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Networks of Inter-organisational coordination during disease outbreaks

A thesis by

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A thesis submitted in fulfilment of the requirements for the degree of

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Project Management Research Program

The University of Sydney

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Statement of Student Contributions

I the undersigned, Fadl Bdeir, declare that this thesis is my own work and has not been submitted in any other form for any other degree or diploma at any other university or institution or tertiary education. Information derived from published or unpublished work of others has been acknowledged in this document and a list of references has been provided.

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ABSTRACT

Multi-organisational environment is demonstrating more complexities due the ever-increasing tasks' complications that are arising in modern environments. Disease outbreak coordination is but one of these complex tasks, which requires multiskilled and multi-jurisdictional agencies to coordinate together in dynamic environment.

This research discusses theoretical foundations and practical approaches to suggest frameworks and methods to study the outcome of some aspects of the complex inter-organisational networks in dynamic environments, specifically coordination during disease outbreak. This dissertation studies coordination as being an interdisciplinary domain, and then uses social network theory to model such coordination.

As part of the investigation, I have surveyed about 70 health professionals from different skillsets and organisational positions whom have participated in the swine influenza H1N1 2009 outbreak. The interviews collected both qualitative and quantitative data in order to build a comprehensive and in-depth understanding of the dynamics of the inter-organisational network that evolved during that outbreak. Then I use three main components of the network theory, namely: degree centrality, connectedness and tie strength to construct a performance model. This performance model uses these three network theory components as independent variables and disease outbreak inter-organisational performance as the independent one. In addition, we study two types of networks that exist during the inter-organisational coordination being the formal networks and the informal ones. Formal networks are the ones that develop based on the standard operating structures, and the informal ones emerge based on trust and mutual benefits and relationships.

Empirical results suggest that the proposed social network components (centrality, connectedness and tie strength) have positive effect on coordination performance during the outbreak in both formal and informal networks, except centrality in the formal ones. In

addition, results suggest that none of those measures influence performance before the outbreak.

The practical implications of such results are that increasing the communication frequency and diversifying the tiers of the inter-organisational links will enhance the overall network's performance in the case of the formal coordination.

In the case of informal coordination, the reasons for creating the links are different from the formal ones. These links are created with the intention to "improve performance". Therefore, all the suggested network measures are relevant and result in improved performance during the outbreak.

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*“There are three kinds of people
One is the learned one who is godly
Another is the learner who is on the road to deliverance
And then there are the uncultivated riffraff
Who follow every cawing, bending with every wind;
They do not seek enlightenment
By the light of knowledge”*

Adapted from “Living and Dying with Grace, councils of Hadrat Ali” translated by Thomas Cleary.

Firstly and foremost the true thanks and praise is, has been and will always be to the One who made me out of nothing, out of no deservance from my side or need for me from His side.

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I will always remember my colleagues and admin staff in the centre for complex systems research at the university of Sydney especially Catherine Wakefield.

The quote at the beginning of the previous page summarizes my view about life and my life story, lifelong learner.

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- 5- Modelling and Simulation Of Cooling Of Buildings Using Solar Absorption System. Master Degree thesis, AUB, 1996
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ABBREVIATIONS

Abbreviation	Meaning
AGPN	Australian General Practitioners Network
CAS	Complex Adaptive System
CHO	Chief Health Officer
DoHA	Department of Health and Aging
EOC	Emergency Operations Center
GPs	General Practitioners
HSFAC	Health Services Functional Area Coordinator
ICU	Intensive Care Unit
ILI	influenza-like illness
NGOs	Non-governmental Organisations
NSW_H, NSWH	New South Wales Ministry of Health
OSC	Open System Coordination
PHU	Public Health Unit
PPE	Personal Protective Equipment
SNA	Social Network Analysis
STS	sSocio-technical System
WHO	World Health Organisation

Chapter 1

1. Introduction

The aim of this chapter is to introduce briefly and broadly the direction of this dissertation. The chapter starts by introducing coordination as a concept that is widely researched and needed in many disciplines. New theories of coordination emphasise that it is a multidisciplinary domain, with a range of methods for its investigation, from a mechanistic view to the new-networked view. The concept of disease outbreak is introduced next, with a historical view ranging from the great Spanish flu to the more recent swine flu (H1N1) of 2009 which created a global phenomenon within less than one month, boosted by globalisation and ease of travel, hence creating a complex coordination problem. The chapter then focuses on one of the methods to study coordination, namely social network theory and briefly overviews the different types of formal and informal network structures and network types. Subsequently the chapter provides an overview of the context of the research, discussing the main Australian approach to dealing with pandemics and introducing the main bodies and organisations that are responsible for the intervention policies and practices. With a basis in previous literature, the chapter then outlines the main questions that guide this research, along with a high-level conceptual framework, and concludes by providing a basic summary of all subsequent chapters.

1.1. Introduction to the research

This section introduces the main themes in this research, in particular coordination, as the main method through which complex tasks are organised. Secondly, the chapter introduces the influenza disease outbreak, with some historical background and consideration of its impact on human welfare.

1.1.1. Coordination

The concept of coordination has been a central issue for many researches, studies and investigations over a long period in academia as well among professional practitioners (Malone and Crowston, 1994). Interest in studying coordination arose not just in one discipline but rather in a wide range of disciplines including economics, psychology, medical sciences and computer science (Richardson et al., 2007, Hollingsworth and Boyer, Tjora, 2004, Swaminathan et al., 1998). The importance of coordination cannot be understated, and many people have an intuitive sense of its meaning. It is actually the lack of coordination, which leads to failure of a project that emphasises its significance and essentiality. Coordination has been proven to enhance performance in different settings such as organisational learning (Cha et al., 2008), the product development cycle (Ancona and Caldwell, 2007) and customer support teams (Rathnam et al., 1995), to name just a few.

Many theorists have explored the need for coordination from diverse organisational perspectives, as illustrated by some examples since the 1950s:

1. Task design and assessment (March and Simon, 1958)
2. Decision-making among choices for actions (Radner and Marschak, 1954)
3. Design response to different interdependencies among actors (Thompson, 1967)
4. Designing patterns of information processing in organisations (Tushman and Nadler, 1978)

Coordination is mostly needed and useful when there is need to manage simultaneous constraints.

The importance of coordination has only been emphasised by the increased specialisation of tasks and skills, which also has also increased the number of individuals and factors needed to perform any specific project. Such diversity has been accompanied by great development of communication techniques, methods and protocols. If these two factors together were not enough, a third factor has arisen: the high sophistication and complexity of many projects in modern life that utilise both specialisation and communication in the interest of complex and contextualised projects (Rathnam et al., 1995, Moore et al., 2003) . All these factors have

paved the way for coordination to develop from being seen as either a parallel or a series layout of tasks, or a combination of both; to being perceived rather as a mesh of complex relationships embedded in a societal ecosystem. Task relationships now dictate that the activities must occur according to certain order and exchange of information to achieve the desired goal. A simple example of this is the coordination that can be seen in manufacturing, where a product is passed along the assembly line as each stage in the production process is performed properly and timely. In the modern business world, however, coordination is looked upon more as an action to “bring different elements of complex activity or organisation into a harmonious or efficient relationship” (Melin and Axelsson, 2005)

These factors have been the main influences in developing coordination theory both conceptually and laterally. The concept of coordination developed from being task design and assignment (March and Simon, 1958) to being the additional activities that must be performed so as to synchronise differentiated work efforts so that they function properly and harmoniously during the course of achieving desired goals (Haimann and Scott, 1970), composing purposeful actions into larger purposeful wholes (Holt, 1988), and entailing the integration and harmonious adjustment of individual work efforts towards the accomplishment of a larger goal (Singh, 1992). Finally Malone and Crowston (1994) redefined coordination as an interdisciplinary domain that involves the act of managing interdependencies between activities performed to achieve a goal (Malone and Crowston, 1994). That definition reflects that one of the aspects of coordination is that it is multidisciplinary.

This acknowledgement of the interdisciplinary nature of coordination provided the momentum to consider it not as a monolithic framework. Thus, laterally coordination research in practice became contextualised across many disciplines. To name just a few of these: there is coordination in hospitals (Uddin and Hossain, 2011), in construction management (Xue et al., 2005), in software development (Kraut and Streeter, 1995), in crisis response (Comfort et al., 2001), in bushfires (De Sisto, 2011).

On the other hand, coordination is no longer perceived as based on relationships that are normally the result of the organisational blueprint. Another form of coordination has been acknowledged and in most cases tolerated, which is informal coordination. This is the organic coordination that evolves from the social relationships between individuals, which do not exist

on any organisational plan or structural draft but rather exist simply because humans are social beings who interact with each other outside the charts that decorate managerial whiteboards. This interaction is based on many factors, such as trust and mutual benefit, and is a conduit in many coordinated tasks (Chisholm, 1992). These informal lateral relationships, which some call a grapevine, has proven to have a significant positive effect on knowledge sharing among different units in large multinational corporations and to comprise a more voluntary and personal mode of communication (Tsai, 2002). This is due to the fact that “most of the activity in an organisation does not follow the vertical hierarchical structure” (Galbraith, 1973). These informal lateral relationships become important as they coordinate activities across different organisational units and substantially improve the design of the formal organisation, and these interactions provide channels for information exchange (Homans, 2013), increase access to resources (Gupta et al., 1999), diffuse new ideas within multi-unit organisations (Ghoshal et al., 1994), and support the formation of common interests that underlie the building of new exchange or cooperative relationships (Tsai and Ghoshal, 1998).

1.1.2. Disease outbreak

The emergence of new infectious diseases and the resurgence of diseases previously controlled by vaccination and treatment have created unprecedented public health challenges (Hitchcock et al., 2007). Disease outbreaks are facets of both human and animal life, and diseases can even cross life-form borders as in the case of zoonotic diseases. Outbreaks have different magnitudes and forms. One example is a localised salmonella infection resulting from food poisoning at a wedding party, in which case the spread is most usually constrained to the attendees and their direct relatives. Such outbreaks that initiate from the food chain are called foodborne diseases and have their own pathogens and treatment mechanisms. These do not usually constitute global phenomena, and hence are not reported as global hazards or crises – except perhaps in few cases like foot-and-mouth disease (Kitching, 2005).

On the other hand, last decade’s disease outbreaks of severe acute respiratory syndrome (SARS), multidrug-resistant tuberculosis, Ebola viral haemorrhagic fever, West Nile viral encephalitis, intentional anthrax, and H5N1 viral infections in humans have heightened concerns about global health security and global economic stability (Hitchcock et al., 2007). In

response to these challenges, and acknowledging their seriousness, the International Health Regulations (IHR) were revised in 2005 (Baker and Fidler, 2006). The IHR mandated that all countries must develop and maintain surveillance, reporting, verification, and response mechanisms at local, intermediate and national level. Any country with knowledge of a disease outbreak of international concern must report it to the World Health Organization (WHO) within 24 hours, regardless of where the emergency is located (Fidler, 2004). These important policy changes are necessary for timely recognition and effective containment of disease outbreaks of international public health significance; however, they may not be sufficient, and concerns about global capacity persist (Hitchcock et al., 2007).

Some outbreaks easily become global phenomena, for many reasons:

1. Globalisation and the ease of rapid travel from one continent to another
2. The nature of the pathogen and its infectivity, such as being airborne and hence the virus can travel from one host to another through breathing or sneezing
3. The severity of the disease itself and its expected mortality and morbidity rate
4. The economic impact of the pandemic due to imposed quarantine and restrictions on the movement of people and goods.

Among the main outbreaks that bear the distinction of combining all these factors is influenza. Influenza, however trivial and minor it can be, has proved to be the deadliest disease in human history. The main example is the 1918 Spanish flu, which became a global infection claiming the life of 50-100 million humans according to current estimates, which in turn have been updated from the earlier estimates of 40-50 million (Knobler et al., 2005). This pandemic has been described as "the greatest medical holocaust in history" and may have killed more people than the Black Death. It is said that this flu killed more people in 24 weeks than AIDS has killed in 24 years, more in a year than the Black Death killed in a century (Knobler et al., 2005).

The most recent influenza pandemic that rapidly became a global concern was the H1N1 2009 swine flu. It arose as a total surprise in small village in Vera Cruz, Mexico in early April 2009, then quickly spread worldwide through human-to-human transmission, thus generating the first influenza pandemic of the 21st century (Girard et al., 2010). The virus was found to be

genetically unrelated to human seasonal influenza but genetically related to viruses known in pigs. In view of its likely swine origin, it is often referred to as “swine flu” or H1N1, with 2009 attached as its year of discovery (Girard et al., 2010). The pandemic spread globally, with the result that on June 11, 2009, the WHO raised the pandemic alert to level 6 in response to the number of countries that had reported H1N1 cases in their communities. The pandemic spread rapidly around the globe, and it was anticipated that it would particularly affect the elderly segment of the population. However, it appeared to affect primarily children and young adults, as well as those with an underlying lung or cardiac disease condition (Malik Peiris et al., 2009).

The actual number of people infected by this pandemic worldwide is still unknown. Most cases were diagnosed clinically and were not laboratory-confirmed, as in most countries the “capacity for laboratory diagnosis was severely stressed” (WHO, 2009). It is likely that the total number of cases of H1N1 2009 worldwide was in the order of several tens of millions of cases. An early estimate of the extent of the disease in the USA was about 50 million cases (Presanis et al., 2009). A recent estimate was of about 200 million pandemic H1N1 cases worldwide, of which about 10 million occurred in France (Hannoun, 2010). There is still controversy about its toll, with estimates ranging from 14000 to 18000 deaths (Control, 2010).

This pandemic challenged the existing coordination mechanisms in many countries and forced many others to revisit their disaster plans. Coordination was global, starting from the WHO, moving to national health authorities, and reaching persons such as a local health practitioner in Lismore, is about 750 km north of Sydney, Australia.

This coordination was by no means either in accordance with the organisational blueprints nor confined to some simple emails bouncing among the mailboxes of intensive care specialists, health bureaucrats, epidemiologists or pathology experts. It constituted a web of interrelationships that linked all those who had a role in the pandemic management and containment. Hence, as the first wave of influenza pandemics of the 21st century, with two more waves still expected before the calendar reaches the 22nd century, the coordination process of H1N1 2009 deserves to be well studied and researched.

1.2. Overview of the research

This section discusses coordination and its research methodology through social networks, with application to pandemic coordination.

1.2.1. Studying coordination through social networks

Coordination can be discussed or presented via different methods such as the hierarchal method or the “conveyer belt” metaphor. Yet a modern and emerging methodology for examining coordination is to view it as a “*networked system*” that is interconnected by nodes (Hossain and Kuti, 2010). These nodes can be anything from individuals to cells to organisations. These networks have characteristics which can vary widely according to the media of communication, the types of node, the environment in which the system is embedded, and the context of coordination (Ahuja and Carley, 1998). The conceptual study of social networks has suggested some concepts that can be used to study the structure of such networks, and these concepts can then be measured empirically. Categorisation of a network as centralised, decentralised or distributed is but one of the major concepts that can be investigated in any network, as shown in Figure 1-1

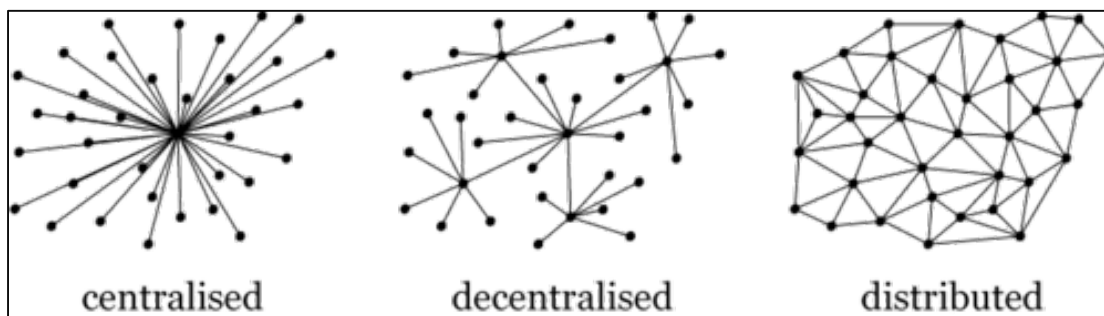


Figure 1-1 Different types of network structure

In a centralised structure, all nodes are linked to single central node. This type of network structure can maintain formal hierarchical network control (Hinds and McGrath, 2006). However, this structure has the risk of failing if the central node becomes unavailable for any reason. A decentralised structure comprises multiple central sub-networks that are connected, thereby reducing the risk of single node dependency. These nodes can be thought of as a

geographically distributed hubs interconnected by a system of links. In such networks, if one of the hubs' central node fails, that will affect only its directly connected nodes while other hubs of the network will continue to function. In a distributed structure the notion of central node is replaced by total connectivity. This eliminates any node dependency, so that a failure of one node will only affect itself, since the communication will be routed easily through other links, thus providing a high level of tolerance. Despite this merit of being highly redundant and tolerant, distributed networks also have their own shortcomings. Major shortcomings are the cost to maintain such a large number of links and the cost of receiving redundant information, since it is expected that information will be carried via multiple channels (Baran, 1964). The formation of social networks as described here is a direct indication that actors, whether they are humans or organisations, need each other, and the links between these nodes are the channels through which they exchange information, goods or resources. Hence these social networks represent a form of social exchange and hence coordination. (Powell, 1990).

Social network theory can identify and quantify informal networks. Investigating informal networks is very useful for identifying network properties such as finding the most influential actor or the opinion leaders (Mullen et al., 1991). The structural attributes of networks (such as centrality, which has been discussed) now can be quantified and used to determine certain qualities of the nodes' attributes based on their structural position. Thus network centrality is now a measure that determines the relative importance of an actor within a network (*e.g. how much influence can an actor exert on other people and on how many of them?*). There are numerous network measures that are discussed in many social network researches (Wasserman and Faust, 1995); however deciding on which ones to adopt in a particular research depends on the constructs that the researcher deems suitable for his study. Hence social networks represent a way of mapping and measuring relationships between actors (Carrington et al., 2005) that can be presented visually and calculated empirically, introducing the notion of social network analysis (SNA).

Once new empirical and mathematical methods had been developed to assess position of nodes within a network, and to evaluate a network's whole structure, SNA became an attractive, feasible technique to apply to many types of relationships and situations. Some examples of situations are the spread of infection or the dissemination of innovation (Borgatti,

2005), the relationships of inter-organisational board members (Carpenter and Westphal, 2001), and measuring social capital and self-esteem (Steinfeld et al., 2008); the list goes on and on.

From this perspective, Malone's (1990) definition of coordination as managing interdependencies works together with the concept of SNA as a system and medium to manage these interdependencies. Coordination serves the needs of people to share information, delegate and decompose tasks, or cooperate to solve problems. Social networks are the medium by which those activities are performed through the combination of nodes and links. Such networks would evolve during the course of attaining goals or completing tasks.

Furthermore, SNA provides the visualisation and mathematical procedures to further analyse node and network characteristics as means of measuring the properties associated with a particular outcome of coordination (Chung et al., 2005). Such an approach for studying coordination helps to provide insight into network conditions such as the level of network involvement for certain actors, the existence of any structural holes, and any other enabling or inhibiting factors that may produce a particular coordination outcome. It is now possible to quantify the positions of each actor within this network and to conceptualise the impact of different network positions of actors: actors' positions in social networks affect their ability to coordinate and the structure of the network as a whole affects the coordination of performance.

1.2.2. Overview of the context of the research

Pandemics not only have economic and social impact on the affected community, but a major impact on human health, welfare and life. Usually, public health authorities are the primary agencies that lead the response to the disease. This response generally begins with horizon scanning and surveillance. New communication technologies and international treaties have globalised the surveillance task, and hence many national health authorities are both suppliers and consumers of global surveillance systems that are mainly managed by the WHO.

In Australia, the Australian Health Protection Committee (AHPC) is chaired at Deputy Secretary level by the Australian Government Department of Health and Ageing (DoHA), and

its core includes the Chief Medical Officer; each State and Territory Chief Health Officer (CHO) (and, if required, public health or emergency personnel nominated by the CHO for relevant agenda items); health disaster officials (up to 3) nominated by States and Territories or the Commonwealth; the chairs of each of the three sub-committees (Communicable Disease Network Australia (CDNA), Public Health Laboratory Network (PHLN) and the Environmental Health Committee (enHealth)); the Director General, Emergency Management Australia; the Head, Defence Health Services; a representative of the New Zealand Ministry of Health; a representative of Emergency Management Australia; representation from the National Mental Health Disaster Response Committee; and clinical experts and others to be co-opted as necessary (AHPC), Figure 1-2 below shows the organisational diagram of the AHPC.

