward causation’ is a matter of curious effect.

Figure 5.8 and 5.9 illustrate the multidirectional nature of causal relationships at the level of the individual agent. Not only do individual agents act as constituents in giving rise to higher system level behaviours (upward causation) they are mutually influenced by those system behaviours which they have contributed towards. Similarly, agents are both influencers of and are influenced by lower levels in the system. Human agents with high access to information and a multitude of influence sources have many interdependent, salient and adjacent networks that form part of a complex web of interpersonal relationships and influence sources. While these may not typically be a part of the immediate system, they have a role in changing ideas, meaning and actions for individuals.

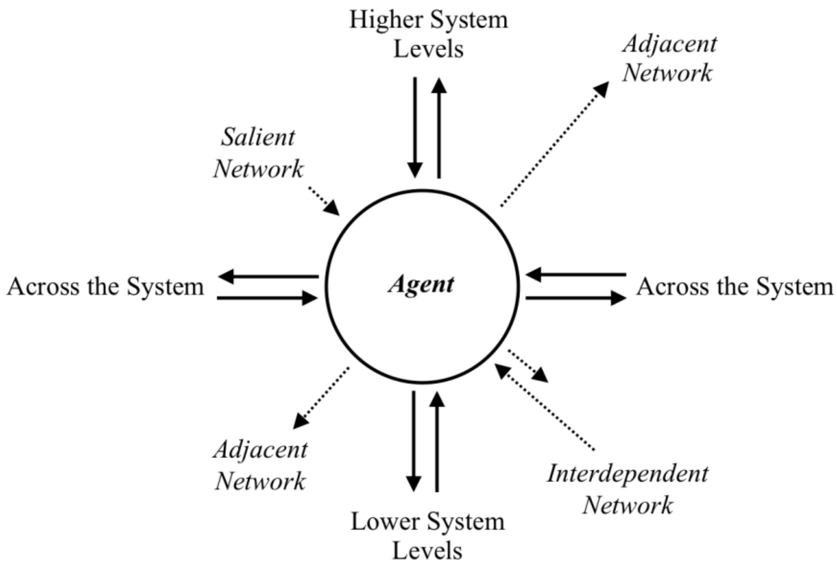


Figure 5.8 Multidirectional Causality for an Individual Agent

Figure 5.9 illustrates the potential for a high complexity of interactions (and causal relations) in a relatively simple hypothetical network. In this example, the relative influence of agents is demonstrated by the size of the circle and indicating the relative proximity of the agent within an organisational system.

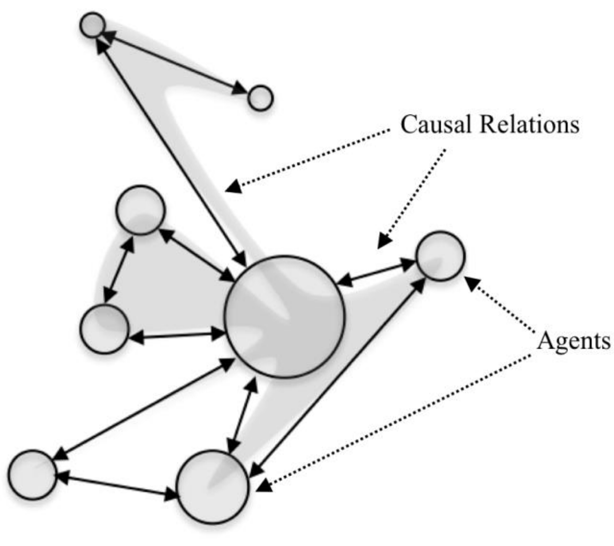


Figure 5.9 Causal Relationships for Individuals in a Simple Network

Findings in this study provide a practical demonstration of the ‘problem’ of downward causation. It is noted however, there appears to be no ‘neat’ solution to exhaustively parameterise the hypothesis in a complex and dynamic open system. While agent interaction gives rise to system level behaviours, those system level qualities that are salient to agents also give rise to changed perceptions and interactions which then form part of the system itself. Luhmann (1986) argued this is a consequence of human social systems tending to exist as autopoietic networks – creating the attributes of which they are comprised. Yet, an unexpected behaviour, of volatility rather than equilibrium, is caused via downward causation through amplifying feedback, by: agents acting on system behaviours and systems reflecting agent behaviours.

Cognitive entropy and influence increments

While not the primary focus of this study, the review of literature and data analysis has highlighted the concept of cognitive entropy as an important, yet underdeveloped area of research. In particular, an empirical understanding of the relationship between influence increments as a vehicle for information transfer (and energy dissipation) and cognitive entropy is largely absent from literature.

Cognitive entropy is a product of the potential for information loss in the transmission of messages between actors, and for this reason has been proposed by previous authors as a means by which the ‘tacitness’ of knowledge can be evaluated (Sigov & Tsvetkov, 2015). Entropy is the context of this study reflects the uncertainty of information loss and impact on cognitive process, caused by natural imperfections of human cognition (Manso & Moffat, 2011). Multiple states can be arrived at as a result of cognition, resulting from information transmission asymmetry and cognitive entropy. Figure 5.10 provides a simplified explanation for the operation of cognitive entropy in human systems, introducing waste (lost information), noise (extraneous information captured during transfer), and the potentially recursive cycle that leads from the influence process to enacted behaviours. The model applies at the level of the individual agent and can be considered at the level of the system, as entropy multiplies throughout a system with multiple actors.

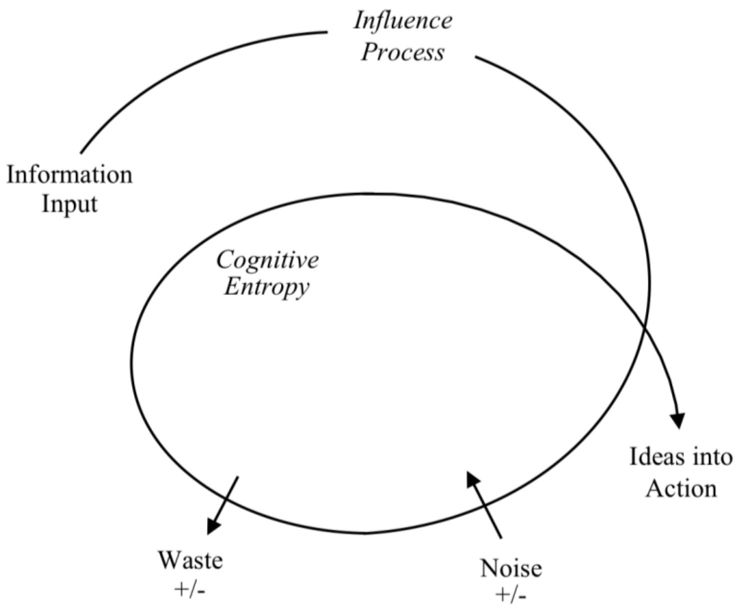


Figure 5.10 Simple Model of Cognitive Entropy for an Individual Agent

The transmission of information between human agents that gives rise to changed ideas into actions, could be considered a derivation of Information Theory's concept of entropy – to describe the extent to which the source of that influence has potency (Gleick, 2011). Very limited empirical research has been located which identifies an explicit or comprehensive relationship between the concept of *influence increment as a mechanism for information transfer* and *cognitive entropy*, both leading to information transmission decay, and as mechanisms of self-organisation in human social systems.

Figure 5.11 expands on the concepts above with an idealised model of cognitive entropy in human social systems. The direction of arrows depicts an alignment of enacted behaviours in relation to others within a small group of actors. The hypothetical model demonstrates the spectrum of high to low entropy – illustrating the potency of influence (and information) transfer within small groups in a human social system. Systems with a high level of entropy (disorder) could be said to have less economical or less potent transmission of influence across actors.

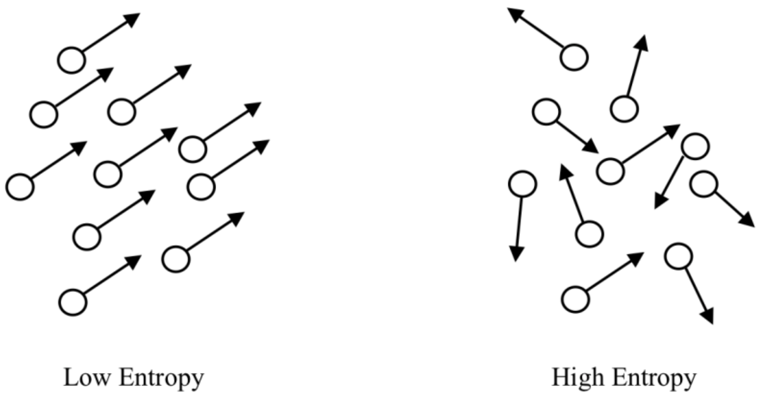


Figure 5.11 High / Low Cognitive Entropy

In Case Two (Subprime), downward causation is demonstrated as a potent source of reinforcing feedback, and a source to amplify volatility – particularly if an increasing number of agents act only on the basis of system level observation. Case Two provides a practical demonstration of downward causation via salience and the probability of inter-agent influence. Actors within organisations in Case Two are highly attuned to patterns in the market and operate in an organisational setting which is deeply focused on the identification of *catalysts* for changes in value.

Catalysts come in many forms and are used to exploit market inefficiency, arbitrage or other complex strategies that create value through the art of prediction – derived of premeditations on system level order. Figure 5.12 illustrates the complex relationship between downward causation, cognitive entropy, agent interaction and information imperfection at a system level. The figure has been developed based on findings of Case Two (Subprime) and is a depiction of observations derived through data collection and analysis obtained through this study. The solid line indicated 'emergent pattern of behaviour' refers to market behaviour, observed by actors whom also comprise the substrate for this pattern. While Case Two presents a highly efficient market system with unparalleled information access, the market is also imbued with imperfect information and entropy among actors, systems and whole markets. The market contains outliers who do not constitute pattern, but are nonetheless players in the market. High levels of salience give rise to downward causation in the market itself driving underlying behaviours, coupled with upward causation in the operation of the market giving rise to macro-economic impacts, such as those observed during the subprime financial crisis and ensuing contagion that precipitated the global financial crisis.