In the state of New South Wales (NSW) the Public Health Act designated the NSW Ministry of Health (NSWH) as the lead combat agency during the H1N1 2009 outbreak. NSWH has prepared plans to deal with different types of pandemic, including the human influenza pandemic; some of these plans are the State Disaster Plan (DISPLAN), Human Influenza Pandemic Plan (HIPP Plan) and NSW HEALTHPLAN. The HIPP plan was drafted based on more severe types of influenza such as H5N1 whereas H1N1 was relatively “mild” (Health, 2010b) The Australian Health Management Plan for Pandemic Influenza (AHMPPI) categorises five management phases: Delay, Contain, Protect, Sustain, and Control that were later collapsed to three: Delay, Contain and Protect. These plans should be updated upon the conclusion of any event for which the plan was activated, on the introduction of major structural, organisational or legislative changes in NSW, or at least every five years (Health, 2010a)

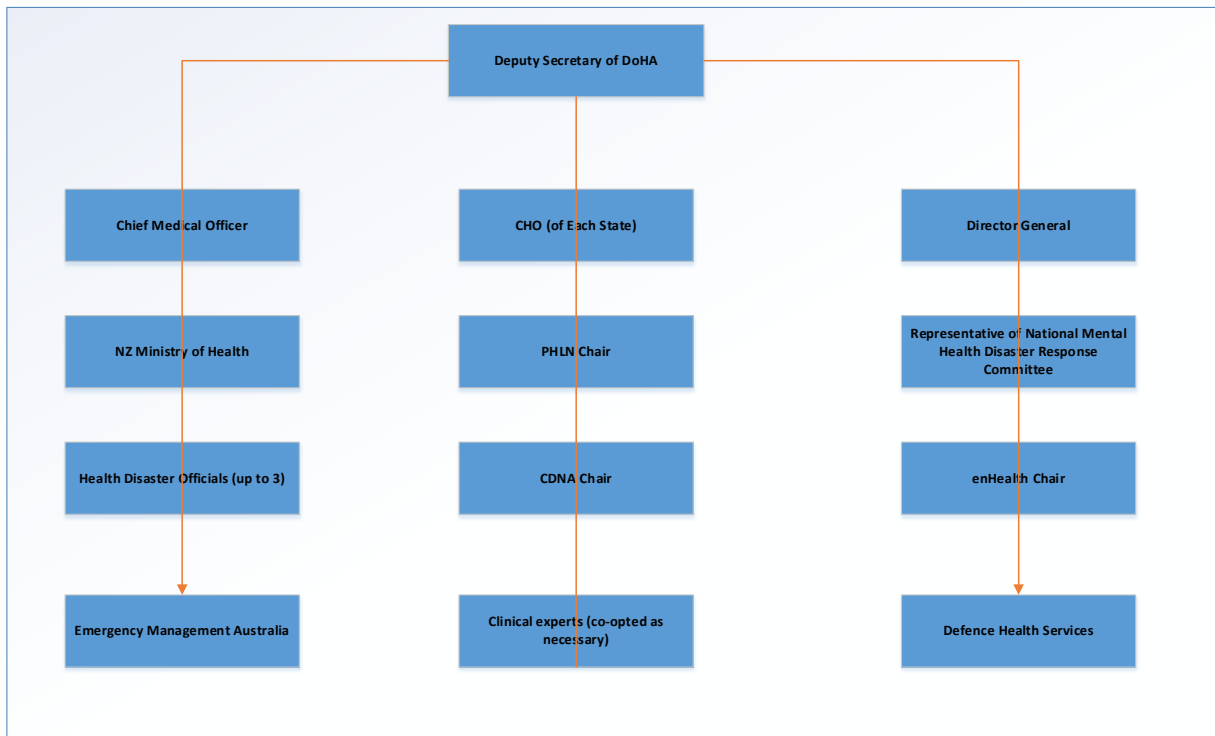


Figure 1-2: Organisational diagram of the Australian Health Protection Committee (AHPC)

NSWH is responsible for the management effort, which starts with surveillance and passes through different components, some of which are (Health, 2010a)

- Various laboratories notify confirmed cases of influenza.
- The Public Health Real-time Emergency Department Surveillance System (PHREDSS), which monitors near real time for influenza-like illness from most Emergency Departments (ED) in NSW.
- Public Health Units (PHUs) receive reports from clinicians or institutions of unusual cases
- Sample of general practitioners (GPs) contribute data on influenza-like illness to sentinel surveillance systems
- The Australian Government supplies absenteeism data.

During the H1N1 outbreak, NSW Health implemented additional monitoring and surveillance measures, including:

- Active public health follow-up of possible and confirmed cases of pandemic influenza

- Border screening for influenza-like illness in travellers from affected regions
- Data provided through collaborative efforts of multiple hospitals (e.g. national data on intensive care or paediatric admissions)

During the pandemic NSW was divided into eight local health districts, each with a local PHU that managed communication locally with health facilities such as hospitals, laboratories, and community health centres. Those laboratories and hospitals in turn communicated with NSWH directly, especially with specialised units within them, such as intensive care units (ICUs). GPs in turn had different bodies to regulate them, and at the same time they communicated with the local and sometimes federal health authorities.

The previous paragraphs provide just a small example of the different organisations that needed to communicate and collaborate during the H1N1 2009 outbreak. All these organisations created a mesh of interconnected nodes comprising a large network of formal and informal relationships.

1.3. Research questions

This dissertation presents a study of the certain network measures on the robustness of coordination during a disease outbreak.

This research will focus on studying the dynamics of the networks during large pandemic outbreak. The social network theory will provide the theoretical foundation for the discussion. Moreover, the social network tools will be the basis for the empirical verifications for the proposed models and hypotheses.

The questions that motivate this research will be divided to two groups. The first group is related to the traditional social and organisational science that will describe the coordination phenomena, and the second group will be related to the research design and verifying in empirically.

Group 1: Coordination as a social networked phenomenon.

1. What are the characteristics of the informal social network that evolves during the outbreak?

2. Does social network measures (namely: centrality, interconnectedness and tie strength) affect the overall formal coordination performance during the outbreak
3. Does these social network measures exhibit different influence on formal coordination *before* and *during* the outbreak?
4. Are these network measures applicable to *informal networks* investigation?
5. Does *informal networks* improve coordination *during* the outbreak and why?

Group 2 Research design and empirical verification

1. Use a proven methodology to develop an instrument to map the inter-organisational coordination during the outbreak and validate the results statistically.
2. Are the reasons that promote *informal* coordination the same as for *formal* one?

1.4. Conceptual framework

The conceptual framework of the research centres on the notion of determining the effect of social network measures (centrality, tie strength, connectedness) on disease outbreak coordination performance. Figure 1-3 presents this concept.

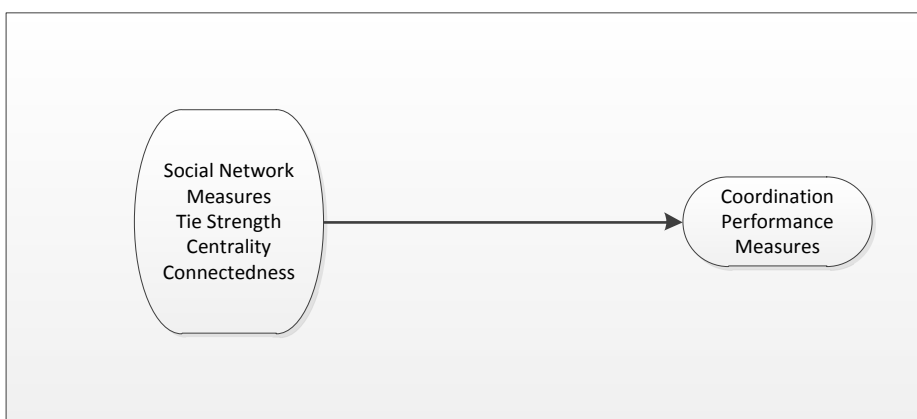


Figure 1-3: Conceptual framework

This modelling is based on the discussed literature, and uses network measures as a means to study coordination as a flat structure rather than hierarchical one. Hence the important node is

not the one that is at the top of the hierarchy, but rather the one that has more connections initiated from it or that is more “*connected to*”. Such connections reflect the importance of the specific node with which everyone is trying to communicate. In some instances such importance might be due to the hierarchical position of that node but in other instances it is due to the acknowledged importance of that node due to the services or resources it provides to others. Hence the coordination is conceptualised as a mesh of interacting nodes embedded in a coalition network of organisations.

1.5. Introduction to the following chapters

This dissertation is comprised of six chapters including this introductory one. The structure of the subsequent chapters is as follows.

Chapter 2 surveys the historical and current literature related to coordination theory. It then considers the dichotomy within coordination theory and the different literature concerning two facets of coordination: formal and informal. The most complex situation requiring coordination is a disaster; therefore three studies are reviewed that explore network theory during disasters: Kapucu studied networks and disaster coordination; Comfort investigated complexity and increased efficiency in disaster response; Zhiang detailed the inter-organisational dynamics during disaster. The tool used in the present study of coordination is social network methods. Thus social network theory is introduced and the work of some of the pioneers in that domain is detailed, such as Granovetter’s work on strong and weak ties, Bavelas’ work on network structure and performance, and Burt’s work on structural redundancy. The chapter then moves into the disease outbreak domain, introducing literature on influenza history and outbreaks, then discussing some of the research that has been done in outbreak management and intervention, and locating the gaps in research on inter-organisational outbreak coordination using network methodology. The chapter concludes by introducing the model and the hypotheses.

Chapter 3 provides the methodological foundation to test the hypotheses proposed. First it provides a brief introduction to SNA and its different aspects including social network data collection, data analysis and overall investigation approach. Then, conceptual descriptions of SNA measures are considered for the coordination models of this study, along with their

mathematical formulae. This is followed by a brief discussion of the qualitative and quantitative forms of data collection. After these theoretical introductory summaries, the chapter moves into particularities of the practical data collection used in the research, first explaining the data collection questionnaire design and how it was piloted to senior health officials. The chapter then details how this instrument was used to build the questionnaire that was the main tool for data collection in the second wave of interviews. The chapter then moves into describing the data collected and how it was synthesised and structured to prepare it for further investigation, as well describing the mathematical method – Redit analysis – that is used to transform data to the format that allows mathematical and statistical handling. The chapter concludes by highlighting the data limitations.

Chapter 4 mainly reports data analysis and findings, stating the results without further elaborating their meanings. This chapter starts with presenting descriptive statistics about the research dataset. Then the methods used to elicit the results from the dataset are detailed. The statistical results and findings are presented for each hypothesis for both formal and informal coordination. For formal coordination, results are presented for both before and after the pandemic. These results demonstrate whether the null hypothesis is correct or incorrect, in turn paving the way for Chapter 5 to elaborate on the results.

Chapter 5 starts by re-stating the primary objectives of this research. Then the results of each hypothesis are presented one by one, along with a comprehensive synthesis of the findings from the network theory and coordination theory in the disease outbreak context. The results are also linked back to the historical research presented in Chapter 2.

Chapter 6 first presents the general findings of this research with regard to theory, method and context. Then the research implications are presented, along with some practical suggestions for inter-organisational network design. Future research directions are suggested, using the methodology of the present study and the dataset collected. Finally, the chapter states the drawbacks of this research.

Chapter 2

2. Towards a Dynamic Coordination Networks for Disease Outbreak

Understanding the coordination required for disease outbreaks is a compelling subject, involving unique complexity in a setting of multi-skilled and multiple agencies that need to utilise existing ties and forge new ones in a dynamic and evolving environment. This chapter reviews theories of social networks and coordination in order to develop a model that determines the influence of some network measures on coordination performance during a specific form of disaster, which is pandemic.

The chapter begins by introducing coordination theory development in the academic literature, examining the facets of coordination and highlighting the importance of both formal and informal coordination. Then complex environments and their characteristics are discussed as a prerequisite to explaining the need to provide new theoretical and modelling techniques for coordination in such increasingly prevalent systems. It is proposed that network analysis method is a good candidate to capture the complexity of such coordination, which leads to a discussion of network theory. A new extension to coordination theory is then proposed, involving formal and organic coordination that will facilitate understanding and modelling coordination in complex environment.

2.1. Coordination Theory

The concept of coordination was born when humans first recognised that they needed to put their efforts together in order to accomplish a goal that none of them individually could achieve, like killing a mammoth. The reward was also shared among all the participants. As the complexities of human life increased and organisations evolved, the importance of

coordination was emphasised (Malone and Crowston, 1990). Along with this arose the need to formulate coordination, and researchers and scientists approached it from diverse perspectives.

2.1.1. Overview of coordination theory

Coordination theory and definition can be traced back to the 1950s with the early definition of March and Simon (1958). Figure 2-1 elaborates the development of coordination theory thinking by superimposing it on a timeline.

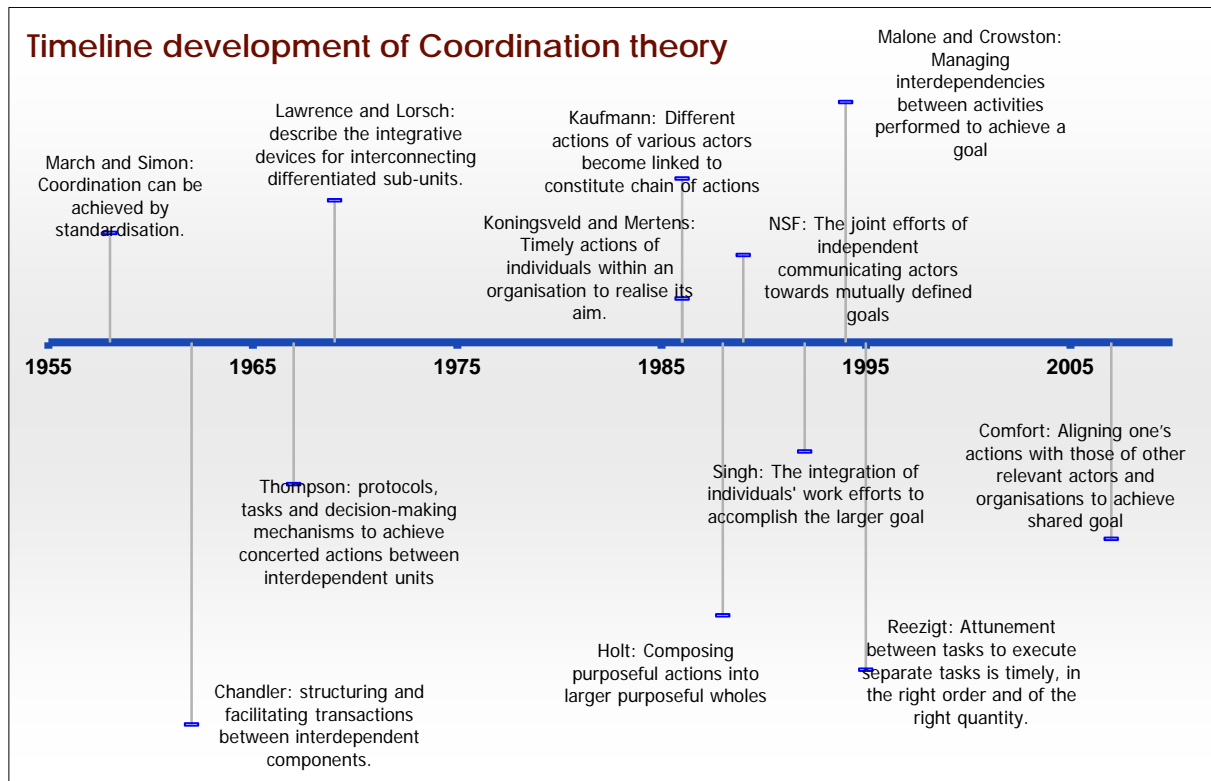


Figure 2-1: Timeline development of coordination theory

The above timeline is also illustrated in Table 2-1 (Weigand et al., 2003):

Table 2-1: Some definitions of coordination partially adopted from (Weigand et al., 2003) with some additions that reflect updated definitions

Coordination can be achieved by standardisation (March and Simon, 1958).
Coordination is structuring and facilitating transactions between interdependent components

(Chandler, 1962).
Coordination consists of the protocols, tasks and decision-making mechanisms designed to achieve concerted actions between interdependent units (Thompson, 1967).
Coordination describes the integrative devices for interconnecting differentiated sub-units (Lorch, 1969).
Coordination happens insofar as different actions of various actors become linked to constitute a chain of actions (Kaufmann, 1986).
Composing purposeful actions into larger purposeful wholes (Holt, 1988).
Networks of human action and commitments that are enabled by computer communications technologies (NSF, 1989)
Actions and decisions of individual actors within an organisation which need to be timely attuned for the organisation as a whole to realise its aim (Konigsveld and Mertens, 1986).
The integration and harmonious adjustment of individual work efforts towards the accomplishment of a larger goal (Singh, 1992).
Coordination is the act of managing interdependencies between activities performed to achieve a goal (Malone and Crowston, 1994).
Establishing attunement between tasks with the purpose of ensuring that the execution of separate tasks is timely, in the right order and of the right quantity (Reezigt, 1995).
Coordination means aligning one's actions with those of other relevant actors and organisations to achieve a shared goal (Comfort, 2007).

In the above literature on coordination, the early definitions primarily focused on departmentalisation of the organisations in an era when the organisations and departments were considered static entities. March and Simon (1958) argued, “under some conditions, coordination can be achieved by standardization”. An important assumption is that applicable situations are relatively stable, repetitive, and few enough to permit matching of each situation with appropriate rules (Thompson, 2003). March and Simon (1958) also introduced the concept of “coordination by feedback” that can be applied to reduce the communications required from day to day. Lawrence and Lorsch (1967) described coordination as entailing the

integrative devices or integrators that “are designed to facilitate collaboration among functional departments at all management levels.”

Coordination is analogous to glue, according to Holt (1988); purposeful actions are composed into purposeful wholes. Thus coordination serves to establish relationships between tasks and their products and is a prerequisite to accomplishing other purposes.

Comfort (2007) studied coordination during crisis management and linked it to communication and control as being the triple c’s; hence “coordination means aligning one’s actions with those of other relevant actors and organisations to achieve shared goals” and “the capacity for coordination depends on effective communication”.

The later literature evolved by introducing “interdependency” as a key term to describe coordination. This was accompanied by the advancement of information and communication technologies (ICT) as well as by organisational development from hierarchical structures into more complex ones that could not be handled by a single person’s perspective (Weigand et al., 2003); hence completely centralised control became simply infeasible (von Hayek, 1945).

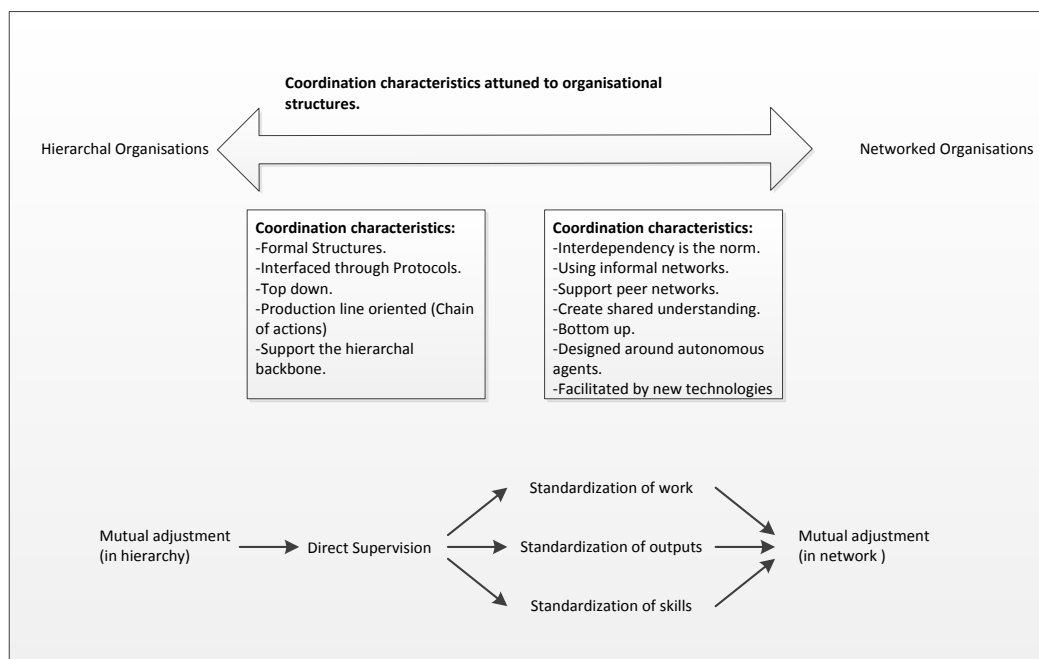


Figure 2-2: Coordination development with organisations along with the evolution of coordination mechanisms (lower part adopted from (Mintzberg, 1979))

Figure 2-2 further illustrates the different characteristics of coordination as it phases between hierarchical structures and networked ones, superimposed on Mintzberg's well-known coordination mechanisms. The new mutual adjustment or horizontal coordination (Weigand et al., 2003) are the most significant contemporary development in organisation design (Mintzberg, 2007).

From the above it can be concluded that coordination in its simplest concept is the genre that brings activities together to achieve one goal (Chisholm, 1992). It describes both a process and the goal. Coordination is further seen as deserving importance due to the complexity and lengthening of chains of interdependent actions (Kaufmann and Franz-Xaver, 1986). The Oxford Dictionary defines coordination as "harmonious combination of agents or functions toward a production of result" (Chisholm, 1992). The concept of coordination has evolved significantly along with its mechanisms, hence it is important to introduce new practical research that reflects these new developments yet is founded on solid theoretical background. This last sentence provides a motive for presenting a new paradigm of disease outbreak coordination.

2.1.2. Review of coordination theory

Coordination is increasingly seen as important as organisations are becoming more reliant on interdisciplinary teams of specialties and distributed operations for addressing complex situations demanding multi-organisational responses (Faraj and Xiao, 2006). (Malone and Crowston, 1990) were the first to propose an interdisciplinary science of coordination (Weigand et al., 2003). They defined coordination as "managing interdependencies between activities" (Malone and Crowston, 1990). This definition is consistent with a long history in organisational theory of emphasising the importance of interdependence (Thompson, 2003, Lawrence and Lorsh, 1967, Pfeffer, 1978, Roberts and Gargano, 1989).