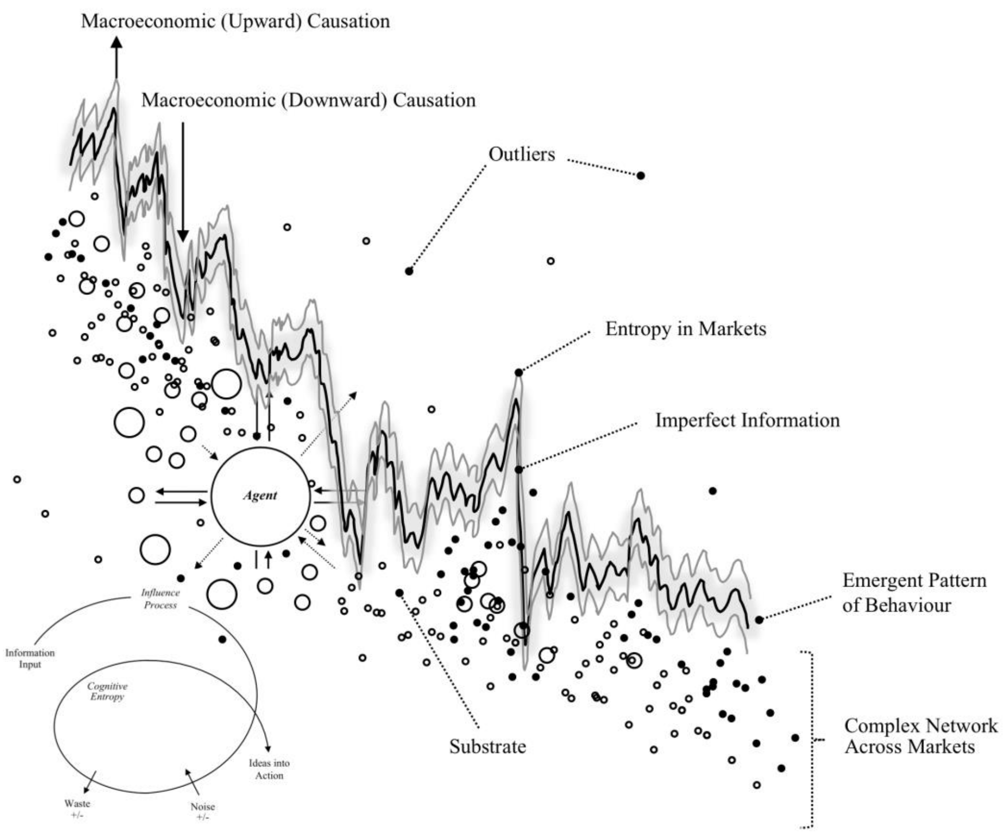


Figure 5.12 Model for Downward Causation in Salient Markets

5.2.4 The Process of Emergence

Broadly, findings of this study agree with the fundamental process of emergence established in the prior research of Lichtenstein (2000b); Lorenz (1963); Nicolis and Prigogine (1977). However, findings reveal a far more nuanced composition of interactions than those comprised principally of individual biological or chemical agents. As discussed, a reconceptualisation of 'energy' is required, while not fundamentally changing the sequences of emergence observed in chemical systems, this substantially alters the potential to make a direct theory-phenomena application ('organisation-science problem)', and calls for a distinct need to add further research in a pragmatic frame to bolster the utility value of complexity research for the world of leadership, management and organisation.

Figure 5.13 provides a detailed illustration for a general process of emergent self-organisation in human social systems, derived of the findings in this study. There are several components to the model, explained in sequence as follows. Firstly, contextual factors are taken into consideration both in the formation of 'energy', resulting interactions and potency of influence. Interaction between agents is required, which give rise to a boundary condition. The boundary for the influence network is the extent to which influence forces act on interdependent agents and therefore compose the network.

Influence is dissipated between agents, subject to entropy, amplification, frequency and rigidity of structures and culture – in a similar manner to structural inertia. These factors are a vehicle for the economy of influence transmission and are measurable in models such as self-synchronisation or models of cognitive entropy. Throughout the process, as far from equilibrium conditions are reached, the system is increasingly exposed to risks of collapse, chaos, disorder and deconstruction.

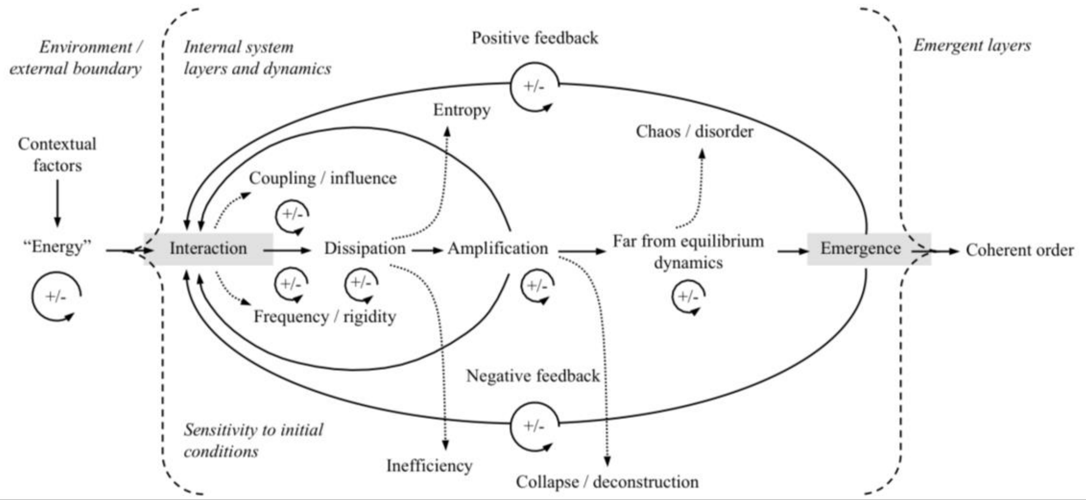


Figure 5.13 Process of Emergence in Complex Human Social Systems

As fluctuations increase, the system is stretched beyond its normal range and high levels of agent interdependency amplify local influences, new patterns spontaneously emerge and achieve coherence through reinforcing feedback. The emergence of pattern forms a new layer, generating an autonomy threshold from the underlying substrate, which continues its dynamic interaction, sustained by positive reinforcing feedback, and continuously adapting with negative feedback on system actions and interactions.

Agent interactions are made on the basis of local knowledge, with salient patterns a means by which causation is transmitted throughout the system (including downwards). Social influence is the 'energetic' ingredient that gives rise to changed ideas that form into actions, between agents and dissipated across the system. The complete pattern of behaviour that is constituted by underlying norms, local engagements and meaning, forms what could be described as a non-living (at the level of the system), autopoietic, complex human social system. The concept of 'living' systems is discussed in detail at Chapter 2.3.9 (Autopoiesis).

5.2.5 Decision Cycles as a Catalyst for Amplification

As highlighted at both cases in this study, the cycle of decision-making within organisations and between actors is a key contributor to amplification of small change and the consequent volatility of markets or system conditions. Figure 5.14 illustrates a synthesis of decision cycles from Case One and Two, and a standardised process through which decisions are made given the preceding conditions described in the threshold state criteria for each case.

The model below can be used not only to map decision process, but also the potential for amplification in agent action and feedback, as indicated on the high and low axes. Agents within the system undertake a (conscious or unconscious) process of (a) *observing* salient conditions, receiving information and being exposed to forces of influence that surround them; (b) *predicting* future states in consideration of conditions, situational factors and potential decisions; (c) *strategising* what can be done, how and when, in a deliberate formation of premeditated action; then taking (d) *action* based on the preceding steps.

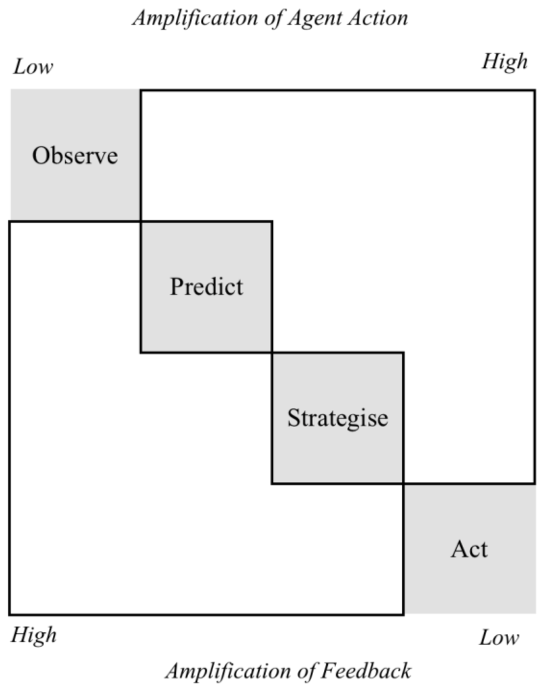


Figure 5.14 **Decision Cycle Amplification Model**

Figure 5.15 illustrates two exemplar patterns using the general model at Figure 5.14, leading to 'low' and 'high' levels of amplification. High amplification is caused by actions and observations following in rapid succession without any substantial reflective process, assessment or attempt to predict potential deviations or systemic risks in following system level patterns. Amplification is high in this case, and subject to considerable forces of downward causation. It is believed that if substantial processes of cognition on emergence are applied as a precursor to action in a complex system, this can be an avenue to avert systemic risk. Quantification on levels of cognition and their relationship to emergent outcomes is an area of research as yet unexplored. Hence, there is the potential for low amplification if future states are predicted, strategies are deliberately formed and actions are made within a strategic frame of reference.

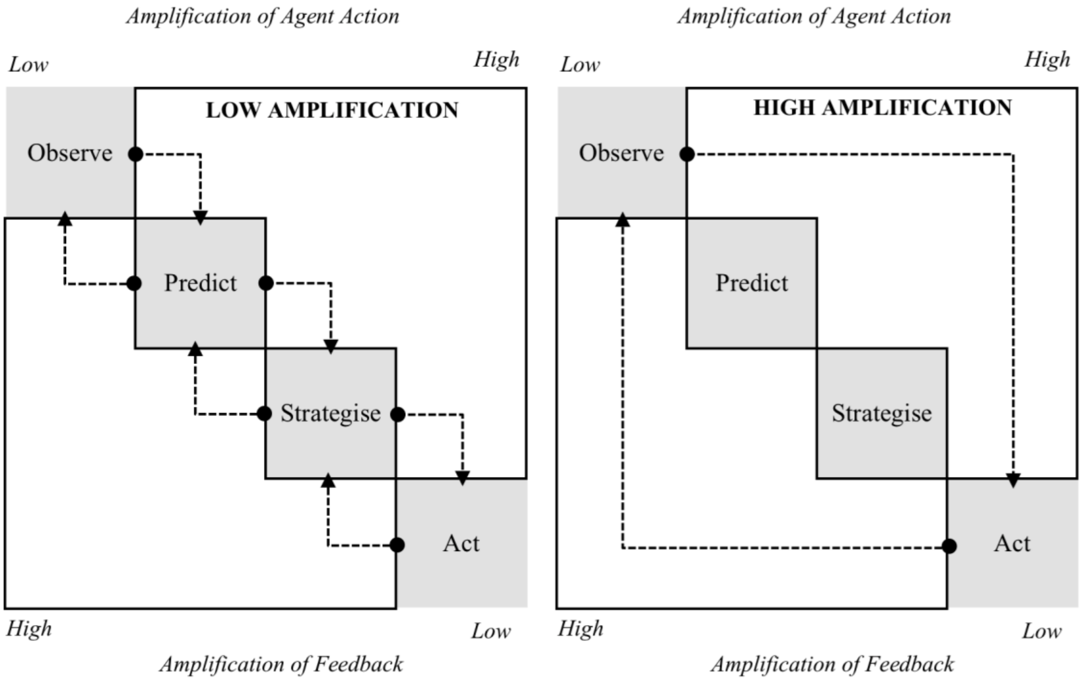


Figure 5.15 Example Decision Cycles with 'Low' and 'High' Amplification

When applying the Decision Cycle model to Case One and Two, it is found that several variants on the previous exemplars can cause high levels of amplification. Figure 5.16 demonstrates how in the case of the floods crisis, environmental conditions were observed, and the prediction of future rainfall values played a significant role.

From these predictions, actions were taken then reported using a post-hoc strategy labelling process, which then led to further observations (and influence input). The lack of a clear, predetermined strategy gradually led to an erosion of strategic choice, irreversibility and amplification of small change.

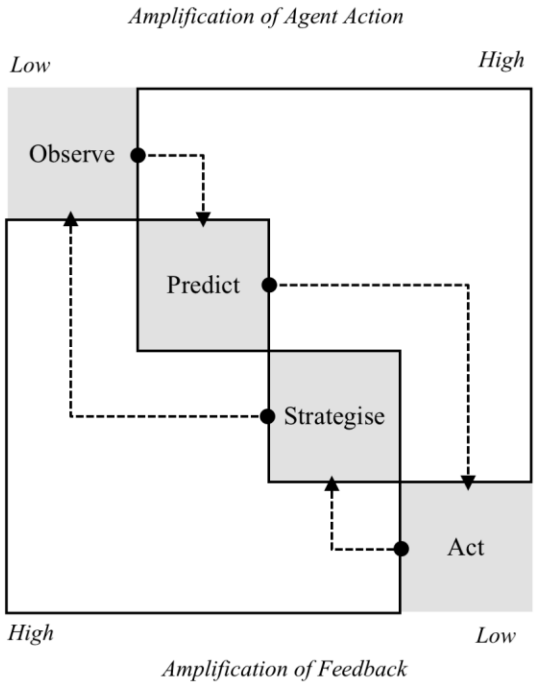


Figure 5.16 **Decision Cycle – Case One (Floods)**

Figure 5.17 applies the decision cycle model to the Case Two (Subprime) crisis. A key synergy between both cases is the function of prediction in the process of decision-making and perceived conditions. In each case, decisions are subject to considerable levels of uncertainty and subjective interpretation, despite the appearance of being quantitative in nature. In Case Two, the process of making observations, predictions and strategies are closely tied and occur in rapid succession. While strategies and complex (market) plays are developed and executed, these do not necessarily characterise the majority of market behaviour. As indicated in the findings, information transfer and small groups have an important function in each firm, but are relatively impermeable; there are many inhibiting factors on the flow of information.

While market behaviours (e.g. price and demand) are taken as self-evident, information imperfection permeates organisations and markets. In this case, predictions lead directly to actions, often occurring in a rapid succession, often with a very high volume of transactions.

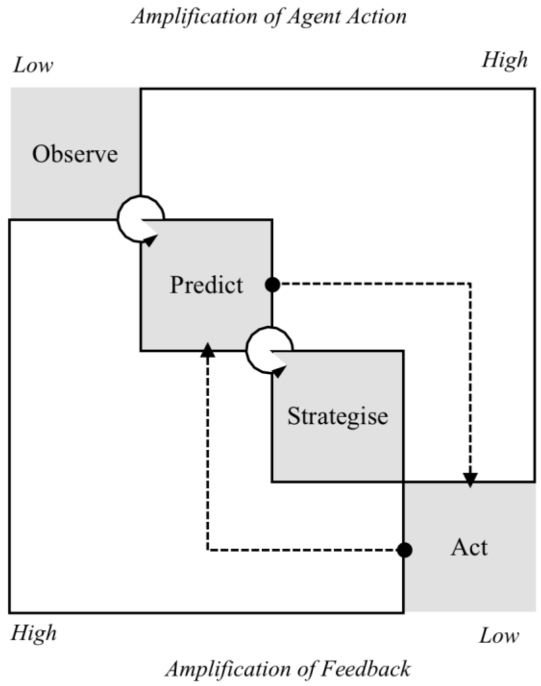


Figure 5.17 Decision Cycle – Case Two (Subprime)

5.2.6 Threshold States of Aggregated Vectors

As an illustrative example, threshold states can be observed in the aggregation of vectors that combine to form new shapes. The diagram at Figure 5.18 is an illustration of straight lines that can be combined on two axes to form a new geometric shape in the empty space that dominates the picture in its final state at (d). The shape is formed by adding lines which join axis *x* and *y* at n=10 points on each scale. The progressive removal of lines from the diagram eventually decomposes the new shape into an asymmetrical jumble of adjacent lines. Each state represents a portion of total lines, at (a) = 22.5%; (b) = 47.5%; (c) = 62.5%; and (d) = 100%.

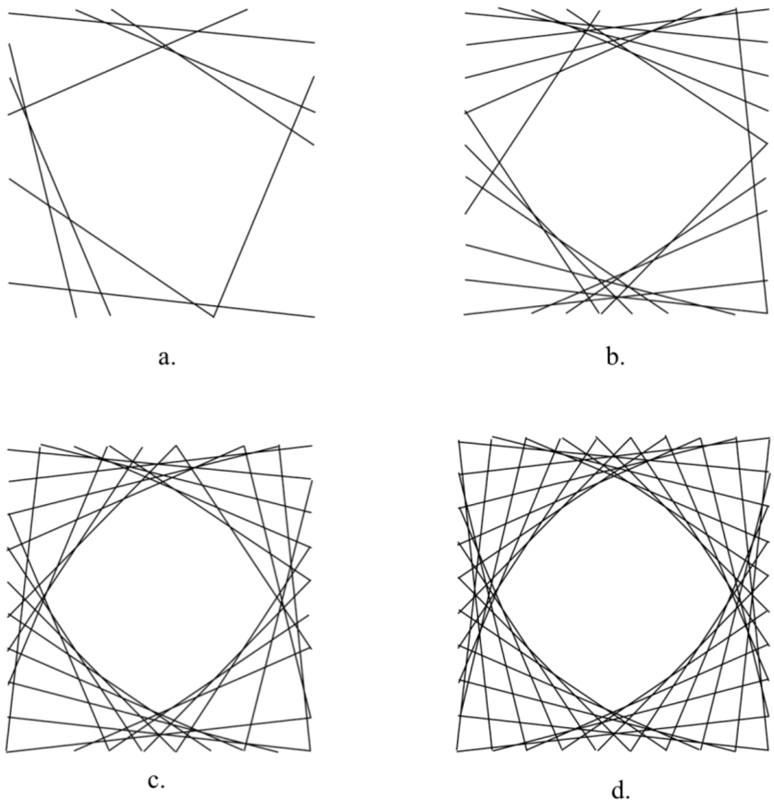


Figure 5.18 Threshold States of Aggregated Vectors

While the diagram is for illustrative purposes only, from the visibility of pattern [a new symmetrical geometric shape in white space] at (d), a number of conclusions can be proposed. For instance, it can be deduced that the removal of more than 50% of lines from the diagram leads to a decomposition of the shape, and without an even number of lines, symmetry is unachievable. The simple diagram is a visual demonstration of the potential to apply threshold states to constituents in an arising pattern, when comprehensive observations on agent behaviour are known. Topological abstractions are a common application in complexity, for instance with the use of point attractors in phase space. While the decomposition of human social systems are far more complex, the visualisation of threshold states using techniques such as network analysis is conceivable.

5.3 Implications

What are the broad implications and potential applications in the application of a theory of emergence for organisations and management?

The study of complex systems is a growing area of research with rich and unique theoretical origins. It could be said that a reason for the increasing adoption of complexity principles to understand organisational and sociological challenges is that complex problems are well suited to theories of complexity (Marion, 2008). Complexity theory applies a novel lens to understand complex human social systems and the subtleties of their behaviour. Moreover, a theory of emergence is the anchor point phenomenon that defines adaptive potential, not only the complex dynamics that give a name to complex systems – but their ability to generate new order. This research has applied principles, concepts and theories of complexity, and evaluated them in the context of applied social science research. There are several implications and applications for this novel approach.

The main implications for applying a theory of emergence to organisations and management is a reconceptualisation of existing models for understanding change, risk, complexity, leadership and the function of social influence. As discussed throughout the thesis, interactions between agents within a system are a cause for volatility, rather than this merely being a cause of external factors. The cycle of decision making, not only the decisions themselves, is also a cause for amplification, where small changes can lead to the erosion of strategic choice and irreversibility that occurs gradually. In addition, a range of specific theoretical and practical applications can be drawn from the findings. These are summarised at Table 5.1.

Table 5.1 Implications of Research

Traditional (Organisation-Science) Paradigm	*Implications / New Perspectives*
Emergents are difficult to observe, prediction is impossible	Emergents can be reliably observed, technology is lacking for data capture and processing – *comprehensive simultaneous data collection at multiple levels of analysis is a technological not ontological limitation*
Examining the potential for predictability is not a useful management function due to inherent system uncertainty which cannot be overcome	Predictability is a useful management function and yields significant practical value that is already being tested and refined – *even when subject to error, predictions give potential for system level cognition at the level of the agent*
Heterogeneity is required to generate novel order	Freedom of choice is required to generate novel order – *homogenous agents are capable of generating novel system level patterns, the coherence and robustness of those emergents are a reflection of the imperfections of the substrate*
Autonomy of emergents is a sharp on/off dichotomy	Autonomy of emergents is on a continuum and operable within threshold states – *the level of autonomy and potential for deconstruction of the emergent form can be tested and established at threshold states*
Emergent patterns tend to improve system functioning and can be trusted	Emergents are error-prone – *emergent patterns often improve system functioning, particularly when the product of purely biological or chemical processes, however, the additional dimension of cognitive process imbues a system and its behaviours with the same erroneous properties as the agents that comprise it*
Leadership is the equivalent of an attractor in phase space	Leadership is an emergent property that belongs to the system – *a focus on single agents within the system is at odds with complexity principles, as it always requires mutual action from multiple agents, influence is at the core of emergence in complex human social systems*
Order is generated at far from equilibrium states through the dissipation of energy	Influence is the vehicle through which order is generated in complex human social systems – *energetic transfer, information transmission and influence increment can be coupled within a single conceptual model to explain the operation of emergent self-organisation on a human scale*
Amplification of small change occurs through feedback and dynamic interaction in a complex system	Amplification can originate through process not only outcomes – *the process of decision cycles can create amplification, when human agents have many response options open which are based on subjective interpretation of environmental factors*

Corporate strategy is defined by strategic plans	The existence of plans does not eliminate the potential for emergent strategy – *emergence is a product of dynamic interaction between individuals, without the need for central control, and is a product of socio-organisational culture; new rules emerge in the absence of explicit instruction*
Structural inertia reduces risk, emergent strategy is high risk	Structural inertia increases systemic risk, emergent strategy may be risk averse – *failure to act on predictions of negative future states increases risk of systemic failure, emergent strategy may be unadventurous and constrained by local actions*

This study highlights the value and importance of a pragmatic approach, which recursively links theory and practice. Further research and application of a theory of emergence would be of benefit to a range of industries, not only those explored within this study. Such additional cases may include organisations comprised of multiple interdependent agents, markets are complex and salient, and organisations are exposed to high levels of uncertainty and rapid change. The following section provides a summary of limitations and contributions, to give a clear indication of limitations within current theories, and how the contributions of this study extend them.