Malone and Crowston (1994) tried to quantify these dependencies, along with the basic processes involved in the coordination act, by providing a non-exhaustive table (Table 2-2) for the processes and dependencies..

Table 2-2: Examples of common dependencies between dependencies and processes (Malone and Crowston, 1994)

<i>Dependency</i>	<i>Examples of coordination processes</i>
Shared resources	First come first serve, priority order, budgets, managerial decisions (hierarchy), market-like bidding (markets)
Task assignments	
Producer / consumer relationships	
Prerequisite constraints	Notification, sequencing, tracking
Transfer	Inventory management (e.g. “just in time”, “economic order quantity”)
Usability	Standardization, ask users, participatory design
Design for manufacturability	Concurrent engineering
Simultaneity constraints	Scheduling, synchronization
Task / subtask dependencies	Goal selection, task decomposition

This approach enables the identification and analysis of a wide variety of dependencies between tasks and their associated coordination processes, followed by allocating them to the relevant actors (Grant, 1996). It sets the task in focus as the goal and then builds an actor-dependency relationship with it. Such typology provides a theoretical framework to propose coordination structures that are needed for successful modelling of coordination. This model is the “pattern of decision making and communication among a set of actors who perform tasks in order to achieve goals (Malone, 1987). Malone suggests four coordination models that conceptualise centralised and decentralised market and product hierarchies. These models require identifying the task that is the subject of coordination, and then selecting the appropriate structure. These models are:

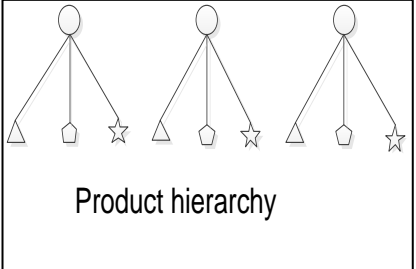
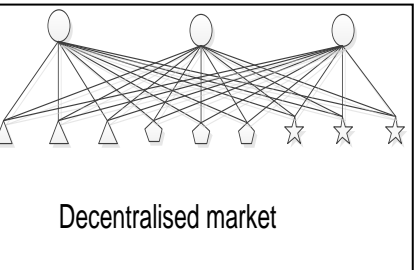
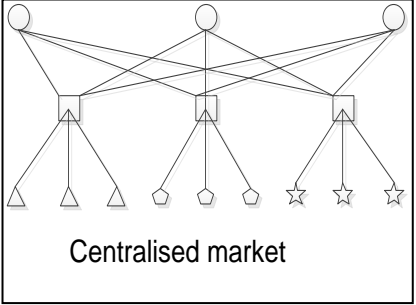
1. Product hierarchy: This term is used for “mission oriented” divisions or separate product divisions. These divisions might be based on products, geographical regions or market segments. Each division has a manager – who can be called a product manager – and has separate departments supporting different functions or specialised processes such as marketing, manufacturing and engineering. Each one of these divisions is a processor. As a task arises, the product manager assigns it to the suitable processor. The product manager is the link coordinating between

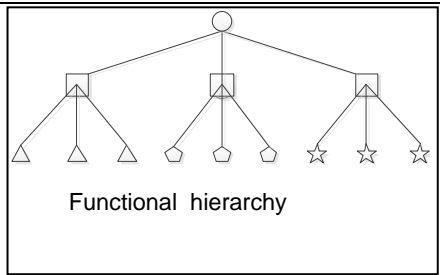





different processors for any interdependent tasks. The consequence of this is that if a processor fails, only the product division it supports will be affected. An example is the production of flu-related drugs and other equipment (such as ventilators or personal protective equipment (PPE)). So if Tamiflu production – or even distribution – is disrupted, it should not affect PPE production or distribution since each is considered a separate product and has discrete distribution networks.

2. Functional hierarchy: This is when number of processors of similar types are pooled in functional departments under a functional manager shared among products. This reduces duplication of effort and may allow processing loads to be balanced over all products. Each functional department has a functional manager connected to an executive office at the top of the hierarchy that decides which tasks need to be done to produce all the products of the organisation. This structure is more complex than the product hierarchy structure because of the extra layer of management involved. This can be exemplified in pandemic management if a hospital becomes infected. Eventually, all the patients that might be admitted to this hospital need to be reassigned to other ones. This structure is also susceptible to another type of failure: if the product manager or the executive office fails, then the processing of the entire organisation may be disrupted. One example of this is when the functional department responsible for the distribution of vaccines fails, which will disrupt the whole distribution process.
3. Decentralised markets: In such markets, all buyers are in contact with all possible suppliers and they make their own decisions about which transactions to accept, without a middleman. Here suppliers play the role of processors and buyers that of product managers. It is assumed that each buyer has a communication link with each supplier. This decentralisation implies that if one processor fails the task can be can be reassigned to another one. An example of the market model is when patients have the freedom to buy Tamiflu from any private pharmacy as they are using their own financial means.
4. Centralised market: In a centralised market, brokers mediate between buyers and all possible sellers. This centralisation of decision-making means substantially fewer connections and messages than in a decentralised market. The broker plays

the role of the functional manager and has communication links to each buyer and supplier. The broker then plays the role of assigning tasks to the best supplier. For an illustration of this in the disease outbreak coordination context one can look at how some specific services or resources are aggregated under certain agencies. For example, “ambulance” distributes the stockpile of vaccine whereas “population health” disseminates information to Area Health Service agencies. Hence ambulance is the broker for the vaccine, and population health is the broker for information. The processors are pharmacies and general practitioners (GPs) for the former, and any agency that distributes information directly to the public for the latter (like public health units).

Table 2-3: Coordination models according to Malone 1987, along with their advantages/disadvantages and examples from disease outbreak management

Malone's coordination models	Advantages/Disadvantages	Example(s)
 <p style="text-align: center;">Product hierarchy</p>	<p>Advantages:</p> <ul style="list-style-type: none"> -Processor failure will affect only one product division. <p>Disadvantages:</p> <ul style="list-style-type: none"> -Duplication of effort can occur between product divisions. 	<p>Production of flu drugs and PPEs. Each is a different product that is manufactured by a separate functional division.</p>
 <p style="text-align: center;">Decentralised market</p>	<p>Advantages:</p> <ul style="list-style-type: none"> -If a processor fails the task is reassigned to another processor. <p>Disadvantages:</p> <ul style="list-style-type: none"> -High communication cost per task. 	<p>Patients approaching pharmacies to buy Tamiflu or vaccine.</p>
 <p style="text-align: center;">Centralised market</p>	<p>Advantages:</p> <ul style="list-style-type: none"> -One general contractor (product manager) can fail without disrupting production of other products. <p>Disadvantages:</p> <ul style="list-style-type: none"> -Production is disrupted if broker (or functional manager fails) 	<p>Resources aggregated under specific agencies, e.g. ambulance distributes stockpile of vaccine whereas population health disseminates information to Area Health Service agencies.</p>

 <p style="text-align: center;">Functional hierarchy</p>	<p>Advantages:</p> <ul style="list-style-type: none"> -Reduces duplication effort and allows loads to be balanced across products. <p>Disadvantages:</p> <ul style="list-style-type: none"> -If a functional manager fails, the processing for the whole organisation may be disrupted. 	<p>Hospital admissions in pandemic case: if a hospital is infected or full, patients can be reassigned.</p>
<p>Key</p> <ul style="list-style-type: none">  Product Manager  Functional Manager  } Task Processors of Different types  }  } 		

In summary, Malone and Crowston’s (1987) main contribution in defining coordination theory is:

- A succinct and actionable definition of coordination.
- A framework for task analysis and modelling for collective processes.
- The beginning of a typology of dependencies and coordination mechanisms (Crowston and Rubleske, 2004).

2.1.3. Evolution of the coordination research

Coordination theory definition has progressed since its inception around the middle of last century, as discussed. This progress was guided by market theory and the development of new

communication and collaboration tools. Market specialisation has put more emphasis on coordination, since any task will need the combined expertise of many parties.

Historically, most coordination research is affected by the factory-product theory. This means that coordination takes place in a static environment where the final product is defined and the tasks and dependencies are identified accordingly. Coordination in such environments enjoys a long dormant period of planning and preparation before application in the workspace. In this situation, coordination occurs between formal channels, with minimal surprises or external perturbations; hence it can follow the four models proposed by Malone.

With the advancement of technology and evolution of complex products and organisational structures, research started to discuss coordination systems as complex adaptive systems (CASs) (Comfort et al., 2001, Uhr et al., 2008). Hence coordination inherits some of the characteristics of CASs' important aspects being self-organisation and system emergence (Drabek and McEntire, 2002). Most of this research is performed in the relation to disaster coordination scenarios, where it is widely acknowledged that coordination is necessary and that it does not follow structured or planned procedures, but rather it rightfully trespasses into the complexity domain.

Adding the social context to coordination resulted in discussing two branches for coordination, the formal and informal coordination (Chisholm, 1992). The formal one is the one according to the structured organisation, and the informal one is based on the social interaction and influence.

Coordination as a theory has further progressed; especially with the acknowledgment that it is an interdisciplinary domain. This is expected to have the positive effect of making the concept itself flexible. It is evident that coordination is contextualised in different applications and domains. This contextualisation also applies to coordination mechanisms, modelling and measures (Comfort, 2007, Harris et al., 2008, Krauss et al., 2004, Abbasi et al., 2010). Thus researchers are developing different coordination models and mechanisms for different environments (Dawes and Government, 2004, Denis, 1995, Edgington, 2010, Moore et al., 2003). Some of these, as we have seen, are based on product or market hierarchy or centralisation; other mechanisms are based on direct supervision, standardisation (Mintzberg,

1979) or feedback (March and Simon, 1958). An evolving trend is the use of network structures to model complex coordination situations, especially in large environments (Borgatti and Foster, 2003, Kwait et al., 2001b). This aspect is further elucidated in later sections of this dissertation.

Frameworks have been proposed to model coordination in complex and dynamic environments, and scholars have considered how such frameworks can be systematically used to develop a coordination model for a specific type of network situation in a complex and dynamic environment (Hossain and Uddin, 2012). A continuing deficiency in coordination research is the lack of generic performance measures as determinants for coordination success or failure. This probably due to the fact that coordination covers a wide spectrum of domains and activities, so that measures are inapplicable across all domains.

2.1.4. Limitations of current coordination research

Malone's seminal studies have successfully established coordination as an interdisciplinary approach. Its strength is the recognition of the complexity of interdependencies in organisational work. It is a step forward from previous coordination models, yet there is still a need to address certain limitations. Some of these are:

- High velocity environments: Conceptually this notion was introduced by Eisenhardt and Bourgeois (Eisenhardt and Bourgeois, 1988) . These environments are characterised by rapid and continuous change in four domain; demand, competition, technology and regulation (Vilkamo and Keil, 2003). In these environments there is the need for rapid and error-free decision making (Faraj and Xiao, 2006). There are also competing needs for formal hierarchal structures versus flexible ones, on-the-spot decision making, and informal coordination modes. In these contexts organisations paradoxically emphasise both formal and improvised coordination mechanisms (Faraj and Xiao, 2006, Bigley and Roberts, 2001, Brown and Eisenhardt, 1997).
- Modelling dynamic coordination: The four coordination models proposed by Malone (1987) impose the precondition that the environment is perceived or predictable enough to allow interdependencies or activities to be characterised sufficiently for predefined mechanisms to be designed for various contingencies. In other words, the

processing demands of the predicted environment are matched by the interdependent activities that are generated by those interdependent organisational units (Faraj and Xiao, 2006). In dynamic environments like disaster management, however, such models fall short of reflecting the true complexities, uncertainties and the variability of the needs and tasks that will be driving coordination processes.

- **New breed of tasks:** Nowadays organisational tasks are not limited to manufactured products. New products have evolved, such as information and knowledge that are sometimes are far more complex than factory-produced products. Hence there is the need to reconceptualise coordination to focus on the content (what is being coordinated) as the mode of coordination rather than the traditional emphasis on how (i.e. the mode) and when (circumstances) to coordinate. This distinction becomes increasingly important in complex knowledge work where there is less reliance on formal structure, interdependence is changing, and work is primarily performed in teams. Complex knowledge work requires the application of specialised skills and knowledge in a timely manner; difficult coordination issues are raised in dynamic and time-constrained environments (Faraj and Xiao, 2006, Faraj and Sproull, 2000, Gittel, 2002).
- **Measuring coordination performance:** As Malone stated, “We sometimes notice coordination most clearly when it’s lacking”, that is, when a supposedly coordinated task fails – such as when we spend hours stranded on an airport runway because the airline cannot find a gate for our plane (Malone and Crowston, 1990). Yet there is no unified framework to measure the efficacy – or lack – of coordination. Each environment develops its own framework to measure coordination gaps, based on the contextualised situation (Rathnam et al., 1995).

2.2. Coordination in Dynamic Environments

Organisational structures have developed from monolithic closed systems based on mechanistic and “centralised communication network for the performance of certain classes of tasks” models to open, dynamic, nonlinear systems subject to internal and external forces (Comfort et al., 2001). These systems consist of interconnected components and exchange resources with the environment where “the appropriate structure for an organisation depended

on the nature of technology and task environment” (Scott, 1981, Galbraith, 1973, Lawrence and Lorsh, 1967). These concepts began to diffuse in the 1960s (Anderson, 1999). Daft and Lewin (1990) suggest that organisations are enormously complex and therefore cannot be dealt with using a normal mechanistic mindset (Thiéart and Forgues, 1995, Jauch and Kraft, 1986, Fombrun, 1986, Quinn and Cameron, 1988, Weick, 1977).

Acknowledging the complexity of organisations requires new approaches to understanding coordination and to modelling the “interdependent delivery systems” (Hage, 1975) between organisations to achieve goals that are “too big for one organisation to handle” (Alexander, 1993, Ven et al., 1975). This makes organisations reliant on each other and hence increases the need for coordination to achieve tasks that no single organisation has the skills or resources to address (Coze, 2005). According to Thomson (1967), “the complex organisation is a set of interdependent parts which together make up a whole in that each contributes something and receives something from the whole, which in turn is interdependent with the larger environment.” Much research literature has followed this line of thinking, contributing to understanding of the nonlinearity dynamics of organisations (Gemmill and Smith, 1985, Smith, 1986, Rasmussen and Mosekilde, 1988, Stacey, 1993). Such understanding only emphasises the importance of coordination in today’s multi-tasked specialised world.

2.2.1. Dichotomy in coordination research

“The increased complexity of the organisational coordination approach created new avenues to study effective coordination”, as has been articulated by Chisholm (1992). Although the contention that higher levels of interdependence in a system demand more coordination is empirically strong, the argument that only formal schemes of centralised character can provide coordination remains weak. Because “that position has been held so tenaciously, other highly effective devices for coordination have been ignored, and their latent utility wasted” (Chisholm, 1992).

Thus a dichotomy in coordination research appeared, giving rise to studies of formal and informal coordination. Formal coordination is mechanistic, in accordance with standard operating procedures, whereas informal coordination is “organic”, developing spontaneously within – and extending beyond – organisations (Hobday, 2000, Lansley et al., 1974).

2.2.2. Formal coordination in dynamic environments

There is much more to be said about the new dynamic organisational structures; however, the best conclusion that can be drawn from the above elaboration is that organisations are now more networked (Salancik, 1995). They are more interdependent on each other to deliver the intended service or product. This networked system is further supported and assisted by the spread of reliable, low-cost technological communication solutions and collaboration tools. Most if not all organisations or departments, except perhaps military ones, no longer have a single line of authority. There are multiple lines of communication, some of them authoritarian, some advisory, some with information flow, and some concerning resource distribution. Most of these lines of communication or coordination are established according to need, i.e. are not permanent. They are initiated and dropped and then initiated again ... multiple times if both organisations at both end points deem it worthy to communicate. This means that these communications are temporal, ad hoc, mutually adjusted and hence dynamic (Mintzberg, 1979). In such new dynamic and complex organisational environments, the standard hierarchal coordination structures are no longer adequate. We need to look at coordination in dynamic contexts to adapt to complex environments. Such coordination is looked upon as an emerging type that is a typical CAS (Atkinson et al., 2005, Uhr et al., 2008, Comfort et al., 2001).

2.2.3. Informal or organic coordination

Another important form of effective coordination is what Chisholm (1992) calls “coordination without hierarchy” otherwise known as informal coordination.

(Roethlisberger et al., 1939) stated, “Too often it is assumed that the organization of a company corresponds to a blue print plan or organization chart. Actually it never does”. Historically, organisations have been viewed through the organisation chart lens (Chung et al., 2005) that shows formal relationships like reporting lines and work divisions. However, research confirms that humans transfer their social behaviour to their organisations (Mayo, 1949), thus creating informal networks virtually in every organisation. Organisations are more and more conceived as embedding a web of coalitions which is an important dimension of

organisational life (Waldstrøm, 2001, Morgan, 2006). Cross, Borgatti et al. (2004) even specified that “work increasingly occurs through informal networks of relationships rather than through channels tightly prescribed by formal reporting structure of detailed work processes”. They deduced that “supporting collaboration and work in these informal networks is increasingly important for organisations”. These networks are not part of the design of the organisation, yet they are pervasive factor of the life of organisation; they cannot be controlled, merely observed and influenced at best (Waldstrøm, 2001).

One reason to establish informal networks is “to get things done”, when individuals in organisations tend to seek help and exchange favours with others (Baker, 1981, Han, 1983). Hence informal coordination fills the vacuum that exists in formal coordination. It capitalises on existing coordination channels to circumvent their complications, inefficiencies, even their inaccuracies. To better understand how formal and emergent coordination work, the self-explanatory illustrations from Chisholm (1992) are presented in Figure 2-3.

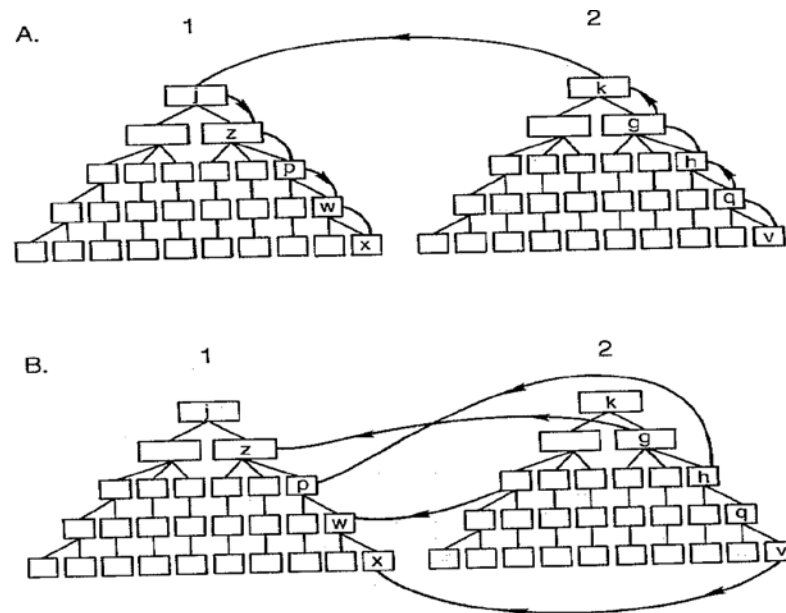


Figure 1 Formal and Informal Channels

Figure 2-3: Formal and informal channels, from Chisholm (1992)

Situation A shows how the formal channels operate between organisations 1 and 2. Intra-organisational communication must go through the formal layers of the hierarchical structure before inter-organisational communication occurs through the designated channel. This is usually somewhat laborious and time consuming. In situation B, where emergent informal

communication occurs, there are more direct and shorter communication channels between the same two organisations, meaning that people needing to talk to one another simply do so directly.

Informal emerging communication is built around reciprocity and trust that cut through the layers of authority, enabling direct contact between parties and providing an effective remedy for slow formal channels. It helps when formal structures mal-adapt to their environment such as forcing the formal structure into a situation when the design is inappropriate. Informal structure will solve these problems without formal redesign, and without failure. Going even further, Landau (1979) suggested that all formal structures have built-in obsolescence; thus, informal mechanisms need to be developed for an organisation to continue to prosper while buying time to make careful changes.

2.2.4. Ambidexterity in organisations

Another way to look at organisational operations in dynamic environments is ambidexterity. As a concept, ambidexterity refers to that the organisation needs to master two diametrically opposed qualities, adaptability and alignment. An example given of this is tennis players using both hands, separately, to play strokes during a rally (Birkinshaw, 2005). *Adaptability* means that organisation should quickly seize new opportunities and rapidly adjust to new situations. They must avoid complacency. An adaptable company is nimble, innovative and proactive. On the other hand, as well as adapting to new circumstances organisations need to make the most of an existing situation. This is where the quality of *alignment* is important. Alignment is about exploiting proprietary assets, rolling out existing business models quickly and stripping costs out of existing operations (Birkinshaw, 2005).

It is very difficult to strike a good balance between the two. Focus too much on alignment and the short-term results will look good, but changes in the industry will blindside the organisational management eventually. Equally, too much attention to the adaptability side of the equation means building tomorrow's business at the expense of today's one (Bröring and Herzog, 2008).