5.3.1 Summary of Existing Limitations in Theory and Associated Research Contributions

The body of knowledge for complexity and emergence is a broad and interdisciplinary field combining many strands of research. This study is significant for several reasons, providing novel insight and perspective on new and existing organisational and research challenges, as summarised at Table 5.2. The following Table 5.2 aims to provide a summary of the limitations of existing theories, how the contributions of this study extend, confirm or disconfirm those theories, and suggestions for further research. It is noted the Table 5.2 is a summary of existing limitations, findings and discussion, from earlier parts of the thesis, and throughout Chapters 2, 4 and 5. Figure 5.19 (after Table 5.2) maps the structure of existing literature and places the contributions within the existing body of knowledge.

Table 5.2 Summary of Existing Limitations, Contributions and Further Research

Existing Limitations in Literature	*Contributions, Findings and Questions for Further Research*
Limitation 1: the term 'energy' and its transmission between agents are used with ambiguous meaning and inconsistent application.	**Contribution 1: e**nergy is tightly coupled with information transfer, which in-turn is tightly coupled with influence increment; therefore *influence* is the primary vehicle for emergent self-organisation in human social systems. Findings do not support a sharp definition for energetic transfer within human social organisations on only a physical basis, and thereby call into question prior research that make this dramatic assumption. The non-physical basis of 'energy' transmission also has implications for phase space models that replace attractors with humans. The reconceptualisation of physical [e.g. chemical] energy to [cognitive] influence increments alters many assumptions for complex social systems. For instance, energy in the form of influence has an uncertain shelf-life, is unpredictable, requires interaction with and interpretation by multiple agents, and may have many desirable and undesirable consequences. Evidenced by Findings 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13 and 14.
Limitation 2: the popular use of complexity science as a metaphorical device has exceeded its practical application as a management tool.	**Contribution 2:** extended research into the field and the application of complexity principles to social science would benefit from the use of a pragmatic approach with real world case studies, which at this point are few. The study suggests the development of a comprehensive text in the form of a handbook, to assist the consistency and robustness of applications in applied social science research. Findings 1-14 provide sound evidence of the practical application of complexity principles with the novel use of a pragmatic frame.
Limitation 3: studies of social influence and complex dynamical behaviour in human systems are inadequately incorporated into the broader science of complexity and the study of self-organisation.	**Contribution 3:** this research provides a strong basis for the deeper incorporation of knowledge on social influence processes into the broader science of complexity, in particular toward a theory of emergence for complex human social systems. Findings of this study argue that the concepts and theories in origin fields for complexity are relevant to human social systems, however, are in many cases ignore a formal method for interdisciplinary translation, to take account of the changed attributes of underlying phenomena. Chapter 2 and Chapter 5 provide extensive explanation to support this.
Limitation 4: the lack of an established practice of linking disciplines through conceptual models	**Contribution 4:** the study proposes further use of the process of *semantic conceptualisation* to

has resulted in direct theory-phenomena applications, referred to here as the 'organisation-science problem'.	strengthen theory-phenomena linkages, and support the development and refinement of theory. Findings 1-14 relate to this contribution.
Limitation 5: the concept of cognitive entropy is underdeveloped and inadequately applied in a commercial setting.	**Contribution 5:** this study proposes a simple conceptual model for cognitive entropy at the level of the agent, derived of the findings. Existing models for dynamic social psychology and self-synchronisation lack an explanation at the level of agent interaction, where 'energy' dissipation (with ambiguous meaning) is a primary vehicle for system adaptation and novel order. The study proposes a model for the operation of cognitive entropy in human systems, introducing waste and noise, within a recursive cycle. The study provides a novel combination of cognitive entropy, downward causation and a process-based approach to emergence. Further research is also suggested to understand the relationship between the concept of influence increment as a mechanism for information transfer and cognitive entropy, both leading to information transmission decay, and as mechanisms of self-organisation in human social systems. The contribution relates to Findings 1, 2, 4, 8, 11 and 13.
Limitation 6: a large body of evidence for a theory of emergence relies on computer simulations with simplified conditions that may not translate to the real world.	**Contribution 6:** as it applies for to Contribution 4, the use of simulations is incorporated as an element within the model for semantic conceptualisation.
Limitation 7: a focus on single points of influence via complexity leadership theory is inconsistent with the dissipative structures theorem, darkness principle, and laws of requisite variety.	**Contribution 7:** the study proposes an understanding of leadership as a relational event that occurs mutually between actors. Therefore, a proper understanding of its function is observable in changed ideas that become action, through the vehicle of social influence. Within this understanding, system autonomy can be observed, so too the emergence of attractors and the autopoiesis of human social systems. This contribution also relates to Finding 1, 3, 7 and 14.
Limitation 8: the use of non-linear equations to quantitatively explain emergence through dynamic social impact are limited mainly to computer simulations, or narrow choices which are an inadequate reflection of complex organisational realities.	**Contribution 8:** The treatment of emergents (pattern, aggregated products or strategies) as distinct or whole entities can exacerbate exposure to underlying risks. This contribution also relates to Finding 8 and Contribution 4.
Limitation 9: the processes of interpersonal influence and the cascading chains of effect that give rise to system level behaviours are not well	**Contribution 9:** The more structured amplification products are used; the more volatility

understood and rely on black box assumptions often from a very different field of application.	should be expected in markets. This contribution also relates to Finding 9.
Limitation 10: second-order Cybernetics is infrequently referred to in complexity theory, but is a major innovation in conceptualising emergent self-organisation.	**Contribution 10:** second order cybernetics has a conceptual relationship with autopoiesis in its reference to the function of circular causality (or feedback loops). This generates the potential for self-observing systems, and the definition of 'life'. The capacity of systems to self-make is an important factor in understanding the functioning of complex human social systems. This contribution related to Findings 8, 11 and 13.
Limitation 11: complexity and emergence in human systems are to a large extent studies of the arising patterns from interacting agents, yet there is limited concrete knowledge about the interface between agent interaction and system behaviour.	**Contribution 11:** this study contributes further understanding about the role, function and process of individual agents, having regard to systemic behaviours. This contribution relates to Findings 1-14.
Limitation 12: theories of complexity and emergence should be redefined in the social sciences, rather than borrowed, therefore the limitations of direct translation of all attributes from root meaning is unnecessary and often fruitless.	**Contribution 12:** as it applies for to Contribution 4, a model for interdisciplinary borrowing would aid the development of a theory of emergence.
Limitation 13: the application of the second law of thermodynamics to human social systems remains ambiguous.	**Contribution 13:** similar to Contribution 1, human agents are not the equivalent of ants or molecules. Contribution 1 extends to Limitation 13 as it relates to energy, and Contribution 5 with regard to entropy.
Limitation 14: the epistemological and ontological foundations for emergence require deep interrogation and discourse, yet are frequently assumed to be universally compatible across all fields.	**Contribution 14:** findings 1-14 demonstrate a unique application of complexity principles is required when applied to human social systems. This also relates to Contribution 1 and 4.
Limitation 15: the use of metaphorical device is necessary to give simplicity to complex ideas, but presents a double-edged sword if the metaphor itself succeeds over root theory as the primary explanation.	**Contribution 15:** the study itself and presentation of findings has demonstrated the utility value in the use of metaphorical device. Metaphors have use in the explanation of complex concepts, particularly when counterintuitive and where their existence is visible only in abstract space. The study is an example of the use of a pragmatic approach, with the use of real world case studies. Further research to apply principles in a real world setting, using case analysis and a pragmatic approach are suggested.
Limitation 16: a focus on state rather than process signals a reliance on black box explanations and / or assumptions.	**Contribution 16:** particularly with reference to theories concerning dynamic social psychology and self-synchronisation, the study cautions

	research, which relies on black box assumptions – at a time when theory is nascent and the underlying axiomatic base remains in question. Further Research is suggested as per Contribution 4.
Limitation 17: discourse on the application of autopoiesis to human social organisation and the definition of a living system is incomplete.	**Contribution 17:** this study has contributed to the discourse on both autopoiesis and mechanisms for human social organisation. In particular, as outlined in Chapter 5.
Limitation 18: the idea of 'emergence' is at risk of becoming a catchall phrase to describe any subsystem behaviour that cannot be quantitatively understood.	**Contribution 18:** as it applies for to Contribution 4, 14 and 15.
Limitation 19: the study of complex human systems is fractured with multiple competing paradigms and limited coherence on basic assumptions, but which is ultimately an emergent body of knowledge.	**Contribution 19:** as it applies for to Contribution 4, 14 and 15.
Limitation 20: the paradox of hierarchical systems of control that emerge from complex dynamics remains unresolved.	**Contribution 20:** as it applies for to Contribution 4, 14 and 15. The study finds that while pyramid structures within organisations are a human creation (evidenced in case notes and context), far more complex underlying structures are evident in behaviour and culture. Findings 1, 2, 3, 4, 5, 7, 11 and 14 provide evidence. Further Research into the natural formation of human social hierarchy is suggested.
Limitation 21: the major sequences of self-organisation in a human social system are inadequately understood, refined and tested.	**Contribution 21:** this study provides further understanding on the function and process of self-organisation in human social systems, explained at Chapter 5.
Limitation 22: the relationship between energetic and informational coupling in the dissipation of structure in human systems is not comprehensively described or explored.	**Contribution 22:** as it applies for to Contribution 1 and 4. The study proposes a model for a recursive relationship between energetic transfer – information – and influence increments, using the developed model of semantic conceptualisation. Further applications of the model through case study research are suggested.
Limitation 23: deterministic non-linear systems are often confused with predictability, by reconceptualising 'actors' as 'attractors'.	**Contribution 23:** the study provides a clear review and distinction between deterministic non-linear (chaotic) systems and non-deterministic systems, applying the catalyst of cognitive capability as evidenced through findings.
Limitation 24: an understanding of the relationship between influence increment as a mechanism for information transfer and cognitive entropy is absent from the literature.	**Contribution 24:** further to Limitation 5, significant research opportunities exist in the application of cognitive entropy in a real world research setting. In addition to this, very limited

	existing research exists to comprehensively describe the relationship between influence increment and cognitive entropy. The study identifies the importance of this limitation, in that cognitive entropy is a product of the potential for information loss in the transmission of messages between actors. Therefore, a more comprehensive understanding of entropy in this context is essential to quantitatively describe emergent self-organising processes in human social systems. The study proposes a simply model, discussed at Contribution 5, and further research to refine, test and develop research in this area.
Limitation 25: a comprehensive classification system based on self-organising systems (not complexity) is absent from the literature, to differentiate patterns which are simply a reflection of self-referential mechanisms (e.g. tiger stripes) and those which are adaptive to a larger purpose (ecosystems).	**Contribution 25:** the study identifies existing scales and classification systems, and confirms the inadequacy of their application for the unique dynamics of complex human social systems. Further research is suggested to develop such a classification system, and would be aided by the function and process outcomes of this study.
Limitation 26: the definitions of 'life' and 'survival' with respect to autopoietic and adaptive systems is not adequately reconceptualised for human social systems or organisational science.	**Contribution 26:** the study identifies the risks and limitations in proposing a definition of 'life' to human social systems, only on the assumption they are comprised of living organisms. The study discusses a reconceptualisation and expansion of autopoiesis for human systems, linked with entropy and causation, suggesting a tentative classification as a non-living autopoietic system. The implications of such a classification are discussed, including with reference to the future potential of artificial intelligence and large increases in computer processing power.
Limitation 27: There are only a handful of cases that have explored the possibilities of emergence as a viable business strategy; therefore the theory has not completed its due course of development, application and refinement.	**Contribution 27:** the study uses a novel application of a pragmatic frame with multiple case study analysis, and with complexity principles. The study provides an appraisal of the state of theory, using Lynham's (2002) general method, concluding the specific areas that require further development, application and refinement. Further research in these areas is suggested.
Limitation 28: the application of theory to emergent system deconstruction and the pattern of organisational collapse are limited.	**Contribution 28:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 29: the use of complexity principles and emergent patterns to detect subversive networks is not widely published.	**Contribution 29:** the study identifies and confirms this as a valuable area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.

Limitation 30: human agents are a qualitatively unique kind of complex system; therefore, arguably, the entire field of complexity ought to be redeveloped via an approach characterised by inductive reasoning.	**Contribution 30:** the study identifies and confirms this as a potential area for further research, and comprehensively explains the distinctiveness of human systems. A program for further research, the use of conceptual models and supporting materials, such as a handbook are suggested to assist in the interdisciplinary practice of complexity research in applied social science.
Limitation 31: far from equilibrium state is ill-defined in the context of human social systems, rather uses common assumptions of 'chaos' and 'disorder' which differ considerably from the adherence to universal physical laws in the chemical world.	**Contribution 31:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 32: following from a more concrete definition of 'energy' and its transmission between agents in a human social system, the ability to exercise control over this force also requires scientific explanation.	**Contribution 32:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein. Significant discussion is provided into the function of leadership, influence and control in human systems. The reconceptualisation of these ideas provides a substantial platform for further research.
Limitation 33: a pragmatist view is noticeably absent from the application of complexity theory, dynamic social impact theory and the theory of emergence.	**Contribution 33:** the study adopts a pragmatic approach and grounded by this tradition, contributes to complexity, dynamic social impact theory and emergent self-organisation. The study also suggests a program of research and supporting tools for further research in this area.
Limitation 34: the field lacks quantifiable measures to define increments of influence with varying degrees of potency.	**Contribution 34:** the study identifies and confirms this as a necessary area for quantitative exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 35: a study on the general cognition on emergence and its impact on various measures of organisational performance or social cohesion in the workplace would be a valuable contribution to literature.	**Contribution 35:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 36: the problem of the rope at the end of the anchor – the fluidity of social structure and transitive state of social influence that exists and vanish without trace.	**Contribution 36:** the study provides substantial discussion and exploration of the ontological adequacy of existing explanations of emergent self-organisation and the problem of empirical links at levels of analysis. A model is used to

	explain these linkages and their implications on existing and future research. Linkages with other proposed models (e.g. semantic conceptualisation) are discussed.
Limitation 37: limited evidence exists in the presenting of real world data on the emergence of patterns via social influence in complex organisations where agents are mutually reachable but widely distributed in physical space, moreover the resulting implications of new technology and new channels of workplace engagement.	**Contribution 37:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the preceding discussion, methods and conceptual models provided herein.
Limitation 38: the emergence of universal, simple rules. If human social systems behave in a similar manner to other complex dynamical systems – why is it that the simple rules that govern them are unable to be located.	**Contribution 38:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 39: limited evidence is available on the use of principles of self-organisation in observable patterns to reverse engineer complex networks, to test theory and remove the self-referential bias in quantitative analysis.	**Contribution 39:** the study identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 40: an opportunity exists to reconceptualise leadership as an emergent property or event, seen in the patterning of follower behaviours and resulting from a relational process; in this way autopoietic leadership is a transient quality that belongs to the system – not the individual.	**Contribution 40:** the study provides substantial discussion and evidence for the reconceptualisation of leadership as an emergent property of complex human social systems, based on the transmission of information and influence among agents. The study argues against an attractor model (of dynamic social psychology) that assumes designated leaders have a fixed point within abstract space based principally on their physical (rather than social) existence and within a deterministic model. Rather, the study argues leaders are potent actors, and the function of leadership itself is a relational event (e.g. a product of relationships, behaviours, influence increment) that is autopoietic, emergent properties of the system – hence, these are attractors, albeit in a non-deterministic system. The study also identifies and confirms this as a necessary area for exploration and suggests a program for further research in this area, drawing on the methods and conceptual models proposed herein.
Limitation 41: literature is unclear on the scope, definition and autonomy of emergent phenomena.	**Contribution 41:** the study provides substantial discussion and a practical demonstration of downward causation in complex financial markets. Drawing on findings and conceptual modelling, several conclusions are drawn on the amelioration of imperfections in the substrate and thresholds for

	the autonomy of emergent forms. This significant insight into emergent self-organisation is a necessary development toward a theory of emergence and provides a strong platform for further research in this area, based on the conceptual models and methods provided.
General Theoretical Limitations: on the *function* and *role* of emergent self-organisation in complex human social systems.	Described below at Table 5.3.
General Theoretical Limitations: on the *process* of emergent self-organisation in complex human social systems.	Described below at Table 5.3.
Methodological Limitations: the application of research methods in applied social science.	**Contribution 42:** the study adopts a novel approach to complexity research, with the use of interview driven data, a multiple case study collection method, and grounded by a pragmatic approach. The method introduces several new analysis methods, combining tools for the analysis of large volumes of text, and conceptual modelling. These tools and methods are discussed in detail, published in two peer-reviewed journals, and proposed for further use and refinement for complexity research in the area of applied social science.
Literature Review Limitations: methods for modelling and systematically reviewing complex literature.	**Contribution 43:** several novel methods for reviewing and evaluating prior literature are developed and suggest for further use, including: McKelvey/Goldstein Grid, Agent Interaction Logic, field-specific chronology, conceptual models and literature maps.
Case-Specific Limitations: Case One (Floods Crisis).	**Contribution 44:** the study presents novel application of the complexity lens and with a pragmatic focus on influence to the case of the Brisbane Floods Crisis. Many new insights have been gathered from this study that confirm, disconfirm and extend prior research and inquiries into the event. The presentation of findings would be of use form a regulatory and operational perspective, and future publications.
Case-Specific Limitations: Case Two (Subprime Mortgage Crisis).	**Contribution 45:** the study presents a novel application of at the complexity lens and with a pragmatic focus on influence to the case of the Subprime mortgage crisis. Many new insights have been gathered form this study that confirm, disconfirm and extend prior research and inquiries

	into the event. The presentation of findings would be of use form a regulatory and operational perspective, and for future publications.

It is also noted that the likelihood future research will surpass the comprehensiveness of case-specific (floods and subprime) qualitative data under examination here is very low. Given the unparalleled access to interviewees and the passing of time this would be extremely unlikely. To further support these implications and further study, an evaluation of research conducted throughout this study and potential for additional research are outlined in the following section.

Further to the tables and figures in previous chapters, Figure 5.19 provides a high level overview of the structure of existing literature and contributions of this study. The literature map is revisited for this purpose, augmented with the insights developed and refined through this research, which are outlined in detail at Chapters 2, 4 and 5. In working toward a theory of emergence, a range of contributions have been made to the existing body of knowledge. As outlined at Table 5.2, these are presented as new propositions, findings, methodologies, theoretical developments and case specific insights. The theory of emergence reflects a confluence of many ideas and observations. Figure 5.19 aims to visually assist the reader to understand how the discussion and findings extend the current body of knowledge.