2.3. Theories of Social Networks and Analysis

Network analysis provides the opportunity to visualise the coordination matrix and investigate the relationships in correlation with coordination requirements, outcomes and performance. For correct assessment, the most appropriate measures need to be applied when the whole networked structure is examined. These measures are called social network measures and this field of study is interdisciplinary in origin. Its concepts have developed from social theory and its application has been linked with mathematical, statistical and computing methodologies (Borgatti and Foster, 2003).

By virtue of his “inventing” the sociogram, Moreno (1953) can be depicted as the father of sociometry, which in the early days was defined as “the measurement of interpersonal relations in small group” (Wasserman and Faust, 1995). Sociometry led to deeper insights about group dynamics (Forsyth, 2009). Simply, the sociogram is a depiction in which people are represented as nodes in two-dimensional space and the relationships among pairs are lines linking the corresponding points. Subsequently, sociograms became multidimensional (Laumann and Pappi, 1973, Laumann and Knoke, 1987) and have been used to study group corporate interlocks (Levine, 1972), roles, and structures in groups (Burt, 1976). Sociometry was further strengthened by the introduction of analytical techniques which brought the power of mathematics to the study of social systems (Forsyth and Katz, 1946).

Soon enough, especially with the maturity of its mathematical, empirical and statistical techniques, social network methods of analysis became attractive to researchers in a wide range of domains such as organisational relationships (Alter and Hage, 1993). On the empirical side, some organisation researchers began to use network concepts (Chapple and Sayles, 1961, Whyte, 1943, Tichy et al., 1979). On the experimental side, the studies of Bavelas and Leavitt conceived of group structure explicitly in network terms (Leavitt, 1951, Bavelas, 1950).

2.3.1. Introduction to Network Theory

This section begins by discussing network concepts and then elaborates on how they can be used in analysis of inter-organisational coordination.

Certain notions lie in the heart of network analysis modelling: namely actor, relational ties, and groups (Wasserman and Faust, 1995). A brief definition of these follows:

1. Actor: The term “actor” is used to represent the social entity, or node. Actors can be individuals, corporates, or collective social units (departments, nation states).
2. Relational ties: These are ties that represent the existence of relationship between a pair of actors. These relationships can have different manifestations, some common examples of which are:
 - a. Evaluation of one person by another (friendship, liking or respect)
 - b. Transfer of material resources (business transaction, borrowing or lending things)
 - c. Association or affiliation (belonging to same organisation)
 - d. Communication interaction (talking together, sending messages)
 - e. Movement between places or statuses (migration)
 - f. Physical connection (road, river, or bridge connecting two points)
 - g. Formal relations (authority, marriage)
 - h. Biological relationship (kinship)
 - i. Geographical proximity (actors in the same place at the same time)
 - j. Partnership (marriage, corporate board, shared project).

These ties on a small scale are represented as dyads (relationships between a pair of actors) which are helpful in understanding the type of relationship between those actors, for example, whether the relationship is reciprocal or not. Another building block for networks is the triad, which is the relationship between three actors and the possible ties between them.

3. Groups: The power of network analysis lies in the ability to model the relationships among systems of actors, and that is where groups come in play. A group is a collection of all the actors whose ties are to be measured for conceptual, theoretical or empirical reasons.

Although the network structure was originally used to analyse human social structures, the modelling technique became attractive to other fields including inter-organisational coordination. In that context, the definitions can be modified to (Alter and Hage, 1993):

1. Networks are clusters of organisations operating as non-hierarchical collectives of separate units. This structure permits inter-organisational interactions of exchange, concerted action or joint production.
2. Networking is the act of creating or maintaining organisational clusters for the purpose of exchanging, acting or producing among the member organisations. This act results in creating the network ties discussed above.
3. Boundary spanners are individuals who engage in networking activities and employ methods of coordination across organisational boundaries (Katz and Kahn, 1978, Aldrich, 2007).

Adopting network theory to investigate organisational theory and coordination resulted in new methods for explaining and quantifying the configuration of relationships among organisations. These stemmed from investigating dyadic relationships between two organisations and trying to understand relational properties such as the resources transacted between them. More interesting, however, was the application of network theory to triads and larger inter-organisational networks (IOR). This provided a wealth of information about lateral non-hierarchical linkages and clusters formed between agencies (Tichy et al., 1979, Van de Ven et al., 1979).

The next section presents three theories that have greatly shaped and enhanced network theory. These theories have explained the network's structural influence on communication and collaboration. Some of these theories consider only node level attributes whereas others inspect network level properties. These theories are used as building blocks for further analysis in later sections and chapters.

2.3.2. Bavelas on network structure and performance

Alex Bavelas conducted his experiment in the Small Group Network Laboratory at the Massachusetts Institute of Technology (MIT) in the late 1940s. This experiment began with the realisation that problems of working relationships, especially communication, arose when tasks needed to be performed by groups rather than individuals. Hence Bavelas (1950) designed an experiment to investigate the effect of group structure on group performance. It involved the communication patterns in Figure 2-4:

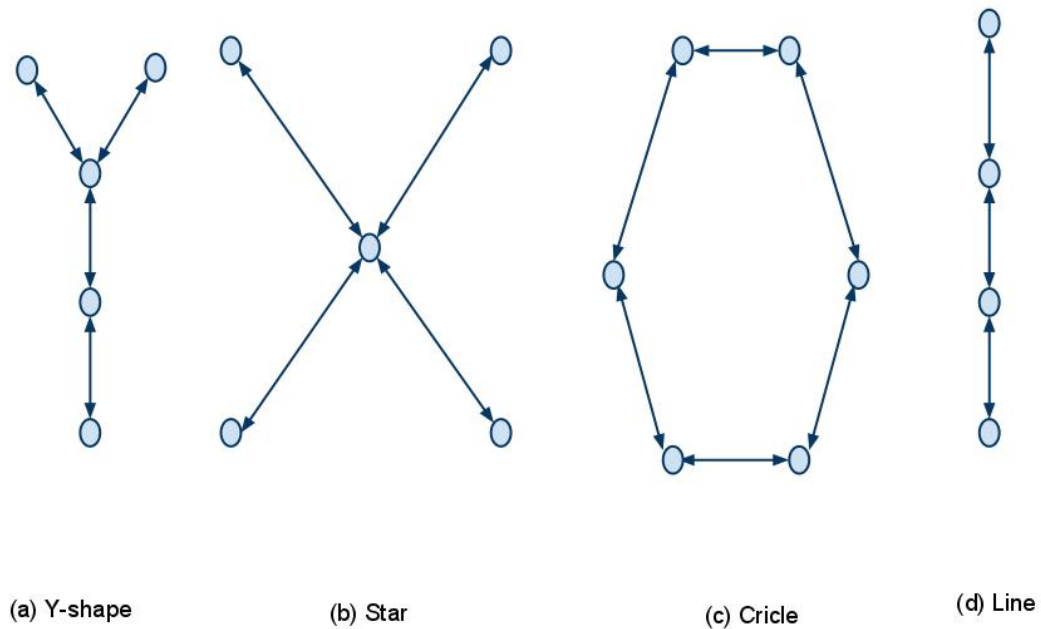


Figure 2-4: Communication patterns investigated by Bavelas

This experiment addressed the questions: What are the effects of these communication patterns on the emergence of leadership, development of organisation, Subjects' morale, Communication effectiveness, and task performance?

In the experiment, five people were placed in enclosed cubicles and were able to communicate only by passing messages through opening slots to solve a puzzle. The slots were arranged so that any desired communication pattern of the images in Figure 2-9 could be imposed. Each subject was given cards showing the symbols O, *, \diamond , Δ , +, \square , with one symbol per card. Four of the symbols appeared at most four times, and one symbol appeared only five times representing the solution for the puzzle. Each cubicle had six switches corresponding to the symbols, and subjects could press a switch when they assumed that they had solved the

puzzle. The experiment was considered solved when all five subjects pressed the common symbol. The process was repeated 15 times. The aim was to find the common symbol in shortest time and with the minimum possible communication among the subjects.

Analysis of the structural properties showed that the centralised structure resulted in higher performance than the circle structure. The highest performer was the star structure (called wheel) followed by the “Y”, then the line, and last came the circle. When a central node existed, it was used as the main forwarding point for all subjects. Then this node made decisions to transmit messages, resulting in a shorter time and lower number of messages to solve the puzzle (Bavelas, 1950).

Behaviour-wise, node level analysis revealed that a leader emerged in the wheel structure by the fourth or fifth trial, as the centre of the wheel, and remained in use throughout (Leavitt, 1951). This emergent leadership led to better performance and higher morale across the structure in comparison to other structures. Expectedly, the next best structure was the “Y”, followed by the line and finally the circle.

These results proved that centralised networks are more efficient in transmitting information and hence in performance than decentralised ones, in which the information is routed around inefficiently. The results seemed to go hand-in-hand with the hierarchical structure methodology prevalent in the organisational domain at that time.

Bavelas’ experiment was followed within five years by an experiment conducted by Guetzkow and Simon (1955), who evaluated different structures for solving complex tasks. They examined three structures, as shown in Figure 2-5:

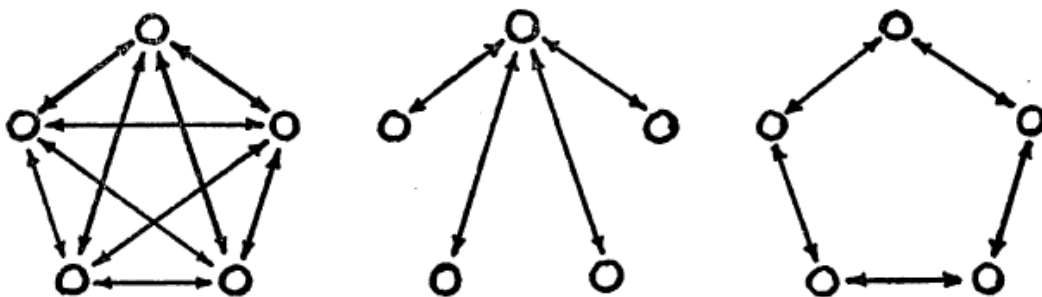


Figure 2-5: Communication patterns investigated by Guetzkow and Simon

It was realised that the performance of a structure depended on how well the channels of communication were used rather than on the structure per se. So, assuming that there is no tie overload, the “all channels” structure has reconfigurable capacity for task-relevant communication. The actors enjoy the following benefits:

1. Having the opportunity to negotiate the direction of communication
2. Communicating details about the type of the task
3. Electing whether specific nodes are brokers of communication.

Also, the actors need to solve two problems:

1. Developing an organisational scheme suitable for finding the common symbol
2. Finding the common symbol.

Guetzkow and Simon (1955) proved that, when tasks become more complex, decentralised network structures tend to be more efficient than the rigid network structure with pre-defined communication patterns.

The experiment of Bavelas (1950) was an eye-opener to the correlation between network structure and its effect on task solving. It highlighted the correlation between performance and network structure, and motivated more researchers to study for such correlations for both simple and complex tasks (Chung et al., 2005).

2.3.3. Granovetter on strong and weak ties and diversity of performance

Bavelas and others demonstrated the implications of network structure on information flow. However, another avenue to be investigated was the effect of the actor’s location on such processes.

To elaborate, the location of an actor in a network is a function of its relations with other actors. The number of these relations and their strength has perceptual consequences on the embeddedness of the actor within the whole structure. On the other hand, these relations determine the novelty of the information to which this node has access from other nodes. This is what the theory of “the strength of weak ties” explores. Granovetter (1973a) analysed the process of interpersonal network to provide “the most fruitful micro-macro bridge...where the

interaction in small groups aggregates to form large scale patterns” (Granovetter, 1973c). His argument starts from the fact that actors with similar characteristics or interests tend to cluster together such that they all become mutually connected. These strongly tied cliques have information shared and circulating quickly within them. As a result, this information becomes redundant or obsolete in a short time. On the other hand, links to actors or nodes outside these cliques have the advantage of passing novel information not shared among the clique members.

Yet subsequent research by Krackhardt (1992) emphasised “the strength of strong ties”, especially in the generation of trust within propagators of major organisational change (Chung and Hossain, 2009) . This dichotomy was further investigated by Hansen (1999a), who studied the association between the characteristics of knowledge transferred and the tie strength. He proposed the conceptual model shown in Table 2-4. Knowledge association with tie strength

Table 2-4. Knowledge association with tie strength, adapted from Hansen 1999.

Knowledge	Tie strength	
	Strong	Weak
Non-codified, dependent	Low search benefits, moderate transfer problems	Search benefits, severe transfer problems
Codified, independent	Low search benefits, few transfer problems	Search benefits, few transfer problems

Hansen’s (1999) findings showed that weak ties help a project team to search for useful knowledge in other subunits but impede the transfer of complex knowledge, which tends to require a strong tie between the two parties to a transfer. Having weak ties speeds up projects when knowledge is not complex but slows them down when the knowledge to be transferred is highly complex.

Reagans and Zuckerman (2001) further illustrated that where knowledge-intensive work is involved and where knowledge transfer and receipt of useful information is crucial for performance, then strong ties rather than weak ones facilitate complex knowledge transfer, especially to heterogeneous audiences .

2.3.4. Burt on structural redundancy

Burt published his influential contribution to network theory in 1992. His proposal represented a new paradigm, where the focus was on network positions besides network structure and network relations. His theory elucidated that actors will gain competitive advantage if they efficiently and effectively optimise their network connections. His contribution is known as the “structural holes” theory.

As early as the mid-last century, it has been noted that research on groups has identified that there is a limit for the individual’s ability to maintain large number of ties with other actors (Hare, 1952, Bales, 1950). Then Burt formalised this by arguing that there are limits to the volume of information people can use intelligently as well as to the links they can maintain. Therefore contacts should be established “where useful bits of information are likely to air” (Burt, 1992). Those who seek novel and, more importantly, non-redundant information, should consciously and selectively establish links to network clusters with which they, or any one from their own cluster, do not currently have a relationship. This chasm is what Burt defined as a “structural hole”. It is the nonexistence of a tie that would otherwise link unconnected clusters. Actors who bridge these holes will have access to information and control benefits not obtained by others. They will enjoy competitive advantage and elicit opportunities otherwise absent for those who do not span the chasm.

Chung (2006) noted that “closer examination on the crux of structural holes theory reveals that it is based on the assumption of betweenness centrality: that power and influence accrue to those who broker connections between unconnected groups of people”. Burt capitalised on and extended betweenness centrality to “explain the role of brokerage as a form of obtaining structural autonomy which leads to improved performance, getting ahead and obtaining good ideas” (Chung and Hossain, 2009) .

2.3.4.1. Redundancy types

Burt (1992) differentiated two types of redundancy, redundancy by cohesion and by structural equivalence.

Redundancy by cohesion is when contacts are connected by strong relationships and the ego (you) is connected to all of them, as illustrated in Figure 2-6. An example is the family relationship (father and sons, brothers and sisters). Relationships with these contacts provide the same network benefits.

Redundancy by structural cohesion is when the ego is connected to contacts that in turn have the same contacts, as in Figure 2-6 each one of these contacts has no direct ties to one another, yet each leads to the same cluster of more distant contacts. The information that comes to them, and the people to whom they send information, are redundant.

Whereas cohesion concerns direct connection, structural equivalence concerns indirect connection by mutual contact. In both structures, ties from the ego to the first level contacts will carry the same redundant information. This means that the ego will be carrying the “cost” of three connections for the actual benefit of one, which is inefficient. Burt then developed two terms to measure network efficacy.

2.3.4.2. Network efficiency and effectiveness

As network size increases; the number of structural holes is expected to increase as well (Burt, 1992). To harvest the information benefits associated with those holes efficiently, two design principles need to be satisfied: efficiency and effectiveness.

Efficiency is maximising the number of non-redundant contacts in the network. Comparing networks A and B in Figure 2-6, one can easily observe that they both have the same number of contacts (16); network B, however, is more efficient as the ego has to establish only four links to non-redundant contacts as opposed to 16 links in network A.

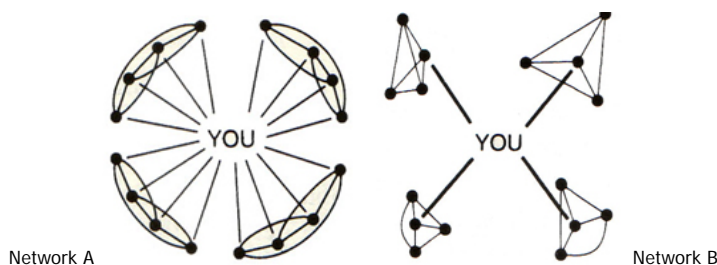


Figure 2-6: Inefficient (A) and efficient (B) networks, adapted from Burt 1992

If the ego wants to manage her network efficiently; then she can reinvest the saved time and effort in developing primary contacts to new clusters and expanding contact diversity. Efficiency therefore maximises the yield in the structural hole per contact.

Effectiveness denotes the number of people reached by all primary contacts or the yield of network. It targets a network with few primary contacts, each having access to a cluster of many secondary contacts. This principle means moving from left to right in Figure 2-7.

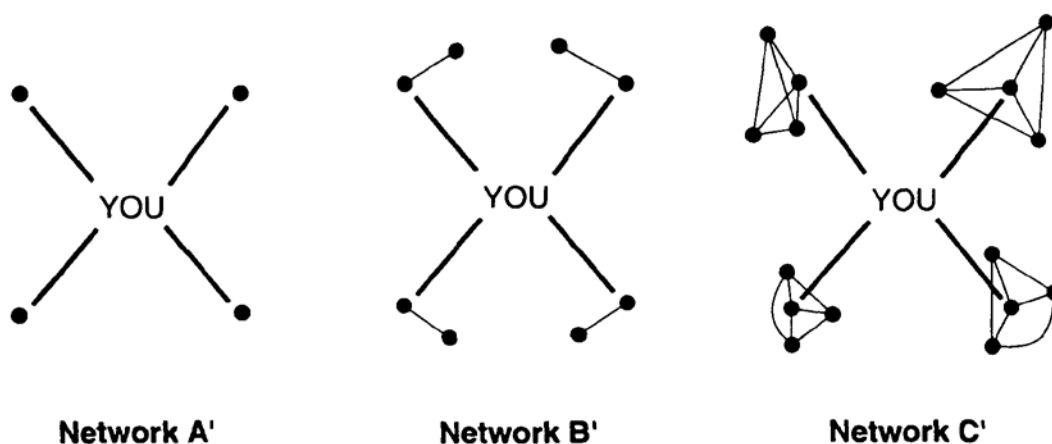


Figure 2-7: Strategic network expansion, adopted from Burt 1992

Network C includes more contacts, ensuring access to more volume and diverse information. Each cluster of contacts is an independent source of information (Burt, 1992). Being at the centre of the structural hole will ensure that the ego is the first to know of new opportunities created by needs in one group, giving her the advantage in coordinating their activities.

Burt (1992) proceeded to critically compare Granovetter's "strength of weak ties" theory and his own structural holes theory. He argued that his theory captures the causal agent of the phenomenon, which is not the weakness of the tie between two clusters but the structural hole it spans. Also the weak-tie theory obscures the control benefits of structural holes, which are in some ways "more important than the information benefits of structural holes". Burt considered that structural holes are the "chasm spanned and the span itself", so it is the structural hole that generates the information benefits, regardless of whether the tie is strong or weak over that hole.

Figure 2-8 is a relationship matrix between the network theorists discussed and the relevant concepts they studied or developed in network theory analysis.

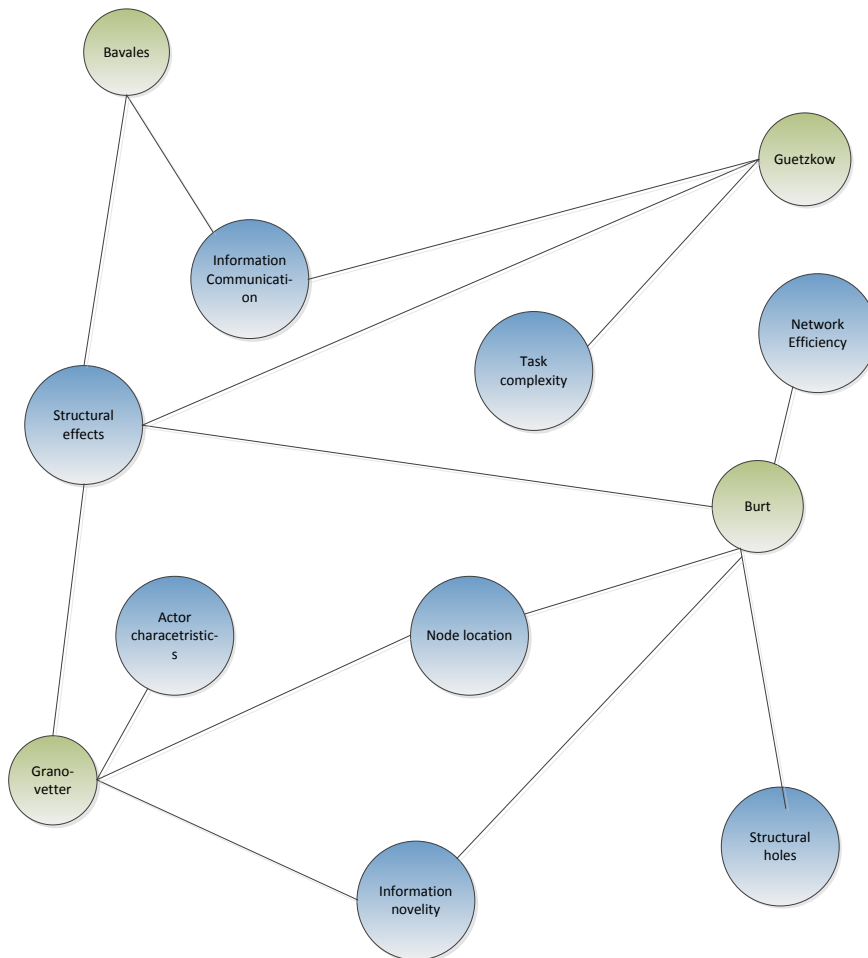


Figure 2-8: Network theorists and theory concepts relationships.