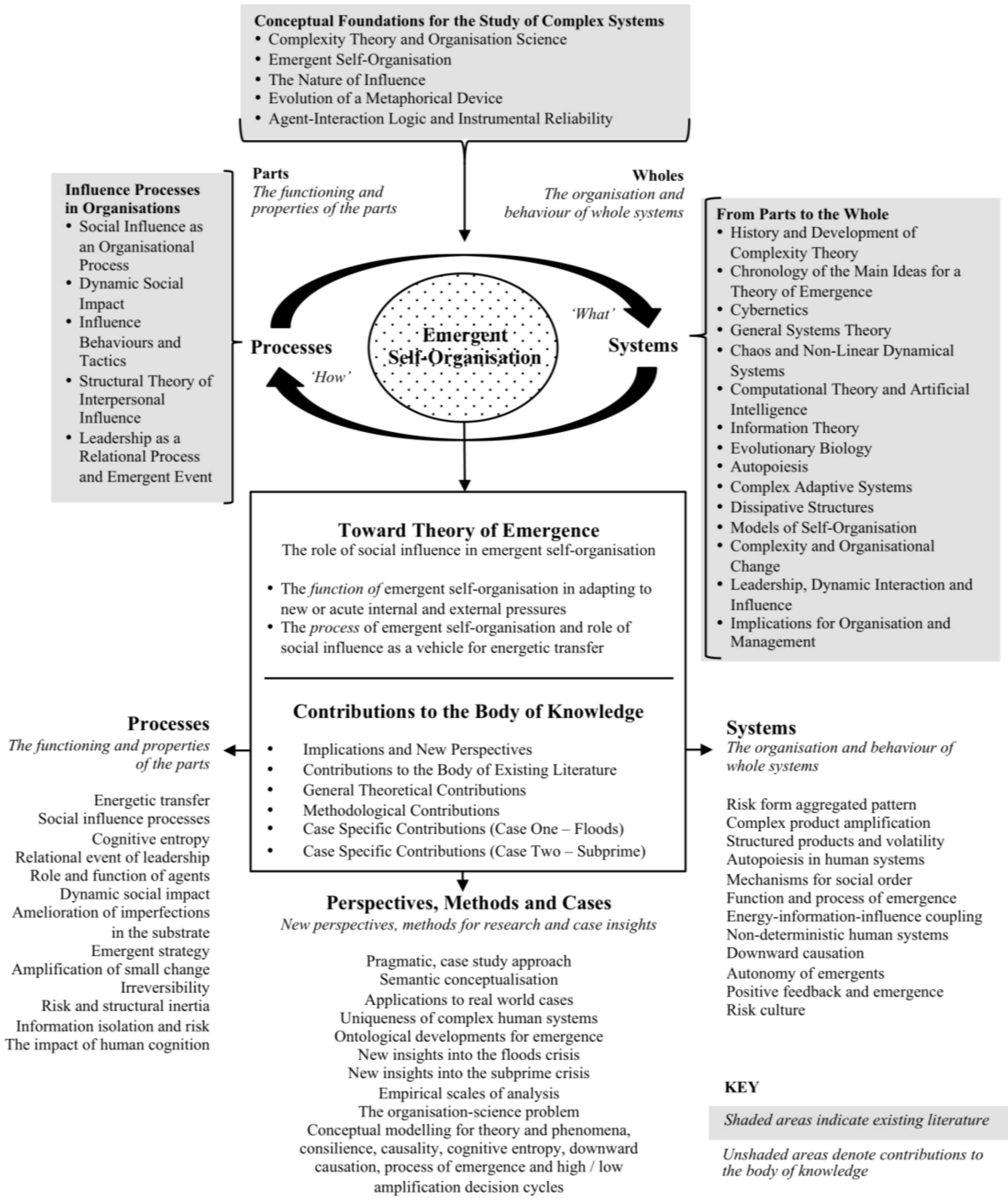


Figure 5.19 **Structure of Existing Literature and Contributions**

5.4 Evaluation of Research Outcomes and Process

5.4.1 Achievement of Research Aims

This study aimed to examine two key questions regarding emergent self-organisation in complex social systems, within the conceptual framework of complexity theory – regarding the *function* of self-organisation in adapting to acute pressures; and the *process* of emergence, as it relates to social influence. In addition to these questions and their underlying considerations, a range of problems, theorems and arising propositions are explored in detail, bringing together limitations in literature, findings and conceptual models. Each research question has enabled exploratory lines of inquiry within the pragmatic tradition and the use of real world case examples to confirm, apply and refine understandings of emergence in complex human social systems.

Overall, research aims have been achieved and contribute a deeper understanding of the role of emergence in complex organisations and the mechanics by which it occurs in a real-world setting. Each case has provided rich insights into the patterning of decision-making and the relationship between agent interaction, transmission of influence, information, and the arising of system-level behaviours. Those system level behaviours are also found to be a potent source of downward causation, across the networks of which they are comprised. Models for downward causation, autonomy and amelioration are discussed and explored in literature, findings and discussion. Table 5.3 provides a brief summary of research outcomes achieved during this project and the main contributions to the body of knowledge for complexity and emergent self-organisation. These outcomes are explained throughout the thesis and provided here as a summary only.

Table 5.3 Brief Summary of Research Outcomes

Research Questions	*Brief Summary of Research Outcomes*
What role does emergent self-organisation play in adapting to new or acute internal/external pressures?	Contributions to the body of knowledge in the function of emergence in adapting to acute pressures in real world case studies, the emergence of pattern in complex organisations, within and outside existing strategy, macro and micro level implications of emergent behaviours, autonomy from constituents, amelioration of underlying imperfection, mechanisms for downward causation, the relationship between planned and unplanned behaviours, and novel methods in applied social science and complexity research.
How do (emergent) patterns of behaviour coalesce in complex organisational systems, can a conceptual model for the theory of emergence be applied to this process?	Contributions to the body of knowledge in the process of emergence in complex organisations through real world case analysis within a pragmatic tradition, reconceptualisation of energetic-informational-influence coupling and dissipation, the mechanism of dynamic social influence in human social systems, the role of positive feedback in emergent strategy, impact of structural inertia on emergence, relationship between risk and emergence, cognitive biases in emergent patterns, observations on the amplification of small change and irreversibility, the erosion of strategic choice, strategic use of pattern identification, the role of information and groups in emergence, warning signals for systemic risk and potential models for cognitive entropy at multiple levels of analysis.

Data collected through this study and its comprehensive positioning within reviewed literature has been a fruitful exercise, defining the state of literature to date and yielding substantial research outcomes. The literature review concludes that a theory of emergence is at a nascent stage of development and currently lacks a pragmatic frame, combined with real-world case study research. For this reason, it is believed the findings of this study are of material value in contributing to the body of knowledge, in addition to offering methodological insights to aid further study.

5.4.2 Issues and Challenges

Complexity and emergence are growing areas of research that are gradually altering our understanding of organisations, management, societies and economies. As the field of study matures toward a general theory of emergence, the breadth and scope of empirical data has considerably expanded and benefited from the use of technology and new methods for collecting data and information.

As noted during the literature review, several modern applications of complexity were not possible in previous decades due simply to the lack of sufficient computer processing power. Big data and complexity are fields of practice with an indelible link. It is believed that in future decades, advances in technology will further aid programs of research for complexity and emergence. This is partly due to the natural limitations on simultaneously processing data and information at multiple levels of analysis, and modelling patterns with real-time information. A good approximation of the current state in this area is the stock market – so explored at Case Two in this study.

In addition to the challenge of technology, methodological consistency and the application of a pragmatic frame are seen as further challenges. Complexity research is a vast and multifaceted landscape, a truly interdisciplinary study of phenomena. This is field of research that challenges the sciences for a method to transfer ideas, theories and concepts across disciplines. Several methodological strategies used and proposed in this study, including a recursive process of semantic conceptualisation, paradigmatic bridging, and reconceptualising axioms (e.g. ‘energy’) when entering a new field.

5.4.3 Limitations

The findings of this study are not without limitations. Three main limitations are noted for the proper interpretation of results, having regard to: the field of study, literature under review, and generalisability of findings. Each is discussed in turn.

It is noted the thesis itself, execution of research and findings are conducted within the conceptual framework of complexity theory and emergent self-organisation, and using a pragmatic research tradition. While complexity research is comprehensive and widely known, it is noted that in organisation science, management, strategy and leadership, there are many competing schools of thought which often provide nuanced explanations of equivalent organisational phenomena. It is noted throughout this study that observations, findings and propositions apply the lens of complexity and are generalisable within certain parameters, as they are defined herein.

Literature presented in this study may not represent the entire body of knowledge for complexity theory or emergence. While the review of literature presented is broad and comprehensive, an exhaustive appraisal of more than a century of research is beyond the scope of the study. Works presented and reviewed in this study reflect the major strands of thought, theory, concepts and ideas that are relevant to emergence and are key to its development and current state. Complexity has reached various stages of advancement in different fields and this is evident in the presentation of findings that are drawn from a wide range of sources (Manson, 2001; Burnes, 2005; Moldoveanu & Bauer, 2004).

Due to the nascent status for a theory of emergence, there is no ‘neat’ field of study with all relevant literature exhaustively defined. From the selection of literature it is possible that there have been parallel findings in other paradigms that may have a relationship to those that are discussed here. Location and discussion on these competing perspectives is provided, however, further conceptual frameworks through an operationalised theoretical framework would benefit from a dedicated investigation into these discrete relationships and multi-paradigmatic links.

While qualitative and quantitative data used in this study present unparalleled quantum of data and research into both cases, findings are not generalisable to all organisations at all times. A section for each case is dedicated to parameterising analytic generalisability and should be used to position findings for wider application or further research. Specific attention has been given to explain the context and situational factors for each case to assist with generalisability, in addition to cross-case synthesis and the design of the study. In light of the limitations identified in the review of literature and findings of this study, opportunities for further research are confirmed and have been outlined in more detail below.

5.4.4 Opportunities for Further Research

Many potential areas for further research exist and have been identified throughout this study. Complexity theory and its underlying constructs offer a new way to understand the realities of what is occurring within and around organisations.

The utility value of a theory of emergence is yet to be fully realised and in its current stage of development has not sufficiently been operationalised, applied, confirmed/disconfirmed or experienced continuous refinement arising from feedback from practitioners.

Following is a tabulation of potential research opportunities placed in context to their contribution and value to an overarching research agenda. The primary goal of the research is to make a further contribution to the conceptual development, operationalisation, application, confirmation/disconfirmation and continuous refinement of a theory of emergence for complex firms. Each research strategy is conceptually related but stands alone and is not necessarily contingent on output in other strands or ongoing developments from the wider field. In addition to the research opportunities identified in previous tables and within the text, Table 5.4 summarises a potential research extension agenda, to take the next logical steps from the findings, limitations from the and review of literature presented in this study.

Table 5.4 Research Extension Agenda with Methods, Output and Linkages

Research Extension Focus Area	*Synopsis*	*Method*	*Output and Linkages to Theory Building*
Emergent Self-Organisation in Complex Firms	In-depth exploration of how organisations adapt through intra-organisational emergence employing a particular focus on the quantification of direction and increment of influence among interdependent agents in a complex adaptive system	Exploratory Interview Driven Multiple Case Study Analysis	Conceptual Development, Application, Confirmation/ Disconfirmation and Refinement
An Operationalised Theoretical Framework for The Theory of Intra-Organisational Emergence	Investigation and development of an operationalised theoretical framework for modern complexity theory reviewing the methods of current research and placing conceptual developments within the context of real world application, confirmation and refinement, as extension from Lynham's (2002) general method	Review and Exploratory Interview Driven Multiple Case Study Analysis	Operationalisation and Refinement

Multi-Paradigmatic Bridging for the Study of Complex Systems	Development of generally applicable multi-paradigmatic bridge between primary constructs within and beyond the theory of complexity including mention of the relative implications for management and general organisational practice, adapting and extending on methods of Gioia & Pitre (1990)	Meta-analysis Review	Operationalisation and Refinement
Managerial Cognition on Emergent Self-Organisation and Adaptive Capacity	Research application based on the assumptions of complexity theory lens to empirically test the correlation of management cognition on emergent self-organisation and product/service innovation, anticipative capacity or adaptation success [e.g. in crisis] and frequency, or other variants	Review, Interviews and Surveys	Application, Confirmation/ Disconfirmation and Refinement
Post-Extinction Network Maintenance, Adaptation And Learning from a Population Ecology Perspective	Investigation of the implications of emergent deconstruction and the maintenance, adaptation and capacity for learning from failed enterprises, consideration of the notion of perpetual novelty from a population ecology perspective	Exploratory Interview Driven Multiple Case Study Analysis	Conceptual Development, Refinement
Loosely Defined Organisation at Play – Dispersed Collectives of Highly Connected Interdependent Agents	The extension of complex adaptive systems constructs to loosely defined systems to further explore the dynamics and function of inter-agent influence, direction and control in the absence of formal organisational structure or process	Exploratory Interview Driven Multiple Case Study Analysis	Conceptual Development, Confirmation/ Disconfirmation, Application and Refinement
Sustainability Principle for Complex Organisations	Development of an operationalised sustainability principle for application in complexity theory, using a review of the energy input assumption in relation to the	Exploratory Interview Driven Multiple Case Study Analysis	Application and Refinement

maintenance of self-organised systems

6 Conclusion

This study has provided a detailed exploration of the function and process of emergent self-organisation in complex human social systems. The study aimed to explore how complex organisations adapt to internal and external forces, through the process of self-organisation, with a focus on the role of influence between agents. The study also provides insights into the function of emergence within the context of organisations and industries that are faced with significant uncertainty, rapid change and crisis. Within carefully considered situational factors and conditions, the process of decision-making and strategy formation is examined yielding many novel results. It examines how emergent self-organisation occurs in complex firms, and the role of social influence as a moderating factor in the creation of coherent structure, form and behavioural patterns.

The study is grounded in the interdisciplinary framework of complexity theory. A pragmatic approach has presented a significant and innovative quality to the study, by seeking to reduce the divide between theory and practice. Despite its rich and diverse origins, the study of complex systems and theory of emergence are relatively new to applied social science research. As a result, many existing studies rely on a direct theory-phenomena translation of root meaning. This study contributes substantial evidence and a robust development and application of conceptual models to two case studies that represent significant complexity and situational turbulence. Data collection is comprehensive and analysis rich, supported by interrogations of current theory.

Overall, findings of the research have contributed to the refinement, conceptual development and operationalisation of theory, within the broader framework of the complexity sciences. This has been achieved using a multiple case study analysis, with each case meeting a range of pre-defined threshold state criteria.

Interviews are a primary source of data, combined with supplementary data to describe situational factors and conditions in detail, and assure objectivity in tracking decisions and actions, and their wider consequences. Qualitative data collection and analysis techniques were used, including theoretical sampling, open coding, formation of themes and clusters, concept analysis and mapping, narrative passage, triangulation, cross-case synthesis and a careful assessment of analytic generalisability.

Results of the study are expressed in 14 key findings, each reflecting a process of recursive validation and data analysis. Findings offer a new understanding of complexity in and the function of influence in organisations, applicable within threshold states. Findings demonstrate that the emergence of strategy occurs despite the existence of plans, with reinforcing feedback a significant factor in the coherence of new order. Both cases place significant and material value on the art of prediction as an individual and/or group function, which seeks to apply cognition to larger system level outcomes. While neither case demonstrates an absolute capability to make sharp predictions on a future state, the act of prediction nonetheless has an important function in both cognitive states and decision-making processes. The interpretations of these predictions and source of causation, give rise to an amplification of small change, downward causation and the potential for systemic risk. Each case provides a characteristically different perspective on the aggregation of decision, but reflect the same complexity principles at work. For instance, in case two, a focus on aggregated strategy exacerbated risk; in case one, a choice-by-choice approach magnified risk. What is missing in both cases is a clear and simultaneous view of both the substrate and the emergent form.

Furthermore, the study makes a clear distinction on the qualitative difference between chemical agents and human agents that constitute a dynamical whole. Many of these distinctions are absent from complexity literature and open a new vista of research and understanding for complex human social systems and the function of influence as a vehicle for the anchor point phenomenon of emergent self-organisation. Explanations of autonomy, causation, cognitive entropy, amplification, amelioration and influence (and information) transfer are logical and novel extensions from existing research.
Both cases provide a practical demonstration of these important concepts supported by unparalleled data collection and analysis. A detailed evaluation of research is provided and discussed. Research aims have been achieved, contributing a deeper understanding of the role of emergence in complex organisations and the mechanics by which it occurs

using pragmatic, real-world applications. Findings provide rich insights into the patterning of decision-making and the relationship between agent interaction, transmission of influence, information, and the arising of system-level behaviours.

A comprehensive review of literature is provided, into which findings and contributions are positioned. The review finds that while the study of complex systems is a significant area of research interest, a theory of emergence has a nascent status. Both complexity and emergence represent a broad and multidisciplinary confluence of ideas and concepts. The study concludes that emergence is an area of significant value to applied social science research with many areas for further research and application in theoretical and practical terms. Research opportunities are explored in detail at Chapter 5.

This study makes three broad conclusions, which summarise the many findings, reviews and discussion presented throughout this thesis. First, the theory of emergence is in a nascent state and currently without concrete definitions on the domains to which it applies, the mechanics of underlying processes, and a tested and refined application in a real world setting. This study contributes to applying a pragmatic approach to complexity; it is noted however, further research in the field is required. The combination of elements used in this study – including pragmatism, symbolic interaction, social influence and emergence – reflect a novel approach. Hence, additional studies within a pragmatic frame, and the many permutations in real world settings would be of value to further advance the body of knowledge.

Second, this study applies complexity principles to the world of human social systems and seeks to develop conceptual models to understand the function, process and interdependencies of multi-level systems. It is concluded that many of the foundation concepts of complexity are inadequately translated to social sciences and therefore often carry ambiguous meaning.
This study offers a novel identification of social influence as the primary vehicle through which emergent self-organisation occurs in human social systems. Findings reveal the process of emergent self-organisation plays a crucial role in adapting to acute internal/external pressures, bringing forth a range of new and previously unattended

behavioural attributes and systemic properties – such as amelioration, autonomy and downward causation.

Finally, this study sought to understand the function and process of emergence in complex human social systems. As referred to above, a deeper understanding of process in human social systems gives rise to changed attributes of the system overall. This is a relatively unattended matter of foundation literature – the impact that the changed character of individual agents causes for aggregate systemic properties. For example, emergent self-organisation is generally considered a process that tends to improve system functioning. While this study finds an economy of pattern creation and transfer of information and value, the improved economy of influence transfer heightens systemic risk and is a vehicle for the spread of underlying imperfection. These imperfections can become ignored when emergents are treated as whole entities, suggesting a need for a simultaneous cognition at multiple system levels. Simultaneous cognition on multiple levels is discussed as a technological (rather than ontological) limitation, extending the earlier notion that many of the features of complex systems have previously been undiscoverable for similar reasons – namely, computer processing power. Simultaneous cognition and the treatment of emergents as whole entities raise many philosophical and conceptual challenges, including autonomy of emergents, causality, cognitive entropy, and amplification of decision cycles that underlie influence-driven self-organising systems. Several new models to tackle these challenges are introduced, reviewed and discussed.

Research outcomes and findings reflect a significant contribution to the body of knowledge for a theory of emergence. The developed process of semantic conceptualisation, a pragmatic frame and attention to the many areas that require further refinement are suggested. While further research is required to bring about a refined and tested general theory, the findings and propositions here mark a key step in moving toward a theory of emergence: for complex human social systems.

7 Glossary

Adjustable-Rate Mortgage (ARM) a mortgage whose interest rate changes periodically over time (FCIC, 2011).

Agent/s used here as per McKelvey (1999), D.A. Plowman, Baker, et al. (2007) and Anderson (1999) to refer to the individual components of an encompassing and complex systems, such as a molecule, unit, person, may also be a complex subsystem within a super system.

Analytic Generalisability in the context of this study, analytic generalisability is the intention not for findings to be generalised to populations, rather to place observations within their relevant contextual factors and limits for generalisability (Yin, 2009).

Arbitrage the simultaneous buying and selling of securities, currency, or commodities in different markets or in derivative forms in order to take advantage of differing prices for the same asset (Black, Hashimzade, Myles, & Oxford University, 2017).

Asset-Backed Security (ABS) debt instrument secured by assets such as mortgages, credit card loans or auto loans (FCIC, 2011).

Attractor in the mathematical field of dynamical systems, an attractor is a set of numerical values toward which a system tends to evolve, for a wide variety of starting conditions of the system. System values that get close enough to the attractor values remain close even if slightly disturbed (Capra, 1996; Poincare, 1892). For example: point attractor, periodic attractor, strange attractor.

Average Height Datum (AHD) the adopted national height datum that generally relates to height above mean sea level. Elevation is in metres (QFCI, 2012b).

Bifurcation the splitting of a main body into two parts; [in complexity theory] the study of bifurcation in complex dynamical systems. First used by Poincare (1892), bifurcation points alter equilibrium and are used in differential equations.

Bricolage [in organisations] trial and error through self-correction of ideas (with feedback), gathered through knowledge and observation, a means and process of improvisation in human endeavour.

Broker/s Poll [ambiguous] senior institutional investors at fund management companies, hedge fund & private equity firms, insurance and wealth management companies from around the world assess sell-side banks and brokerage firms. These results can then be formed into a ranking of institutions and brokers.

Capital assets minus liabilities; what a firm owns minus what it owes. Regulators often require financial firms to hold minimum levels of capital (Black et al., 2017).

Capital Purchase Program program providing financial assistance to assist US financial institutions through the purchase of senior preferred shares in the corporations on standardised terms. Also see TARP (FCIC, 2011).

Cartesian [in science and mathematics] relating to the French philosopher and mathematician René Descartes, meaning dualism, the distinction between mind and body, coordinate system, modern rectangular coordinate system.

CDOsquared CDO that is comprised by (holdings of) other CDOs (FCIC, 2011).

Cognitive Entropy (Information Theory) *cognitive* entropy is a compound term derived of ‘entropy’ (see ‘Entropy’), used qualitatively in human social systems to describe the extent to which the (information) source of influence has potency (Gleick, 2011), therefore as a measure of collective disorder (in self-synchronization) in the cognitive domain (Manso & Moffat, 2011).

Collateralised Debt Obligation (CDO) a type of structured asset-backed security. Originally developed for corporate debt markets, over time CDOs evolved to encompass the mortgage and mortgage-backed security markets. CDOs are often composed of the riskier portions of mortgage-backed securities.

Commensurability is a concept, in the philosophy of science, whereby scientific theories are commensurable if scientists can discuss them using a shared nomenclature that allows direct comparison of theories to determine which theory is more valid or useful. Conversely, situations arise where multiple research paradigms describe the same phenomena in accurate, yet incommensurable terms.

Community of Practice a group of people who share a craft and/or a profession. The group can evolve naturally because of the members' common interest in a particular domain or area, or it can be created specifically with the goal of gaining knowledge related to their field (Wenger, 1988).

Complementarity [of General Systems Theory] two or more points of view on a given scenario may coexist and provide observations that are neither entirely independent nor entirely compatible.

Complexity [complexity theory] referred to here as the study of complex systems, referring to the complexity of a system, especially with reference to the interacting agents within complex adaptive systems – complex systems of numerous parts capable of adapting to their environment without external control or a central point of coordination (Goldstein, 2008; Kauffman, 1993; Marion, 2008; McKelvey, 2001).