Figure 2-8 elaborates some of the main social network concepts that were researched; especially network structure, task complexity, information communication and novelty, and the researchers who investigated them. One of the most researched topics was the structural effect of networks, which four scholars investigated. Also “structural holes” and “node location” can be considered part of the structural characteristics. This further emphasises the importance and the impact of network structure on the discipline and subsequently on practical applications, as discussed further in the next sections.

2.3.5. Using network theory to model coordination

With its definition as a multidisciplinary domain, coordination means that different players will be interacting together using sophisticated means to achieve a certain task. One of the challenges remaining is how to model this process: namely, what is the best representation of the structures and processes of coordination. As discussed earlier, Malone (1990) proposed some modelling structures, which nevertheless remain as some form of modified hierarchical structures. Yet one of the developing methods for modelling coordination is network modelling.

The network model has its origins in the social network structure where nodes represent individuals and links relationships. This modelling method focuses on the horizontal pattern of exchanges, interdependent flows of resources and reciprocal lines of communication (Powell, 1990). This approach de-layers the coordination structure. An inter-agency network is modelled as a pattern of inter-relationships between meshed organisations in a social system of exchange to attain collective and self-interest goals or to solve specific problems for the target population (Van de Ven et al., 1979). It is not unusual to use networks to model interagency coordination in normal or in crisis situations (Harris et al., 2008, Kwait et al., 2001a).

One of the advantages of such a method is that it develops systems understanding that facilitates analysing how different parts relate to each other (Comfort et al., 2001). This modelling technique and de-layering approach results in new conceptualisations of agencies' roles within the structure. These roles need to be explored by reframing the traditional questions to accommodate the new methodology. So the question "*Which agency is located on the top layer of the coordination hierarchy?*" can be reframed as "*Which agency is more central in the coordination structure?*" where centrality is determined by the number of links to and from this agency (represented as node). These new questions can also be extended further by investigating connections as being either outbound – established by the organisation to seek information or resources – or inbound – other organisations seeking information or resources from this agency. This depicts an emergent bottom-up coordination architecture that can be envisioned as agents interacting on a need basis rather being dictated as to whom to

interact with. This framework better suits multi-resourced multi-skilled decentralised environments, disaster management being one clear example of such systems.

2.4. Coordination complexity in disasters

Complexity arises when multiple agents interact with each other and their environment. Coordination is necessary when a task needs to be accomplished by interdependent activities. These two concepts seem close. Conceptually, there is difference between complicated problems and complex ones. In complicated systems, the problems might be sophisticated; however, there is high degree of certainty in the outcome. The problems – and hence its solution – are repeatable to great extent like sending a rocket to moon increases assurances that the next mission will be successful as well. However, complex problems like raising up a child where the uncertainty of the outcomes remains even though raising up the first one provides experience but no assurance of success with the next whereas every child is unique (Glouberman and Zimmerman, 2002)

Yet perhaps the best theatre that exposes coordination complexity is the disaster phenomenon. Disaster usually puts into action an emergency response system which is regarded by many researchers as a complex adaptive system (CAS) (Uhr, 2009). However, can the standard top-bottom mechanistic hierarchal command and control structure deal with such complexity?

Disasters are inevitable in life. However, as Barkun (1986) wrote, “a disaster is perhaps easier to recognise than to define”. No definition of disaster is accepted universally (Turner and Pidgeon, 1997), because the definition is dependent upon the discipline using the term (Shaluf, 2003). Quarantelli (1985) collected statements reflecting “what the social and behavioural scientists assume when they use the term disaster”, some of which are:

1. Physical agents or the impact of such agents
2. The social disruption resulting from an event with physical impacts
3. An imbalance in the demand-capability ratio in a crisis occasion.

Parker (1992) reviewed the concept of disaster. He suggested that the preferred definition of disaster is an “unusual natural or man-made event, including an event caused by failure of technological systems, which temporarily overwhelms the response capacity of human

communities, groups of individuals or natural environments and which causes massive damage, economic loss, disruption, injury, and/or loss of life". This definition encompasses medical accidents and disasters such as "whooping cough vaccine and HIV/AIDS haemophilic cases" (Shaluf, 2003). Here the concept of disaster is broadened beyond the agents that create physical destruction to those that creates social disruption such as disease outbreaks.

Discussion of disasters leads directly to discussion of responses. Comfort and Kloos (1988) summarised the debate and challenge of effective disaster response well: "Creating effective organisational response under the complex, uncertain operating conditions of a major disaster poses a sobering challenge to public service". The generic approach for managing response to disaster is the command and control one.

David Neal (1995) contended, "The bureaucratic, command and control approach can provide an effective means for accomplishing goals under two conditions. The organisational environment around the bureaucracy must be both predictable and stable." (Perrow et al., 1972). However, these structures are not designed for effectiveness in dealing with complex situations such as disasters (Perrow, 1999).

Yet, "four decades of systematic research show that rigid, bureaucratic command and control approach to emergency management generally leads to an ineffective emergency response." (Neal and Phillips, 1995). Other researchers and organisational theorists have a negative view of command and control as the basis for disaster management or as a basis for management in general (Uhr, 2009). Drabek and McEntire (2002), Denis (1995), Comfort (1999), Wise (2006), Takeda and Helms (2006), Neal and Phillips (1995), Mendonca, Jefferson and Harrald (2007) have criticised the command and control. Comfort and Kloos (1988) elucidated the argument neatly: "The emergency response process, initially designed in standard, hierarchical organisation format for reactive agency operations, demands careful consideration in the rapidly changing, increasingly independent social environment of 1980s". Quarantelli (1998), a sociologist and disaster researcher, explained that even though there is strong tendency to assume that the best model for disaster organisational preparedness and management is what has been called the "command-and-control model" which adopts from the military a top-down, rigidly controlled, and highly structured social organisation, direct studies in disaster

areas have shown not only that command and control models are seldom organisationally viable, but also that they are poor models for disaster planning.

2.4.1. The need for networked enabled approach

The problem during disasters is that *of coordination not of control* (Quarantelli, 1998). Hence new methods to achieve successful coordination in disasters have been researched, namely networked coordination (Uhr, 2009, Comfort et al., 2004b, Kapucu, 2006, Naim, 2005, Kwait et al., 2001b).

Network theories deals with coordination using the systems approach. That approach makes it possible to look at the relationship of different parts of the system and their interactions (Uhr, 2009). The process begins by identifying the nodes, which can be individuals, agents, or organisations. The next step is to collect data about the relationships between these nodes, and about the new nodes to which the relationship develops This is a typical method for studying distributed coordination (Hossain and Kuti, 2010).

Basically, network modelled coordination uses social network analysis modelling, deriving its procedures and techniques to apply them in the organisational interaction context. Next, two seminal studies are briefly discussed. These studies used networked analysis to study coordination and communication during emergencies and disasters.

2.4.1.1. Kapucu on networks and disaster coordination

Interaction among agents (organisations) within the coordination system engaged in crisis response results in the emergence of nonlinear system in theory and of a CAS in practice. This system responds to both the demands from the environment and the degree of pressure or support from other organisations (Comfort and Kapucu, 2006). The dynamics of complex adaptive systems are ever changing. Kauffman (1993), a research biologist, described these systems as residing at the “edge of chaos”, where there is enough structure to hold and exchange information, and sufficient flexibility to adapt to changing conditions. In this region, organisations are self-organising and are able make the most creative responses and reallocate resources and actions to meet changing demands from the environment and to achieve a better

fit with it (Kauffman, 1993, Holland, 1995, Wasserman and Faust, 1995, Alter and Hage, 1993).

Using CAS theory, Kapucu (2005) analysed the inter-organisational interactions among public, private and non-profit organisations that evolved in response to the September 11, 2001 terrorist attacks. He identified the primary organisations that were involved in the response to the attack and then elicited the primary nodes of interactions among those organisations in order to model the inter-organisational coordination that evolved during the response process. He used situation reports from the Federal Emergency Management Agency (FEMA) and interviewed selected public and non-profit managers involved in the response. He then identified reciprocal organisational interactions and constructed a matrix for network analysis, proceeding to analyse the network data to measure the degree of closeness betweenness centrality and cliques and groups using UCINET (Version 6). The FEMA situation report included 41 actors (organisations), as depicted in Figure 2-9:

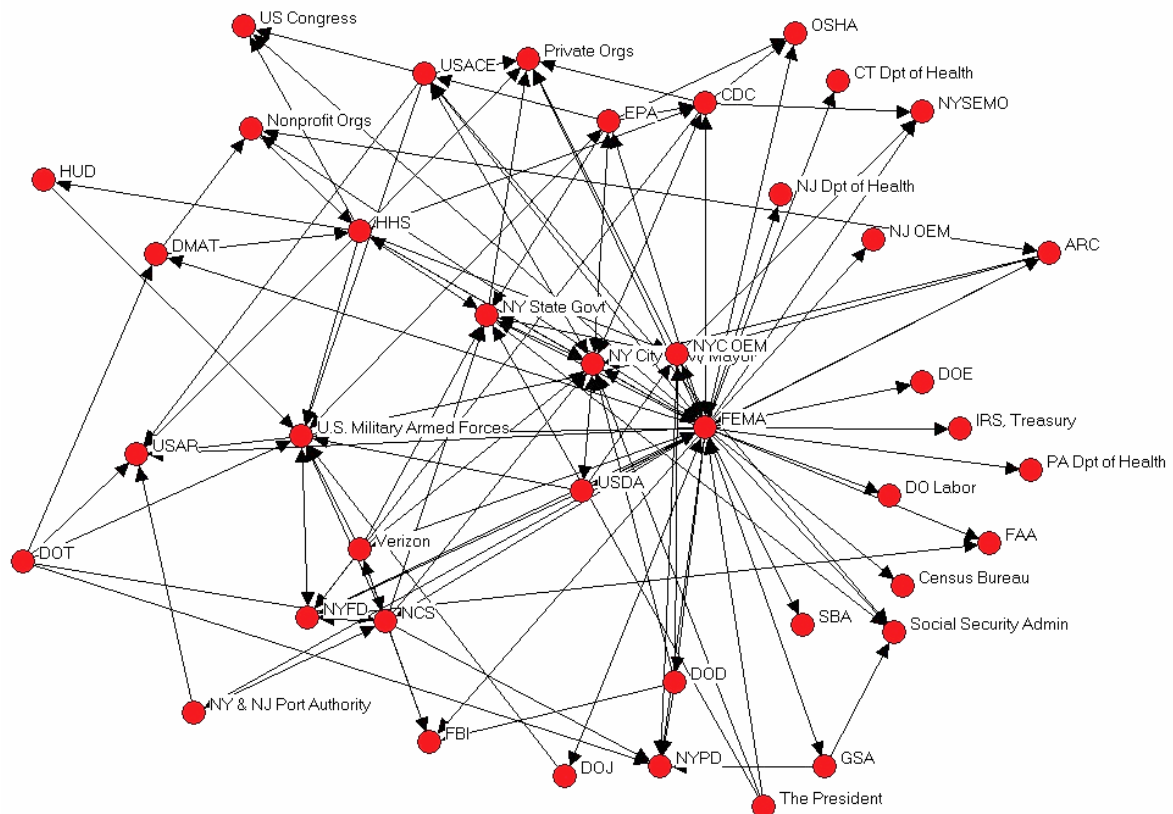


Figure 2-9: Organisational Network – FEMA situation reports

Content analysis indicated that interactions were limited and occurred primarily between organisations of similar types, but were infrequent across jurisdictional lines. For example, public organisations interacted most frequently with other public organisations of the same jurisdiction. The same applied to private and non-profit organisations (Kapucu, 2005).

Evaluating the location of actors in the network is one of the methods used to understand both networks and their participants. The centrality measure is the basic tool to determine the importance of a node in the network (Everett and Borgatti, 1999). It describes the locations of individual organisations in terms of how close they are to the centre of action in the network (Kapucu, 2005). Kapucu calculated and discussed three measures of centrality: group, closeness and betweenness.

Group degree centrality is defined as the number of non-group nodes connected to group members. By having more ties to other actors, these have access to more resources (Everett and Borgatti, 1999). Kapucu's (2005) calculations showed that FEMA was the most central, hence most influential organisation.

Using closeness centrality, which accounts for the immediate ties an actor has (Wasserman and Faust, 1995), results again showed FEMA as the most central actor, followed by the US Military Armed forces, the NY Government/Mayor and Health and Human Services. On the other hand, the Department of Housing and Urban Development (HUD) and the Department of Transportation (DOT) had the greatest farness.

Betweenness centrality measures an actor's position on the geodesic paths between all pairs of actors. Higher betweenness centrality means that the actor is more independent as how it decides to route its communication to others. This analysis also revealed that FEMA was the most central node, followed by the NY City Government/Mayor (Kapucu, 2005).

Kapucu then proceeded to briefly analyse the groupings of the response network, namely the cliques. This approach is important in understanding the structure of the network by emphasising how dense connections are compounded and extended to develop larger cliques and subgroupings (Wasserman and Faust, 1995). Understanding the embeddedness of an organisation in the structure of groups within a larger network is important for understanding

its behaviour, such as acting as a bridge between groups. The way the organisation is embedded has “profound consequences for the ways that these actors see the network, and the practice that they are likely to practice to sustain or dysfunction the collaboration” (Kapucu, 2005). Calculations using UCINET showed that FEMA, Verizon, HHS, NY City Government/Mayor, NYCEMO, USDA and the US Military Armed Forces were in the middle of the action in the sense that they were members of many of the groupings and served to connect them by co-membership (Kapucu, 2005).

2.4.1.2. *Comfort on complexity and increasing efficiency in disaster responses*

Comfort, Dunn et al. (2004) argued rightly that rapid response to extreme events is one of the least understood problems in administrative practice. Hence, coordination in multi-organisational settings is extraordinarily difficult to achieve, as it is perceived as a conflict between order and flexibility. They used CAS theory as the basis to study the multi-organisational coordination process in disaster mitigation and response. They propose that such coordination can be viewed as a self-organising process whose main foundation lies in the quick information exchange and feedback that leads to mutual adaptation and reciprocity. This extensive information exchange process is beyond the cognitive capacity of human decision makers, hence the need for coordination.

Comfort, Dunn et al. (2004b) then proposed a socio-technical system (STS) which uses the flexibility of current information technology systems to support adaptive behaviour by individuals and organisations (Coakes et al., 2002). In practice, a STS represents an interacting set of individuals, organisations and technical entities that are capable of adjusting their behaviour reciprocally to one another and to their operating environment in order to achieve a shared goal of improved performance (Comfort 1994). There is a reciprocal relationship between the technical components of the system and the individuals and organisations they support. The technical systems extend the knowledge base, memory and reasoning capacity *for those individuals and organisations*, whom would in turn monitor the performance of the technical components to ensure that they are functioning as expected.

Then Comfort et al. (2004a) trailed decision support demonstration project to implement a STS called an interactive, intelligent spatial information system (IISIS) for disaster mitigation

and management in the Pittsburgh Metropolitan Region. An important characteristic of the IISIS is that it is a decision support system that adapts advanced information technologies to support increased coordination among multiple organisations at different jurisdictional levels engaged in risk reduction and response operations. The system used three technologies to create the event-based prototype IISIS:

- 1- Interactive communication via both Internet and secure intranet networks
- 2- GIS and remote sensing imagery to provide graphic representation of the area
- 3- Intelligent reasoning to provide estimates and probabilities of known losses and likely consequences.

The trial demonstration linked the following jurisdictional levels:

- 1- University of Pittsburgh, with a daytime population of 32,000
- 2- Three municipalities (Pittsburgh, Penn Hills and Wilkins Township), population about 400,000
- 3- County level represented by Allegheny County, population 1.26 million.

As a result of the simulation, 100% of the participants, who were emergency management managers, reported favourably on the innovative use of information technology in disaster management and considered that IISIS would improve the daily operations of the agencies. They also reported that they would be willing to invest time and resources in learning more about IISIS system.

Furthermore, findings from a set of expert interviews with responsible emergency managers identified five critical issues that affected performance in inter-organisational disaster management operations:

- 1- Intermittency in assessment
- 2- Lack of timely information about the impact of an impending threat on critical infrastructure for the community
- 3- Loss of information when an emergency escalates from one jurisdictional level to the next

4- The lack of real-time monitoring of threatening events as well as the lack of capacity to transmit this information between field operations units and emergency operations centres.

5- The lack of systematic means of monitoring multiple sites simultaneously in order to provide practising managers with a comprehensive profile of the evolving disaster in a region-wide event.

When the results above are considered, communication, which is a form of coordination and a prerequisite for it, represents a main concern for disaster management practitioners and is attributed to the high risk that exists in some impending threats. This is especially relevant when coordination is multi-jurisdictional and spans multiple geographical sites.

2.4.1.3. *Zhiang and the dynamics of inter-organisational ties during crisis*

Zhiang (2002) investigated the dynamics of inter-organisational coordination during crisis situations from the perspective of the usual process organisations would use and the efficiency of this process. He noted that researchers have devoted much less attention to the underlying dynamics of how and why inter-organisational ties are used. He also argued that there is a lack of exploration into the role of resources in social networks at the organisational level. He discussed that organisational effectiveness, and ultimately survival, is not just a matter of intra-organisational design but also a matter of how they rely on each other. In crisis those ties become more important.

Zhiang first explored the dynamics of inter-organisational relationships from a resource dependence perspective; then he used an agent-based modelling technique to build a computational model to simulate those dynamics.

Putting the above methodology into perspective, ties between different organisations have a purpose being resource access. Hence, two nodes connect to each other in the hope of extending resource access that will be mutually beneficial (Blau, 1986). These ties are also directional, reflecting the amount of resources one node receives compared to the other node. The content of the ties reflects the different resource needs of the organisation, and their strength reflects the quantity and the content of the contacts.

Zhiang (2002) applied this method to analyse the Hurricane Andrew incident in August 1992. Hurricane Andrew hit southern Florida, causing billions of dollars in damage to the social, biological and economical systems. The crisis began at the local level of organisations, being the county government agencies (police, public works), which had frequent communication due to their formal relations and geographical distances. One level up from the local governance level was the Florida state level (Florida State Government, Florida National Guard). Links established to those agencies were not as strong as connections at the local level. The third level was the Federal level, including the Federal Emergency Management Agency (FEMA), Government executive office, and US Public Health services. Links from the local to the federal level were weak due to infrequent use of the connections, with an exception being the American Red Cross which maintained local branches in the South Florida area.

We will look at the stages through which links were activated or mentioned but not activated:

Stage 1: On 23rd of August; the day prior to Hurricane Andrew hitting the southern Florida area, local agencies relied on their strong ties to provide resources to the local community but they soon recognised the potential impact of insufficient resources. The tie with the state government was mentioned but not activated, the National Guard was alerted, and the tie with the American Red Cross (ARC) began to be used, see Figure 2-10.

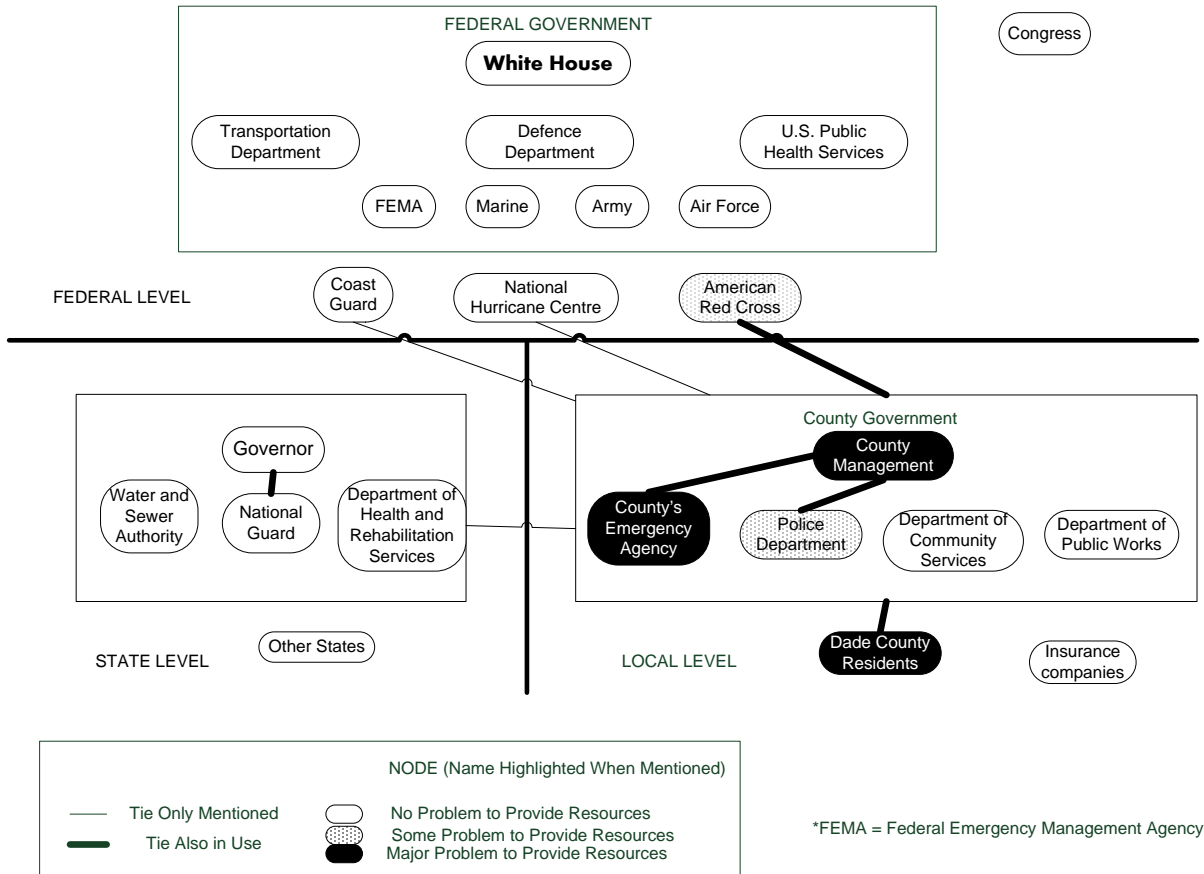


Figure 2-10: Reported dynamics of organisational ties in the Hurricane Andrew incident on August 23, 1992. (Lin, 2002)

Stage 2: Ties with Florida State Government were introduced along with ties to National Guard troops, the National Hurricane Centre in Florida and the Coast Guards. Figure 2-11 shows those links.