Counterparty a party to a contract.

Credit Default Swap (CDS) a type of credit derivative allowing a purchaser of the swap to transfer loan default risk to a seller of the swap. The seller agrees to pay the purchaser if a default event occurs. The purchaser does not need to own the loan covered by the swap (FCIC, 2011).

Credit Rating Agency private company that evaluates the credit quality of securities and provides ratings on those securities; such as Fitch Ratings, Moody's Investors Service, and Standard & Poor's (FCIC, 2011).

Credit Risk risk to a lender that a borrower will fail to repay a loan (Black et al., 2017).

Critical Values / Threshold States the point at which energy build reaches unstable levels within a system to the extent that recombination/deconstruction is imminent (Lichtenstein & Plowman, 2009; Osborn et al., 2002).

Cybernetics (from Greek *kubernētēs*, or 'steersman'), an approach to understanding the regulation of system behaviours through feedback mechanisms, originated as the *theory of messages* and defined by Weiner (1948) as the 'scientific study of control and communication in the animal and the machine'.

Darkness Principle [general systems theory] posits that all factors of a system's characteristics and behaviours cannot be exhaustively known, therefore complex systems are ultimately unpredictable (Skyttner, 1996).

Debt-to-Income Ratio one measure of a borrower's ability to repay a loan, generally calculated by dividing the borrower's monthly debt payments by gross monthly income (FCIC, 2011).

Deconstruction [of complex systems] emergent self-organisation may also cause the effect of, or directly result in a deconstruction of existing forms to give way to new structures, or as a failure of the stability of a complex system beyond a threshold state.

Delinquency Rate the number of loans for which borrowers fail to make timely loan payments divided by total loans (Black et al., 2017).

Depository Institution / Bank [US] financial institution, such as a commercial bank, thrift (savings and loan), or credit union, which accepts deposits, including deposits insured by the FDIC.

Derivative financial contract whose price is determined (derived) from the value of an underlying asset, rate, index, or event.

Emergence (or emergent self-organisation) has distinct meaning as used in organisation science (esp. complexity theory) as the process by which system level order emerges in complex adaptive systems, not to be confused with self-management or other forms of democratic or liberal workplace policies (Goldstein, 2008).

Emergent an emergent system, pattern, autonomous or semi-autonomous composite arising from the dynamic interplay of underlying agents – the entity which is a product of emergent self-organising processes (Bedau, 2008).

Entropy defined by the *Australian Pocket Oxford Dictionary* as the 'measure of the unavailability of a system's thermal energy for conversion into mechanical work; measure of disorder in a system'; or the *Oxford English Dictionary* as 'the name given to one of the quantitative elements which determine the thermodynamic condition of a portion of matter'; therein related to the *Laws of Thermodynamics*: (first law) the energy of the universe is constant; (second law) the entropy of the universe always increases (Gleick, 2011).

Federal Deposit Insurance Corporation (FDIC) [US] independent federal agency charged primarily with insuring deposits at financial institutions, examining and supervising some of those institutions, and shutting down failing institutions (Treasury, 2017).

Federal Reserve [US] central banking system created in 1913 in response to financial panics, consisting of the Federal Reserve Board in Washington, DC, and 12 Federal Reserve Banks around the country; its mission is to implement monetary policy through such means as setting interest rates, supervising and regulating banking institutions, maintaining the stability of the financial system, and providing financial services to depository institutions (Treasury, 2017).

Federal Reserve Bank of New York one of 12 regional Federal Reserve Banks, with responsibility for regulating bank holding companies in New York State and nearby areas (Treasury, 2017).

Fleissgleichgewicht from German, meaning 'flowing balance', a steady state of dynamic equilibrium. Used by von Bertalanffy to describe living ecological structures as 'open systems' emphasising their interdependence on the surrounding environment (Von Bertalanffy, 1951).

Foreclosure legal process whereby a mortgage lender gains ownership of the real property securing a defaulted mortgage (Black et al., 2017).

Fractal [geometry] self-similar patterns, where self-similar means they are the same from near as from far. A curve or geometrical figure, each part of which has the same statistical character as the whole. They are useful in modelling structures (such as snowflakes) in which similar patterns recur at progressively smaller scales, and in describing partly random or chaotic phenomena such as crystal growth and galaxy formation (Capra, 1996).

Freddie Mac [US] nickname for the Federal Home Loan Mortgage Corporation (FHLMC), a government sponsored enterprise providing financing for the home mortgage market (FCIC, 2011).

Government Sponsored Enterprise (GSE) private corporation, such as Fannie Mae and Freddie Mac (FCIC, 2011).

Investment Bank [US] a private company that provides various financial-related and other services to individuals, corporations, and governments such as raising financial capital by underwriting or acting as the client's agent in the issuance of securities (FCIC, 2011).

Leverage measure of how much debt is used to purchase assets; for example, a leverage ratio of 5:1 means that $5 of assets were purchased with $4 of debt and $1 of capital (FCIC, 2011).

Leveraged Buyout (LBO) is a financial transaction in which a company is purchased with a combination of equity and debt, such that the company's cash flow is the collateral used to secure and repay the borrowed money (FCIC, 2011).

LIBOR London Interbank Offered Rate, an interest rate at which banks are willing to lend to each other in the London interbank market (Black et al., 2017).

Liquidity holding cash and/or assets that can be quickly and easily converted to cash (Black et al., 2017).

Loan-to-Value Ratio (LVR/LTV) ratio of the amount of a mortgage to the value of the secured asset, typically expressed as a percentage. 'Combined' loan-to-value includes all debt secured by the house, including second mortgages (Black et al., 2017).

Mandelbrot Set mathematical set of points whose boundary is a distinctive and recognisable, an extremely intricate and continuously unfolding two-dimensional fractal shape (Mandelbrot, 1982).

Mark-to-Market the process by which the reported amount of an asset is adjusted to reflect the market value (Black et al., 2017).

Mortgage loan that the borrower uses to buy residential or commercial real estate (Black et al., 2017).

Mortgage-Backed Security (MBS) debt instrument secured by a pool of mortgages, whether residential or commercial. When mortgages are bundled, they are often considered to be less risky because loan defaults generally do not occur all at once. Ratings agencies such as Standard & Poor's or Moody's can provide ratings on MBS products (FCIC, 2011).

Phase Space a multidimensional abstract space in which each axis corresponds to one of the coordinates required to specify the state of a physical system, all the coordinates being thus represented so that a point in the space corresponds to a state of the system (Capra, 1996; Nicolis & Nicolis, 2012).

Phyletic Gradualism is a model of evolution that theorises that most speciation is slow, uniform and gradual. When evolution occurs in this mode, it is usually by the steady transformation of a whole species into a new one (through a process called *anagenesis*) (Capra, 1996).

Proprietary Trading occurs when a trader trades stocks, bonds, currencies, commodities, their derivatives, or other financial instruments with the firm's own money, as opposed to depositors' money, so as to make a profit for itself (FCIC, 2011).

Punctuated Equilibrium a hypothesis in evolutionary biology that proposes that most species will exhibit little net evolutionary change for most of their geological history, remaining in an extended state called stasis. When significant evolutionary change occurs, the hypothesis proposes that it is generally restricted to rare and geologically rapid events of branching speciation called *cladogenesis* (Capra, 1996).

Repurchase Agreement ('repo') method of secured lending where the borrower sells securities to the lender as collateral and agrees to repurchase them at a higher price within a short period, often within one day (FCIC, 2011).

Requisite Variety [law of] meaning the variety of the controller in a complex system must be at least as great as the system itself to affect complete control. Hence, it is not possible for a single agent to exhaustively control an entire complex system (Skyttner, 1996).

Residential Mortgage Backed Security (RMBS) a type of mortgage-backed debt obligation whose cash flows come from residential debt, such as mortgages, home-equity loans and subprime mortgages (FCIC, 2011).

Risk Velocity the speed with which a risk manifests itself, first as an occurrence and then as an impact.

Schemata [of agents] from the Greek word *skhēma*, which means shape, or more generally, plan. The term schemata is used here to describe a set of malleable rules on the basis of which human agents act and interact, while continuously reforming their own plans (Anderson, 1999).

Second Law of Thermodynamics [also see Entropy] the total entropy can only increase over time for an isolated system, in which neither energy nor matter can enter or leave. The total entropy can remain constant in ideal cases where the system is in a steady state (equilibrium) or undergoing a reversible process. The increase in entropy accounts for the irreversibility of natural processes and the arrow of time (Gleick, 2011).

Securitisation [in financial institutions] process of pooling debt assets such as mortgages, car loans, and credit card debt into a separate legal entity that then issues a new financial instrument or security for sale to investors (Black et al., 2017).

Shadow Banking financial institutions and activities that in some respects parallel banking activities but are subject to less regulation than commercial banks. Institutions include mutual funds, investment banks, and hedge funds (Black et al., 2017; FCIC, 2011).

Structure anything composed of parts arranged together in some way; an organisation (Macquarie Encyclopaedic Dictionary, 2010).

Structured Investment Vehicle (SIV) an investment company spun off from a bank or a similar financial institution, intended to profit by borrowing money cheaply and then buying securities such as mortgage-backed bonds, and more complex instruments such as collateralized debt obligations, that pay higher rates of interest (Black et al., 2017).

Sub-Prime Mortgage loan made to a borrower with a relatively low credit score and often insufficient income to obtain a conventional mortgage. Sub-prime borrowers are more likely to default (or be unable to make payments) on their mortgages, therefore subprime markets are high risk (FCIC, 2011).

Synthetic CDO a CDO that holds credit default swaps that reference assets (rather than holding cash assets), allowing investors to make bets for or against those referenced assets (FCIC, 2011).

Systemic Risk in financial terms, is that which poses a threat to the financial system. Similarly, systemic risk in other industries is one that could trigger the instability (or collapse) of an entire industry, market, economy (or other system) (Black et al., 2017).

Throughput inputs [to a complex system] converted through the use of energy (Katz & Kahn, 1978).

Tranche [financial markets] from French, meaning 'slice'; used to refer to the different types of mortgage-backed securities and CDO bonds that provide specified priorities and amounts of returns: 'senior' tranches have the highest priority of returns and therefore the lowest risk/interest rate; mezzanine tranches have mid-levels of risk/return; and 'equity' (also known as 'residual' or 'first loss') tranches typically receive any remaining cash flows (FCIC, 2011).

Troubled Asset Relief Program (TARP) a program of the US government to purchase toxic assets and equity from financial institutions to strengthen its financial sector that was signed into law by President George W Bush on 3 October 2008. TARP was a component of the government's measures in 2008 to address the subprime mortgage crisis (Treasury, 2017).

WWI pertaining to the period during World War One (1914-1918).

WWII pertaining to the period during World War Two (1939-1945).

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