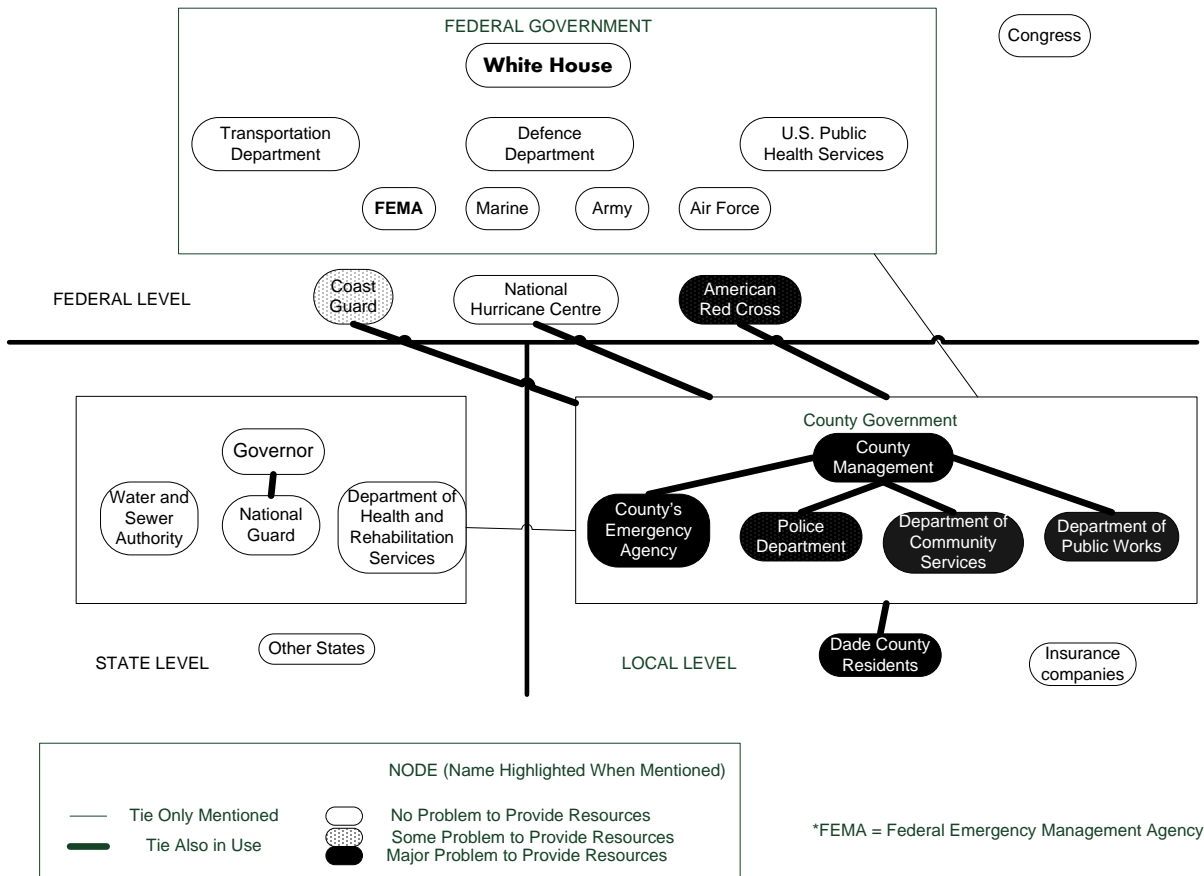


Figure 2-11: Reported dynamics of organisational ties in the Hurricane Andrew incident on August 24, 1992 (Lin, 2002)

Stage 3: From August 25 to 27, the second to fourth days of the Hurricane, the tie with the Florida State Government was more intensively used along with the Florida Department of Health and Rehabilitation. The State Government and the County requested urgent help from the State Government; see Figure 2-12:

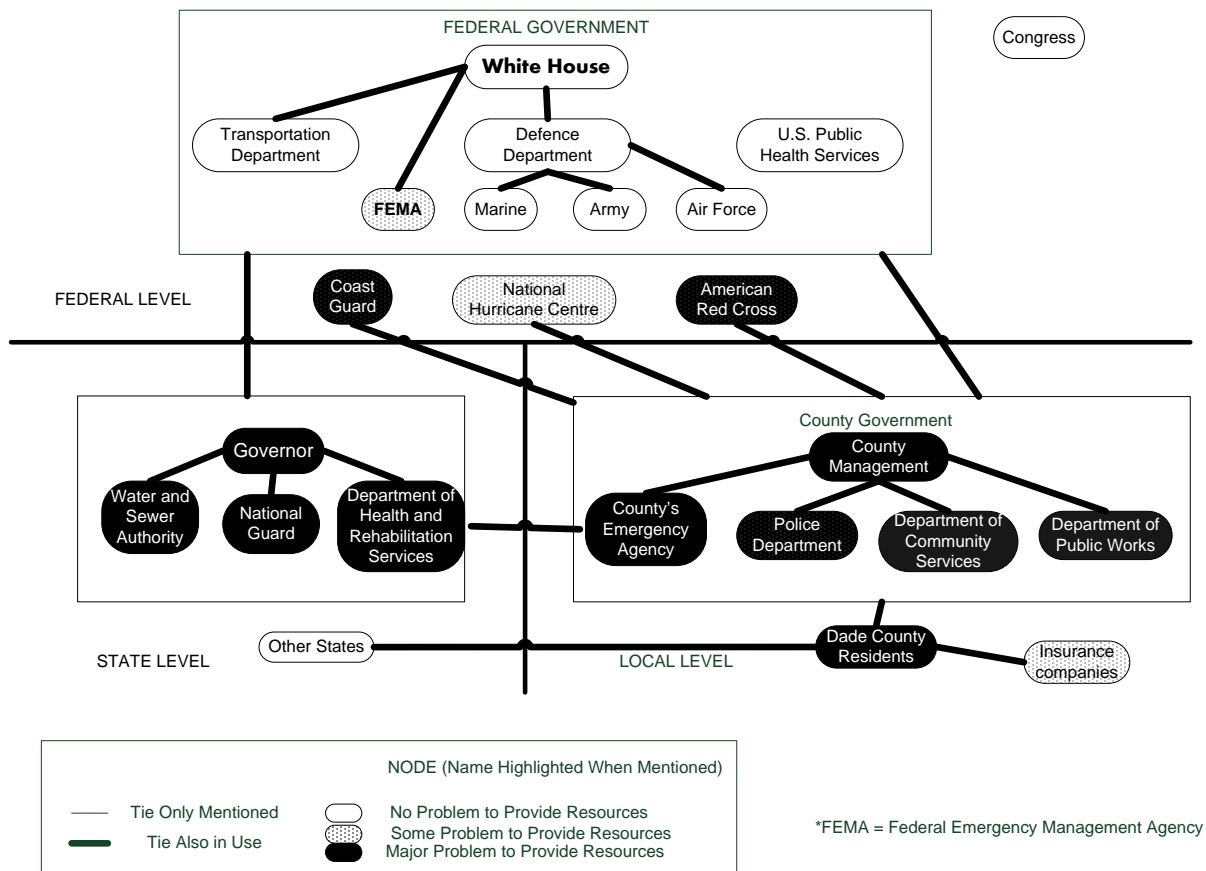


Figure 2-12: Reported dynamics of organisational ties in the Hurricane Andrew incident from August 25 to 27, 1992 (Lin, 2002)

Stage 4: From August 28 to September 8, state and local governments realised that tier resources were insufficient to resolve persisting problems such as providing home and shelter for homeless residents and raising funds for wide-scale reconstruction. Ties with the Federal Government and FEMA were intensified. Also any weak ties that could bring possible resources were enlivened; this is illustrated in Figure 2-13.

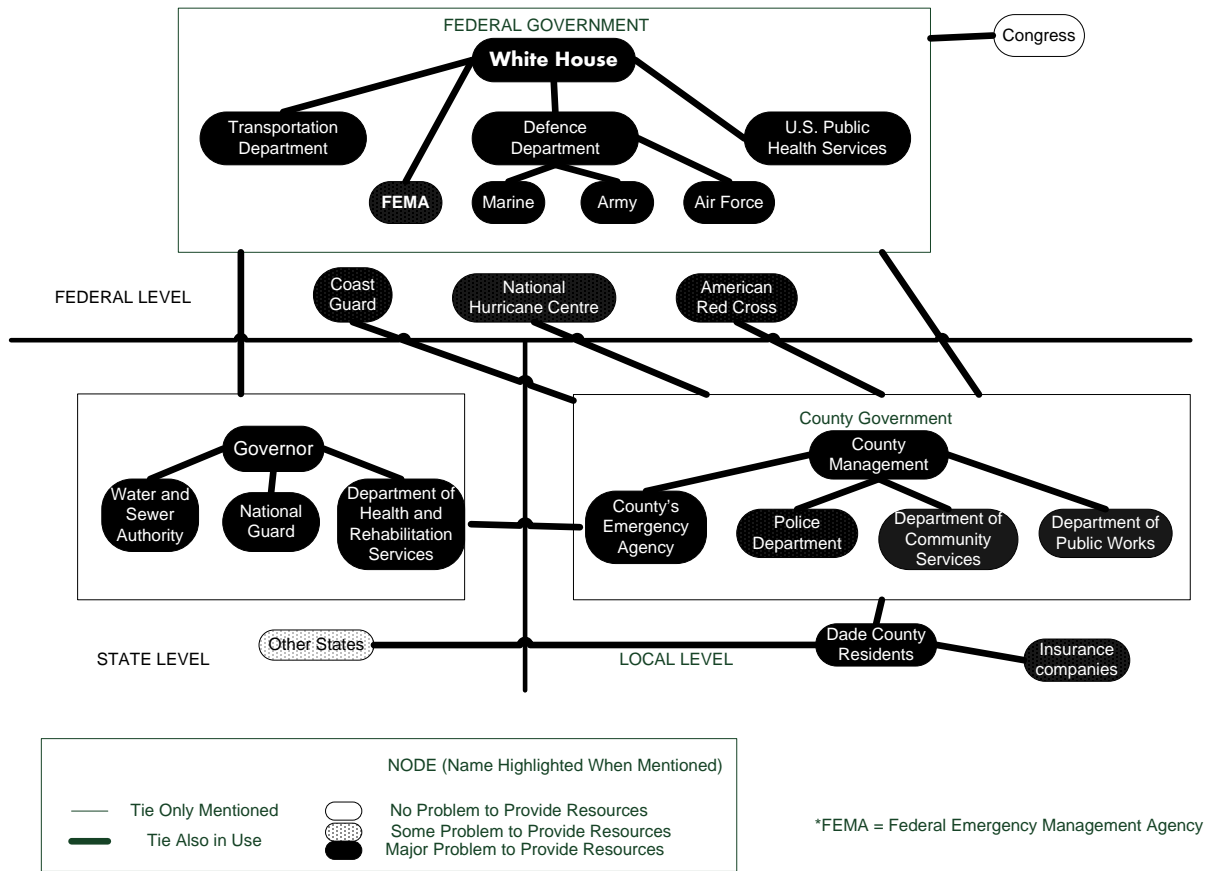


Figure 2-13: Reported dynamics of organisational ties in the Hurricane Andrew incident from August 28 to September 8, 1992 (Lin, 2002)

This case analysis provided interesting results. Firstly, when faced with situations with huge resource demands, organisations rely on their stronger ties first to satisfy those needs and later on the expansion of weaker ties. The rationale is that the organisations’ bounded rationality limits their foreseeing the impacts of the crisis. Secondly when they don’t have enough resources, the organisations start cascading their links. The results also indicated that organisations used these links to exchange resources without diffusing decision powers to the upper levels.

The three cases discussed above illustrate the complexity of disaster management and the different approaches to tackling such topics. Kapucu’s work represents a formal investigation on how “organisational design can be used to help track the inter-organisational coordination

in emergencies” (Kapucu, 2005) by investigating interdependencies in complex environments. Comfort, Dunn et al. (2004a) emphasised the complexity of this topic and piloted a socio-technical solution for managers. Zhiang (2002) used network principles and the concept of weak and strong ties to study how networks are formed and then cascaded based on resource needs. Yet all these researchers approached multi-agency coordination as a dynamic subject and applied the networking perspective, using social network principles to model this complexity.

2.4.2. Comparing standard coordination theory and dynamic coordination in complex environments

Dealing with coordination as a dynamic system creates new challenges, qualitative and quantitative, theoretical and analytical. In preparation for addressing those challenges later, Table 2-5 highlights the similarities and differences:

Table 2-5: Comparing standard to dynamic coordination

Standard coordination	Dynamic coordination
Predefined tasks and boundaries.	Most of the time, tasks have no defined boundaries.
Modelling is based on conventional organisational structures.	New modelling techniques: organisations are autonomous agents interacting with each other on a needs basis.
Coordination structure is pre-determined.	Coordination structure is emergent; might use existing structures as blueprint for the emerging one.
Uses standardisation (work processes, outputs, and skills) as a form of coordination.	Standardisation is not always achievable due to different organisational cultures/methodologies.
Limited degree of flexibility due to predefined structures/tasks/boundaries.	Flexibility is the norm to deal with variability of environmental demands.
Considers ad-hoc coordination, mutual adjustment, as a phase of the coordination process.	Ad hoc coordination is an integral part of the coordination process.
Usually bureaucratic, based on norms and procedures (Neal and Phillips, 1995).	Non-bureaucratic, loosely coupled organisational approach (Dynes, 1983).
Accepts a certain degree of decentralisation, like Malone's decentralised market structure.	Has a high degree of decentralisation where organisations are loosely coupled.
Top down.	Bottom up.

The overview above demonstrates the necessity for a distinctive view about dynamic coordination in complex environments. It is important to note that one of the prevalent illustrations used for dynamic coordination are disasters, which require multi-agency coordination in changing environmental demands.

Such complex environments “need an enormous coordination effort and are implemented through both types of mechanisms: structural and formal, plus informal and subtle” (Jon and Jarillo, 1989, Galbraith and Kazanjian, 1986). Thus, neglecting one facet of coordination does not constitute a complete coordination framework. In this thesis I propose to use a “hybrid coordination” method in researching and creating coordination models. This hybrid coordination is designed to create a complete coordination overview by viewing formal mechanistic coordination with the left eye and informal organic coordination with the right eye. Merging both represent a unique opportunity to model “realistic” coordination mechanisms and structures, especially when moving from a uni-dimensional to a multi-dimensional perspective. Other researchers have agreed that informal and subtle coordination mechanisms must be added to existing structural and formal mechanisms to cope with complex conditions (Lawrence and Lorsh, 1967, Galbraith and Kazanjian, 1986).

This integrated networked coordination strategy must include new coordination tools besides the earlier ones. These new tools might contain lateral relationships that cut across the formal lines of the macro-structure such as teams, task forces, committees and integrative departments (Jon and Jarillo, 1989). Hybrid coordination emphasises the need to be responsive to different strategic requirements in today’s complex and diversified environments. It will enhance the development of sophisticated coordination mechanisms, avoiding the simplistic centralisation-decentralisation dichotomy. All informal mechanisms must be used, so that organisations have sufficient flexibility to be responsive and adaptive to changes in environment and conditions (Bartlett and Goshal, 1999).

2.4.2.1. Proposing Open System Coordination

It is evident from the coordination literature presented earlier that extension of theory into more dynamic environments (Kapucu, 2005) which demand “interdependent delivery systems” (Hage, 1975) to achieve goals that are “too big for one organisation to handle” (Ven et al., 1975, Alexander, 1993) is lacking to date. Capitalising on the discussion in Sections 2.2.2–2.2.5 above, one can deduce that coordination theory needs to be extended to cater for such dynamic, complex environments. I propose to call this extension “Open Systems Coordination” (OSC). I use the term “system” because such coordination exhibits systems thinking characteristics such as dynamism, interdependency between components (agencies)

and complex behaviour (Leischow and Milstein, 2006, Trochim et al., 2006). Some of the characteristics of this coordination would be:

1. **Emerging structures:** New structures emerge when dynamic interaction between the micro parts of the system creates a coherent emergent macro-level structure. It is desirable that this structure is self-organised (De Wolf and Holvoet, 2005). Such structures are heavily reliant on communication facilitated by today's advanced IT structures. The self-regulating process is mutually adjustable, multi-directional, and even asynchronous.
2. **Ad hoc coordination:** This resembles the "adhocracy" structure described by Mintzberg (1979) but on larger scale. It is mutually adjusting, decentralised, horizontal and organically structured. Warren (1974) described "mobilization coordination" as activities set in motion by a single organisation gathering resources and forging ad hoc relationships as needed to pursue the organisation's objectives. An ad hoc coordination structure emulates organisation adhocracy in that it is based dynamically on functional requirements and not on rigid predefined structures. Warren also pointed out that ad hoc mobilisation is an important source of coordination, although it is frequently overlooked because of an implicit equating of coordination with "structural coordination alone" (Ven and Gordon, 1984). The initiation of OSC might not be an organisation seeking its own objectives; rather it might be originated by many based, on their interest in the task.
3. **Anticipated heterogeneity:** Not all of the organisations have the same intra-organisational structure, nor skills or products. Of course, this does not suggest that homogeneity does not exist. Rather, some organisations with homogeneous natures are part of the coordination consortium, but they are not the exclusive case. The coordination process can be viewed as a joint task force or a coalition network of hybrid entities. To illustrate the concept, a small-scale example would be a call to an emergency call centre reporting an accident. The different organisations involved would be the person making the call, the customer service centre receiving the call and then instigating requests to fire brigade, police, ambulance and other private agencies (car-towing, private health care providers) to attend the accident site. The person making the call is an end user who will benefit from the

service. The call centre is an organisation both receiving and disseminating information to coordinate appropriate parties. The teams attending the site have different skills, organisational hierarchies, even communication protocols and objectives. They coordinate with each other for the benefit of the end user, without further direction from the call centre. They assess the end user's needs and the local environment and might arrange more teams from their parent organisations or from other organisations as per need.

4. Information decentralisation: With this coordination there is no single organisation sitting at the top of the coordination hierarchy that has the complete information, or what is called a single cognitive entity. Every organisation has partial information that it shares with others in order to build, and help others build, a better understanding of the environment. Sometimes localised and/or specialised information is what each organisation seeks to collect. An example of specialised data is that in a disaster situation, medical teams will be more interested in collecting epidemiological data rather than collapsed building and structural data. One can even anticipate that there are organisations whose sole task is to process data and relay it to interested parties, bridging information gaps and holes.
5. Diversity of goals: In OSC, it is tolerated that each coordinating party might have slightly different objectives. The combination of these objectives should comprise the overall goal behind the coordination process. Such tolerance of goal diversity is rarely present in other coordination models. A good example of this is the civil and military cooperation during complex emergencies, presented by (Rietjens et al., 2009) regarding Afghanistan. It has been always the case that the military, non-governmental organisations (NGOs) and local government have different objectives. These objectives might overlap, and may even conflict. However, the total goal for all is stabilising the country and enhancing the population's living standards. The diversity might be due to different reasons: an organisation's mission statement, culture, stakeholders, beneficiaries, skills, etc. As well, there are variables imposed by the environment, including population, security, culture, religion and need. By agreeing to coordinate, the military, NGOs and local government acknowledge that none of them is able to meet the final goal alone.

Hence a coordination mechanism needs to evolve that enables each party to achieve its own goals. This need is appreciated and tolerated by all.

6. The coordination structure demonstrates self-organising behaviour. Nodes route the communication through the most efficient path and seek to acquire the information or resources they need by using the routes they learn through their connections. The structure re-organises if a node is disconnected or a new one is added. This, it can be added, is a typical characteristic of biological networks such as fungal networks.

In OSC, each organisation is an independent entity making its own decisions, but interdependent on others to manage the larger task. In this sense every organisation is an “agent”, extending relationships with other “agents”, resulting in a multi-agent dynamic environment. This emergence process is called an evolving dynamic coordination, and is expected to be temporal in that it will last as long as the task entails.

OSC can be used in uncertain or loose coupled coordinating environments where coordination mechanisms cannot be perceived enough to be structured beforehand. It is comprised of a coalition of multi-skilled organisations that want to deal with a situation in hand. Some of these scenarios might be:

- 1- Disasters such as earthquakes and disease outbreaks
- 2- Decentralised military operations where units need to organise with each other most of the time rather than with the command and control centre
- 3- Huge project consortiums, especially during the early beginnings of their formation
- 4- Coordination between civil and military organisations during complex emergencies or in the aftermath of war.

OSC coordination can provide a theoretical framework for dynamic environments, and yet there remains the need for a method to quantify and measure such coordination. For this, network theories and measures for analysis of OSC are introduced in the next section.

2.5. Disasters in the medical context

Disaster management is inherently complex due to the interdependent nature of the responses from multiple organisations that have responsibility for dealing with the situation collectively (Comfort et al., 2001). An infectious disease outbreak can be considered a particular example of a disaster where the dynamics of the situation are particularly important. It is distinct from earthquakes, bushfires or floods that affect only a particular geographical area (that might be large but is nevertheless bounded). Another difference is that the microbial world is complex, dynamic and constantly evolving. Pathogens proliferate rapidly, mutate frequently, and mutate with relative ease to new environments and hosts as well as developing resistance to the drugs used to treat them. The phenomenal growth of international travel has vastly increased the speed with which pathogens, incubating in unsuspecting human beings and animals, can cross continents, invade new territories and set up residence (Heymann and Rodier, 2001). Table 2-6 is a comparison chart highlighting some differences between disease outbreak and bushfire or flood disasters.

Table 2-6: Differences between disease outbreak and bushfire/flood disasters

Disease outbreak	Bushfire/flood
Wave pattern behaviour determined by the pathogen infectivity; might re-infect the same affected area/population.	After burning a certain area, does not return to it.
Can arise out of another disaster (flood or earthquake) due to environmental and population behavioural changes.	Rarely preceded by other disasters.
Outbreaks can cross geographic boundaries to become a global phenomenon (e.g. H1N109, SARS).	Bounded by geographical characteristics (Bush, river locations)
Population discriminative; usually some population segments (elderly, children) are more vulnerable than others.	Population is targeted based on geographical location vulnerability alone.
Mutative and adaptive (influenza is the best example). This antigenic drift adds to the complexity of spread patterns.	N/A
Spread patterns are influenced by different factors including pathogen contagion, demography and behaviour.	Spread is based on simple factor(s), mainly geographical characteristics.
Might have a deterministic effect on health workforce (health workers will have families to protect; more infection in health workforce as a result of greater contact with pathogens).	Relief effort workers can relocate family to safe location.
Creates dynamic clusters that “move”, “die” or fragment to hundreds of other locations depending on population movements.	Hotspots are population independent. Can be predicted based on geography and meteorology.
Can be nature made or human-made (bioterrorism).	Can be nature made or human-made (arsonists).

Infectious or communicable diseases have been a risk for human society since the onset of the human race. The large-scale spread of infectious disease can have a major impact on the society and individuals alike, and sometimes has determined the course of history (McNeill,

1977). Infectious disease can originate from natural causes or be introduced by terrorists who may choose to attack by deliberate transmission of infectious disease using biological agents. Whether the origin of the infectious disease is natural or bioterrorism, it can spread at a rapid rate due to expanded trade and travel, resulting in potentially significant loss of life, major economic crises, and political instability (Chang et al., 2003).

One of the intriguing facts is that outbreaks have different transmission and infection rates not only between countries but between different states in a single country, as well as within each state of similar demographics and geographic characteristics. As an example, Table 2-7 shows the reported cases of infection in Australia for the H1N1 2009 outbreak (Eastwood, Durrheim, Massey, and Kewley 2009):

Table 2-7: Confirmed H1N109 infection rates in Australian states and territories at the end of the Contain phase, 17 June 2009, from Eastwood, Durrheim, Massey and Kewley 2009

State	State population†	Confirmed cases	Rate per 100 000
New South Wales	7 041 400	313	4.4
Victoria	5 364 800	1230	22.9
Queensland	4 349 500	194	4.5
Australian Capital Territory	347 800	75	21.6
South Australia	1 612 000	107	6.6
Western Australia	2 204 000	117	5.3
Northern Territory	221 700	35	15.8
Tasmania	500 300	41	8.2
Australia total‡	21 644 000	2112	9.8

†Population figures are based on estimated residential population 31 December 2008

‡The Australian total includes all territories.

Table 2-7 shows that within the same country the infection rate differed by up to five-fold from one state to another (e.g. compare the New South Wales (NSW) rate to those of Victoria and the Australian Capital Territory). Table 2-8 disaggregates information about outbreaks within the same state (Eastwood, Durrheim, Massey, and Kewley 2009).

Table 2-8: Confirmed H1N109 infection rates within NSW at the end of the Contain phase June 2009, from Eastwood et al. 2009

New South Wales area health service	Population [†]	Confirmed cases	Rate per 100 000
Rural			
Hunter New England	862 967	8	0.9
Greater Southern	483 282	42	8.7
Greater Western	301 052	9	3.0
North Coast	495 329	10	2.0
Metropolitan			
Northern Sydney/Central Coast	1 134 200	33	2.9
South Eastern Sydney Illawarra	1 209 111	46	3.8
Sydney South West	1 394 652	82	5.9
Sydney West	1 131 294	83	7.3
New South Wales total [‡]	7 011 886	313	4.5

[†]Population figures are based on estimated residential population 31 December 2008

[‡]The discrepancy with the NSW total in Table 1 is due to differences in population projections.

From Table 2-8 , the Hunter New England (HNE) area had the lowest transmission rate (0.9 per 100000 population), whereas an adjacent health area (North Coast) had a transmission rate more than twice as high (2 per 100 000). Also, HNE had the lowest number of confirmed cases in the state of NSW (only 8). Table 2-8 indicates that within the same state there was about an eight-fold variation in infection rates. Taking into consideration that demographics were similar and the pathogen was the same, then management and coordination of the response to the outbreak were factors influencing the number of cases. This effort was led by corresponding agencies in each individual state and area health service within the states.

Outbreak detection and intervention plans usually standardise each type of outbreak according to disease type. Hence, researchers and epidemiologists prepare tuberculosis plans, influenza plans, etc. In contrast, coordination of the multi-agency response is left to public health officials, with very little academic research to support their decisions (Chen et al., 2008, Comfort et al., 2004a) . As a result, there are discrepancies in the application of resources, which impact on infection rates and may partially explain the variation in the rates shown in Table 2-7 and Table 2-8.

2.5.1. A quick overview on disease outbreak research

The World Health Organization (WHO) has defined a disease outbreak as “the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. An outbreak may occur in a restricted geographical area, or may extend over several countries. It may last for a few days or weeks, or for several years. A single case of a communicable disease long absent from a population, or caused by an agent (e.g. bacterium or virus) not previously recognised in that community or area, or the emergence of a previously unknown disease, may also constitute an outbreak and should be reported and investigated” (WHO, 2011). Such outbreaks are usually beyond the capacity of single jurisdiction or agency. Rather, they require the collaboration of a distinctive pool of skills, resources and authorities. The success of such coordination effort requires that “all relevant agencies be involved in the response and that effective structures are in place to coordinate them” (Jackson et al., 2006).

Infectious disease outbreaks, epidemics, and pandemics attract enormous research efforts both quantitatively and qualitatively. According to the ARC journal list of March 2010, there are 68 journals specialising in that domain. The esteem of these journals is partially reflected by some of their high rankings: *Lancet Infectious Diseases* (15.58), *Journal of Infectious Diseases* (5.81), *Clinical Infectious Diseases* (8.20), and *Emerging Infectious Diseases* (6.79) (Reuters, 2011), based on 2009 rankings. Many other journals publish on disease outbreaks without specialising in this domain.

Another related research field, namely “disease outbreak coordination research” has gathered momentum specifically in the last decade after the swine influenza (H1N1 2009), and Severe acute respiratory syndrome (SARS) outbreaks as well as following the interest in surveillance due to public health concerns and bioterrorism (Edgington, 2010, Eizenberg, 2009, Franco-Paredes et al., 2009, Gerberding, 2003, Jackson et al., 2006, MacLehose et al., 2001, Neumann and Kawaoka). However, the outcomes of these researches are scattered among non-specialised journals and publications such as *Disasters*, *Disaster Prevention and Management*, *British Medical Journal*, *Social Science and Medicine*, *Journal of Immune Based Therapies and Vaccines*, *Biosecurity and Bioterrorism: biodefense strategy, practice, and science*, *Science*, *Foodborne Pathogens & Disease* and the *Journal of Public Health Management and*

Practice, to name just a few. Some of this research has focused on the coordination of outbreak surveillance (Olsen et al., 2000, Guardado and Clará, 2004, Levy et al., 1998), others on post-mortems and lessons learned (WATERER et al., 2010, Eastwood et al., 2009), and yet others have dealt with policies and practices (Beyrer et al., 2006, Aday, 2005, Wolfe et al., 2001). Since diseases spread through different mediums, outbreak coordination research has followed the same trend; respiratory intervention and coordination has had a good share of such research since it was relevant to most recent outbreaks such as influenza, SARS, and H1N109 (Heymann, 2004, Tan, 2006, Gerberding, 2003, Abdullah et al., 2003). Other research has focused on foot and mouth disease coordination (Sutmoller et al., 2003, Rweyemamu et al., 2008, Rich et al., 2005), coordination of zoonotic outbreaks (Jackson et al., 2006, Dudley, 2004, Leslie and McQuiston, 2007), foodborne diseases (Todd, 1997, Sobel et al., 2002, Majkowski, 1997), waterborne diseases (Frost et al., 1996, Cassady et al., 2006, O'Brien and Stelling, 1995), and sexually transmitted diseases (Chen et al., 2002, Catchpole, 1996, Chen et al., 2003).

Organisational network analysis has been extensively used in political and private organisational analysis but has only recently appeared in public health studies (Luke and Harris, 2007, Borgatti and Foster, 2003). These studies have looked at specialised public health collaboration systems such as AIDS service organisations (Kwait et al., 2001a, Wright and Shuff, 1995, Shumate et al., 2005), services for the mentally ill and mental health (Albert et al., 1998, Kawachi and Berkman, 2001), health policy (Cattell, 2001) , services for the social wellbeing (Rook, 1984) and health promotion (Bandura, 2004) . Coordination in the case of disease outbreak has been researched mostly from the surveillance and evaluation perspective (MacLehose et al., 2001). Here the focus is extended the management and intervention perspective.

2.5.2. Influenza H1N1 disease spread phases

A considerable amount of research has been undertaken into infectious disease outbreaks from an epidemiological perspective, including analysis of the role of pathogen transformation, mutation and infection (Fraser et al., 2004a) , and the modelling of disease spread (Newman, 2002).Some of these approaches represent epidemics of communicable diseases as Markovian

(Zhang et al., 2007) or non-Markovian processes (Becker, 1977) and apply stochastic epidemic threshold theory to guide public health measures aimed at preventing major outbreaks (Becker, 1977, Gani and Jerwood, 1971, Streftaris and Gibson, 2002); Other approaches identify general properties of emerging infectious agents to determine the success of different public health measures such as isolating symptomatic individuals or tracing and quarantining their contacts (Fraser et al., 2004b). There has also been a promising attempt to develop a disease outbreak event corpus (Conway, 2010)

2.5.2.1. A brief introduction to influenza

“Influenza killed more people in a year than the Black Death of the middle ages killed in a century; it killed more people in twenty-four weeks than AIDS has killed in twenty-four years.” So wrote John M. Barry in his bestselling account of the horrific “Spanish flu” pandemic of 1918-1920, *The Great Influenza* (Barry, 2005). The “Spanish flu” was a global phenomenon – see Figure 2-14 – that caused the death of 40 to 100 million humans at a time when the communications and means of transport were not as fast and efficient as they are today (Cordova-Villalobos et al., 2009).

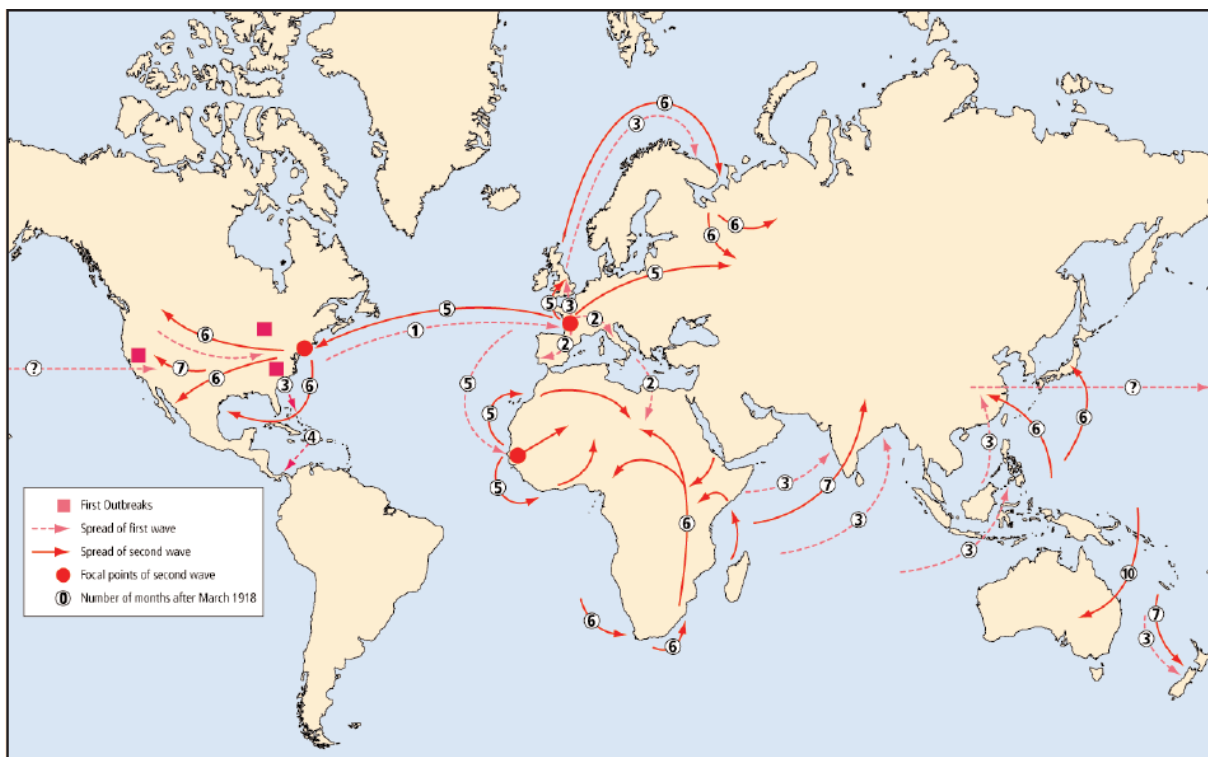


Figure 2-14: Transmission of Spanish flu around the world, from Nicholson GK et al., eds. *Textbook of influenza*, 1998

The 1918 influenza pandemic was not the only one that the 20th century witnessed. It was followed by another in 1958-1959 and finally the one in 1968 (Davey, 2007, Taubenberger and Morens, 2006).

The first decade in the 21st century welcomed what will be known as the first influenza pandemic of the 21st century: H1N1 2009, or what is commonly called “swine flu”. The first cases were reported in early April 2009, characterised by acute respiratory tract infections in individuals in Mexico City and the state of San Luis Potosi and Oaxaca, Mexico. The cases were young adults with increased duration of transmission of seasonal influenza. To the bewilderment of microbiologists, the influenza A virus that was isolated could not be typed in the reference laboratory (Fraser et al., 2009). On April 13, in the capital city of Oaxaca, a 39 years old female died of severe atypical pneumonia. On April 17, Mexico issued a national pandemic alert, and the necessary steps were taken to prevent the population from attending crowded places. On April 23, laboratory tests fully identified the virus as influenza A (H1N1) from a virus strain unknown until then, which means that its behaviour, virulence, transmission capacity origin, susceptibility to the available antivirals, and pandemic potentials were all unknown (Cordova-Villalobos et al., 2009). On April 25, the WHO declared a “public health emergency of international concern” (Bishop et al., 2009). On 29 April, the WHO announced that H1N1 warranted moving the global pandemic alert to level phase 5 (www.who.int/csr/disease/swineflu/). Phase 5 indicates “sustained human-to-human transmission of a novel influenza strain of animal origin in one WHO region in the world, and exported cases detected in other regions” (Fraser et al., 2004b).

The pathway to communicate and achieve such results in one month (from pandemic discovery to identifying and isolating the virus then to announcing phase 5 pandemic) branched all around the globe. Mexico sent samples to Centres for Disease Prevention and Control (CDC) and then to Winnipeg laboratory in Canada (Cordova-Villalobos et al., 2009). The WHO communicated with health authorities all around the world and many activated their influenza pandemic response plans in response to WHO’s announcements (Bishop et al.,

2009). This network formed a unique coalition of nations and organisations that worked collectively and swiftly to understand the new threat on hand.

The official number of deaths from laboratory-confirmed pandemic influenza A H1N1 2009 infection worldwide reported to the WHO as of 28 March 2010 was 17 483. The economic impact of the outbreak in Mexico was estimated at more than \$3.2 billion, but the global economic impact of the pandemic is uncertain at the present time (Girard et al., 2010).

2.5.2.2. *Influenza background information*

Influenza is a highly contagious viral disease of the respiratory tract. It can spread rapidly through populations and has a tendency to mutate, which can lead to new strains of the disease. It spreads by large droplets when infected people cough or sneeze. It can spread both directly (such as by shaking hands) or through indirect contact with objects contaminated with droplets from an infected person (such as a contaminated tissue or door handle).

Influenza is generally categorised into three types A, B and C. Influenza A and B outbreaks occur as seasonal influenza. “A” is the type that usually causes pandemics (Yang et al., 2009).

Influenza A subtypes are characterised by distinct features in the surface proteins (antigens) of the virus. Small mutations regularly occur in these surface proteins, creating new variations. This phenomenon, called antigenic drift, means that seasonal influenza vaccines often need to be modified each year to better match the circulating strains. Aquatic birds are the natural reservoir for influenza A viruses but various subtypes also circulate in humans and other animals, including pigs and horses.

Unpredictably, entirely new influenza A subtypes can emerge with the capacity to infect humans. This comes as a result of a large mutation in the virus (called antigenic shift), or when the genes of two type A viruses mix to produce a new strain (called re-assortment). The virulence of the virus (how sick it makes people) and its infectivity decide the impact of the pandemic, with the most severe types being both highly transmissible and causing severe illness. For influenza pandemic to occur, three criteria must be met:

1. A new influenza virus must emerge to which humans have little or no immunity.

2. The new virus must be virulent enough to cause death in humans.
3. The new virus must have the capacity to spread efficiently (sustainably) from person to person. (Tobin, 2010)

2.5.2.3. *H1N1 spread model*

A novel pandemic brings many challenges stemming from many uncertainties about all the aspects of the outbreak, including the virulence, transmissibility, and origin of the virus. This in turn results in uncertainty in judging the potential of the pandemic and the appropriate reactive public health measures such as decisions for school closures (Fraser et al., 2009). Hence, scientists have used mathematical models to understand the spatial-temporal transmission dynamics of influenza. These have been used as tools to predict the effect of public health interventions on mitigating pandemics (Coburn et al., 2009). Early in the 20th century Kermack and McKendrick (1932) developed the first mathematical model that could be used to describe the influenza pandemic. This model is known as the Susceptible-Infectious-Recovered (SIR) model and is shown in Figure 2-15.

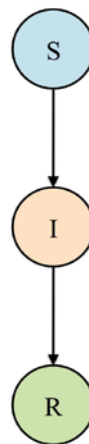


Figure 2-15: SIR model of disease transmission, from Kermack and McKendrick, 1932.

In this model, the population is segmented into three classes: susceptible (S), infectious (I) and recovered (R). Individuals who become infected proceed from class S to class I at a rate determined by the infectiousness of the virus and the prevalence of the infection. Infectious

individuals recover and move to class R, at which point they are immune to future infection. This model can be and has been extended to include immunity that wanes over time. Hence other models were developed like the SIRS model – the last S standing for the recovered population that is susceptible again (Coburn et al., 2009).

2.5.3. Disease outbreak workflow and tasks

Managing disease outbreaks is an information-intensive task that relies substantially on information collection, validation, sharing, and visualisation (Baber et al., 2007). (Tschoegl et al., 2006). This leads to the need for establishing a multi-agency coordinating complex system consisting of cross-disciplinary public and private health professionals supported by advanced information systems. This can be described as infectious disease informatics (IDI), which is “an interdisciplinary research area that focuses on the design, implementation, and evaluation of advanced systems, techniques, and methods for managing infectious disease and epidemic outbreaks, ranging from prevention to surveillance and detection” (Hitchcock et al., 2007). Approaching the same issue from a different angle, the organisations interacting during the disease outbreak process represent a unique form of inter-organisational coordination. They create a matrix of interdisciplinary agencies coordinating within certain time constraints (disease infectivity characteristics). To understand the complexity of such a task, it is necessary to review some of the activities usually performed during disease outbreaks. The general schemes of these tasks are shown in Figure 2-16.

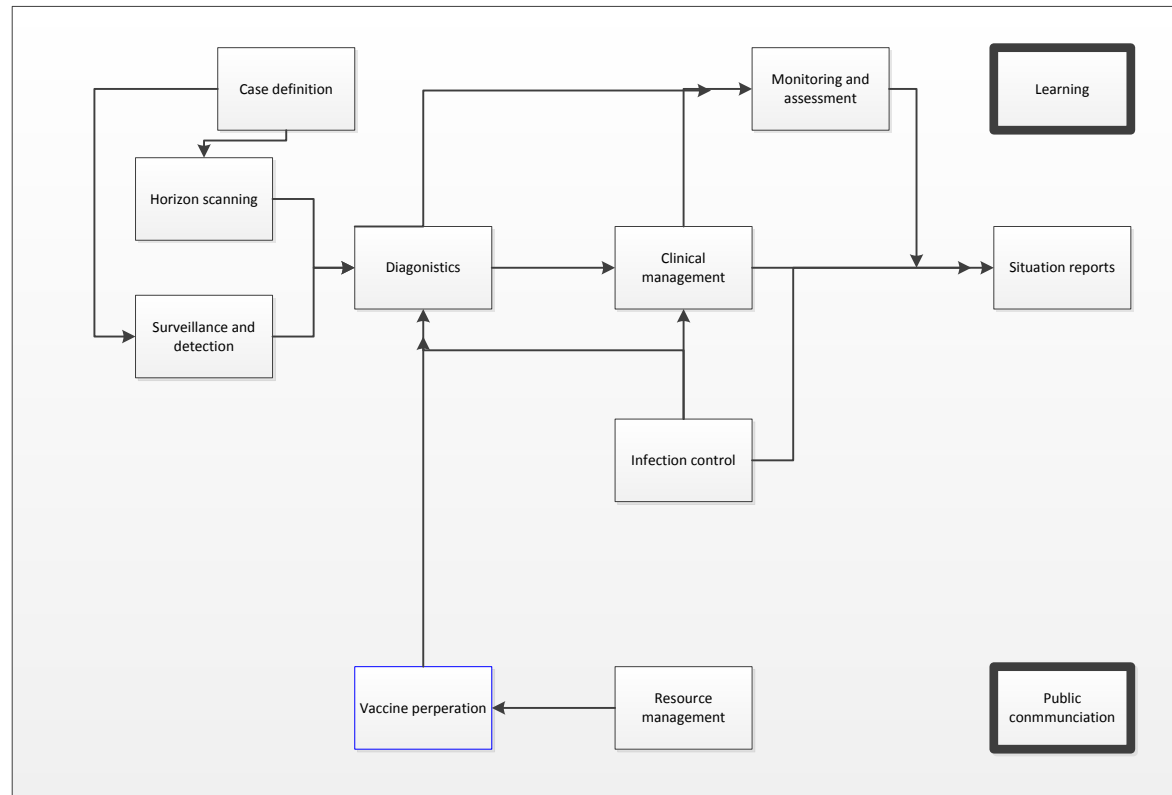


Figure 2-16: Schematic diagrams for the tasks during the outbreak

Some of these tasks are:

- 1- Horizon scanning: Horizon scanning is done to provide advance notification and understanding of the new and re-emerging infectious diseases. It is also used to communicate knowledge and technologies to health departments and policymakers to avert such potential risks.
- 2- Surveillance and detection: Disease surveillance is a basic tool for discovering the initiation of infectious diseases. It is the ongoing collecting, reporting, and analysing of public health data in a systematic manner to detect and monitor those diseases. Public health authorities use this term to define systems that use different methodologies to collect data and monitor outbreaks origination and progress. Surveillance keeps the world alert to changes in infectious disease threat and provides the background data needed to detect any unusual up-surge in cases of well-known endemics, the

appearance of a previously unknown pathogen, or an outbreak caused by deliberate use of a biological agent (Heymann and Rodier, 2001). There are different approaches to surveillance systems: Some infectious disease surveillance programs monitor a disease over time, like the WHO's Global Influenza Surveillance Network (Layne, 2006); others attempt to detect and track specific diseases, like the U.S. Department of Defence Biological Threat Reduction Program (Levac, 2006). Still others report on unusual clinical cases or disease clusters that are judged by experts to be of concern to the infectious disease community (Hutwagner et al., 2003). Other systems rely on "case definitions and clinical observations; others monitor laboratory test results (e.g., serology); some use analysis of samples routinely collected by sentinel clinicians; some derive data from routine computer-based searches of patient or public health records; and some use media reports about disease outbreaks" (Hitchcock et al., 2007). Not only does disease surveillance provide information about novel diseases, spikes in routine diseases, and characteristics of pandemics; it also informs about actions, which can be further investigated, response plans and strategies (Sell, 2010). Yet surveillance data by itself does not suffice to create successful response; the data must be carefully analysed by organisations that will utilise it to create situational awareness, develop plans and mobilise resources (Arita et al., 2004). Surveillance is a necessary prerequisite for successful reporting and response (Hitchcock et al., 2007).

The importance of surveillance cannot be understated. It can define the behaviour of diseases in populations and on this magnitude the public health problem can be assessed and an effective strategy developed (Arita et al., 2004). For example, the importance of surveillance was vividly illustrated during smallpox eradication in India and West Africa in the late 1960s and early 1970s. It was found that only 10% of cases were reported to health authorities. Hence it was deduced that mass vaccination without surveillance was ineffective: it must be guided by surveillance (Fenner and Organization, 1988).

Traditionally, surveillance lay solely in the domain of public health, but as the economic, social, and political effects of diseases have been recognised, and due to bioterrorism threats, it is now a mission pursued by defence, intelligence, and national

security-focused agencies as well (Sell, 2010). Surveillance systems try to collect information about:

- a. Outbreaks of unusual or novel diseases, such as SARS or Ebola.
- b. Increase in routine diseases, such as measles.
- c. Monitoring the outbreak: information can be collected on the spread and severity of disease and on potentially vulnerable populations to manage intervention and produce recommendations.

Surveillance can be passive or active. Passive surveillance relies on reports being sent to public health agencies from hospitals, laboratories and outpatient visits. Active surveillance involves outreach to actively collect disease information from specific groups, such as sentinel medical providers or hospitals. Typically, active surveillance is undertaken to look for a specific disease, such as influenza or whooping cough. Active surveillance is more labour-intensive and requires more public health resources than passive surveillance (Gordis, 2004) .

One interesting facet of surveillance was set up by the WHO which is using informal sources of information to detect suspected outbreaks as well as the usual formal ones such as U.S. Centres of Disease and Control (CDC), the U.K. Public Health Laboratory Service and the French Institutes Pasteur (Heymann and Rodier, 2001). One of the most important informal sources is a semi-automated electronic system called the Global Public Health Intelligence Network (GPHIN) that continuously scours world communications and crawls websites, social media, newswires, and electronic discussion groups for rumours of unusual disease events. Another example of informal surveillance collaboration, established in 2003, is Alumni for Global Surveillance Network (ASGnet). This group was initiated in Japan and consisted of principal government officials who dealt with infectious disease surveillance, forming 60 sentinels in 29 countries. They reported quarterly, by email, the infectious disease cases reported to them (Arita et al., 2004). The importance of such informal systems is that they accounted for 65% of the world's first news of infectious disease events between 1997 and 2001 (Heymann and Rodier, 2001).

- 3- **Diagnostics:** Diagnostics is the process of attempting to determine a possible infection. The diagnostic procedure attempts to classify an individual's condition so to allow medical decisions about treatment and prognosis to be made. A number of tests can help in the diagnosis of influenza and its clinical management, but the preferred test is collecting respiratory samples for influenza testing include nasopharyngeal or nasal swab and then using lab-developed reagents to test for viral presence and type. This test obtains results usually within 1 to 4 hours (CDC, 2011).
- 4- **Clinical management of patients:** This is the management of patients with influenza-like illness (ILI). It might include sending some patients home since they do not have complicated influenza infection and would be expected to recover within one week. Other patients who might have complications will need to be admitted to hospitals, and others who might have developed influenza-related pneumonia are at high risk of death and should be managed as having severe pneumonia. Such patients will need to be admitted to an intensive care unit and need to be managed by specialists with appropriate training in intensive care, respiratory medicine and/or infectious diseases (This, 2007). It is also well known that during a pandemic, the demand for acute clinical care will be high. Hence hospitals and clinical care facilities need to adjust their services to maximise the benefit of scarce resources and to plan their surge capacities to accommodate the expected influx of patients. The facilities can be expected to begin a phased deferral of non-influenza services or to scale back some elective services.
- 5- **Reporting:** Reporting pandemics is a multi-tiered complex process. It can start bottom-up, such as with a surveillance team (be it an emergency department, a GP or a laboratory test result) instigating the investigation about a possible outbreak. Or it can be top-down, such as the WHO releasing a regional or global declaration or warning for a certain pandemic. Between these two simply conceived reporting extremes, a complex multi-agency reporting process gathers and follows up information and combines it in intelligence reports for decision makers. Besides their reporting lines or directions, these reports also differ in content. For instance, WHO issues case definition reports which define who is included as a case in an outbreak investigation. Other reports aggregate reported case data based on demographics, age, etc.

- 6- Infection control: There are methods and strategies by which the transmission of influenza agents can be reduced. These can be as simple as performing hand hygiene. Other methods such as social distancing, home isolation or quarantine aim to proactively protect susceptible population. Some more drastic measures can be taken if need be, such as school closures. Hospitals can apply more sophisticated infection control methods to protect non-infected patients and the hospital workforce.
- 7- Public communication: influenza pandemic generates immediate, sustained and intense demand for information from the public, healthcare providers, policymakers, and news media. People need information about what is known and unknown, as well as interim guidance to formulate decisions to help protect their health and the health of others. Coordination of message development and release of information among federal, state and local health officials is critical to help avoid confusion which can undermine public trust, raise fear and anxiety, and impede response measures (Reynolds and Quinn, 2008). The messages should be timely and transparent to build public confidence on one hand and to induce the public to act and maybe change some behavioural patterns on the other hand, such as adapting the “etiquette sneeze” (Cordova-Villalobos et al., 2009). Tools available for communicating with the public include traditional media such as television, radio, newspapers or websites, and new media such as social networking sites. The messages should cater for linguistically and culturally diverse segments of the population in multicultural countries.
- 8- Response: A pandemic response involves the collective action of every part of the of the health sector. After the response is initiated, continuation of the measures is required to address the evolving situation. Response includes some of the tasks discussed previously (such as clinical management, public communication). It is usually a multi-jurisdictional process by which reports, surveillance information and intelligence are used to mobilise resources, based on predetermined operating plans. It is important for these plans to be flexible enough to adapt to unforeseen circumstances. Governments usually have national response plans, yet international collaboration is becoming the standard where WHO plays a leading role in such collaboration.
- 9- Intervention: Intervention entails using medical resources to treat and follow up the treatment of infected cases, Mainly antiviral agents for influenza can be used to

prophylactically prevent infection given exposure, to reduce the probability of clinical illness given infection, and to reduce the probability of transmission to others given infection (Longini et al., 2004). Given the limited antiviral stockpile, public health officials use preventive or prioritised intervention to vaccinate the high-risk and susceptible segments of the population such as the elderly and children or the kin of an infected person. Intervention also means using other medical means such as ventilators for critical care patients who are admitted to intensive care units.

10- Inter-organisational communication: Communication plays a key role in the ability of different agencies to attain and maintain superior coordination. The two concepts are linked because communication can be regarded as a necessary and sufficient precedent associated with coordination (Miller and Moser, 2004). The wide range of tasks and activities performed during an outbreak mandates a great deal of communication between relevant agencies. These communications need robust, stable, effective and compatible informatics systems (Bdeir et al., 2011). Highlighting the importance of communication, a study has shown that the real problem in Hurricane Katrina was lack of information and information management. Not enough information was shared between those at different levels: field, local Emergency Operations Centres (EOCs), hospitals, and the state (Pou, 2008). Many types of information are communicated during a pandemic, including:

- a. Case definitions: This is the set of diagnostic criteria standardised for the purpose of identifying a particular disease. It can be based on clinical, laboratory, epidemiological, or combined clinical and laboratory criteria (WHO, 2012). It is usually set by WHO and then disseminated to countries concerned. However, each country might customise the case definition according to its own standards. It is important for the case definition to be accurate, since it dictates which patients with influenza-like illness are to be treated as cases. Also case definition changes and updates must be rapidly communicated to Emergency Departments, GPs, hospitals, and public health officials to ensure accurate reporting of new cases.
- b. Diagnostic results: Like laboratory results; these need to be communicated to patients, the test requestor (might be the GP) and public health officials.

Compatibility of laboratory systems with other health systems is an important factor in getting results to relevant parties quickly, without putting further strain on the laboratories to deliver these results.

- c. Situation reports: These reports are used to provide the most recent and accurate available information about the pandemic status within a defined jurisdiction or geographical boundary. These reports are aggregated from hospitals, laboratories, and public health unit data to the state and federal level. They are meant to provide decision makers with a clear view of the current situation, such as confirmed and suspected cases, hospitalisations, number of people tested and treatment given, along with statistical comparisons with previous or historical data. Some situation reports also contain resource utilisation ratios.
- d. Directives and decisions: These are instructions and/or guidelines that are issued from higher levels of the pandemic management committee(s) to those who are in executive positions in middle and lower management roles. They are then translated to tasks and duties for front line staff in emergency departments and other facilities.

One last note about communication is that it can either pull or push information. In the former case, a second party has to be queried in order to gain access to information; in the latter case information is provided proactively.

11- Continual monitoring and assessment: It is necessary to monitor circulating influenza strains in order to contribute to ongoing pandemic risk assessment. This also includes detecting new cases of new subtype influenza infections.

12- Resources management: Managing pandemics requires a range of resources, apart from human ones, some of these being: PPE (personal protective equipment), antibacterial gel, vaccines and swabs. Public health authorities usually stockpile these supplies so to avoid any shortages during the pandemic period. Authorities distribute these to parties that need them; those parties include GPs and facilities such as hospitals, community health centres, schools, etc. By using infection control measures,

authorities can effectively reduce the strain on the antiviral stockpile by decreasing the expected number of infections.

- 13- Antiviral and vaccine preparation: It is not logistically or practically possible to prepare reagents and vaccine against all strains of influenza, therefore virus subtypes must be prioritised for pandemic vaccine and reagent preparation. This is due to the different virus subtypes and antigenic drift that some subtypes such as H1 and H3 experience (Webby and Webster, 2003). The general stocks of antiviral drugs are too low to cope with an epidemic and would be quickly depleted (Smolinski et al., 2003). One main method of vaccine preparation is through growing influenza genome in embryonic chicken eggs to produce the desired antigenicity. Although this method creates safe and effective influenza vaccines, it is too time consuming and too dependent on a steady supply of eggs to be reliable in case of pandemic emergency. During inter-pandemic periods, 6 months is required to organise sufficient fertile chicken eggs for annual vaccine manufacture (Catherine, 2003). Hence scientists and virologists are working on other methods such as reverse genetics, that can produce vaccines more quickly in pandemic situations (Webby and Webster, 2003) .
- 14- Learning: Extreme situations impose a steep learning curve on intervention participants from different disciplines. Certainly exercises and training sessions are conducted before a pandemic, yet each situation brings unique challenges. Continual sharing of new techniques, best practices and personal experiences through continual communication and interaction will reduce errors and sub-optimal processes and help teams to be adaptable, flexible and receptive to new input (Marshall et al., 2008).

2.6. Hypothesis

There is an increasing interest in utilising network theory techniques in research and subsequently applying them to increasingly sophisticated coordination scenarios (Zakour, 1997, Chwe, 2000). The discussion has also demonstrated how these have been applied in disaster research. One of the gaps in that research is the application of such techniques to studying inter-organisational coordination for a specific form of disaster, disease outbreak. To study such a case I explore the H1N1 2009 outbreak within the state of NSW in Australia.

In such a coordination framework, different attributes of the node are used, the node being the agency or organisation engaged in the coordination. And network measures define its positional characteristics. These attributes are those of the social network such as centrality, betweenness, and tie strength. The assessment criteria are then compared against a measured outcome.

This modelling technique is based on the concept of independent variables influencing the outcomes of the process, which in turn are called the dependent variables. The independent variables are the network measures determined by the network structure. They in turn influence the dependent variables (Creswell, 2009), which represent some type of performance or measure for the coordination process. The dependent variable should be a measurable and quantified value that can provide an outcome correlated with the independent ones.

Figure 2-17 is a high-level view of such a model.

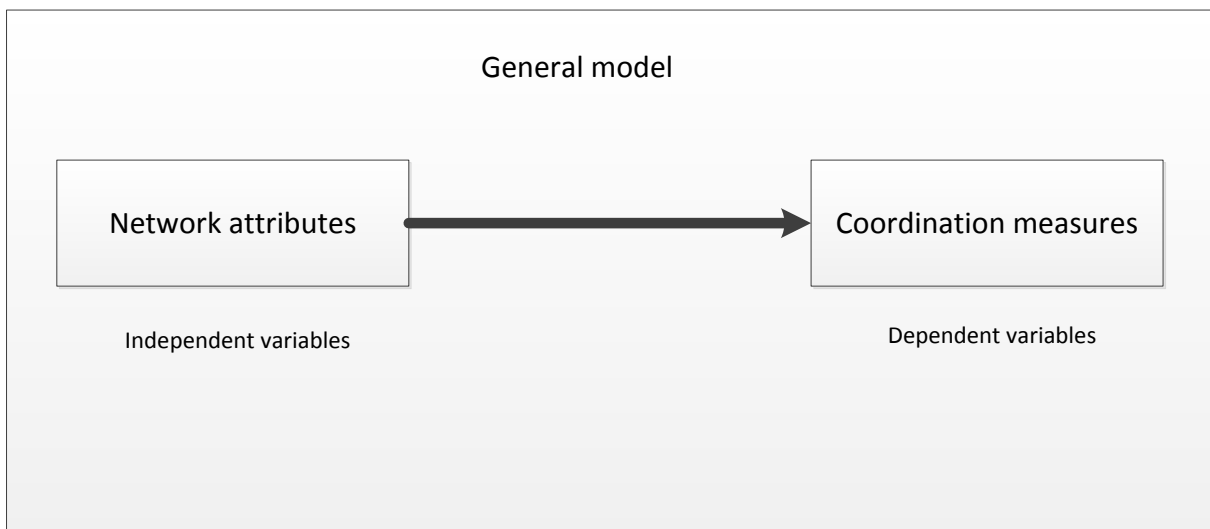


Figure 2-17: Social networks-based model for coordination

Working further to populate this model, it is necessary to decide the appropriate variables to be used on each side of the diagram. These should be measurable, selected in accordance with the literature, and be collectable, i.e. data that can be quantified from the field.

2.6.1. Dependent and independent variables

Most of the important network measures were discussed in section 2.3.3. Here I briefly describe those that have been found indicative for coordination facilitation.

Degree centrality might be the first measure that shows up as a powerful candidate. In coordination related research, degree centrality was found to be an index of a position's potential for activity in the network (Freeman, 1978). (Hossain et al., 2006) showed that out-degree centrality had a stronger correlation to coordination than in-degree centrality. Hence centrality has been chosen as a network based measure, to further determine its effect on coordination.

Another network measure is tie strength, an important attribute for defining the quality of relationship between nodes. Several studies have focused on the strength of network ties as a source of different kinds of information exchange (Granovetter, 1983). This relationship quality is specifically important during disasters and is directly linked to the frequency of information sharing and exchange (Uddin and Hossain, 2009). An egocentric analysis of tie strength against coordination has found that an increase in the quality of relationships can improve coordination attributes such as quality and accessibility of information and overall readiness for an emergency situation. That correlation may be due to the context of the data itself more than an overarching statement of tie strength (Hossain and Kuti, 2010).

The last network measure to be used is tier connectedness. Tier level refers to the layer in which an organisation exists, such as federal, state, local, private or other types. Tier connectedness can be used as a measure to assess the current state of actor involvement. It has been suggested that by increasing the efficiency of an actor's tier connectedness within the network, an increase in the potential for the network to coordinate effectively may be found. Tier connectedness, henceforth called connectedness, works as an enabler of coordination efficiency rather than an inhibitor, by limiting the network involvement to the needs of a given tier, thus preventing the circulation of redundant or unnecessary information through the network as a product of excessive ties (Hossain and Kuti, 2010).

These three measures are the independent variables. They are all indicators of how well an organisation can coordinate and how efficient the coordination structure itself is. Some of

these measures have previously been used as independent variables to measure coordination in soft target organisations- being the common access places such as schools, parks and sports facilities - and disasters (Hossain and Kuti, 2010, Uddin and Hossain, 2009).

The dependent variable for disease outbreak should be a clear indicator of performance results that can be correlated or not, so as to prove or disprove the null hypothesis. In this research I have decided to use the speed with which the coordination began after the outbreak was announced, *as well as respondents' perception about how long it took for the coordination to become optimal*. More detail is presented in Chapter 3.

Although in this research the main focus was on the state of NSW, during the course of interviews it became necessary to classify the organisations that dealt with the outbreak into two main broad categories: State and local organisations. State organisations are those that work on the state jurisdictional level, with their authority, influence and interest covering the whole of NSW. Local organisations are those that act at the area health service jurisdictional level. NSW is divided into eight area health services (formerly called local health districts). Differences between organisations at each jurisdictional level are expected to reflect on their networking characteristics and variables. These elaborations allow a more detailed depiction of the model as presented in Figure 2-18.

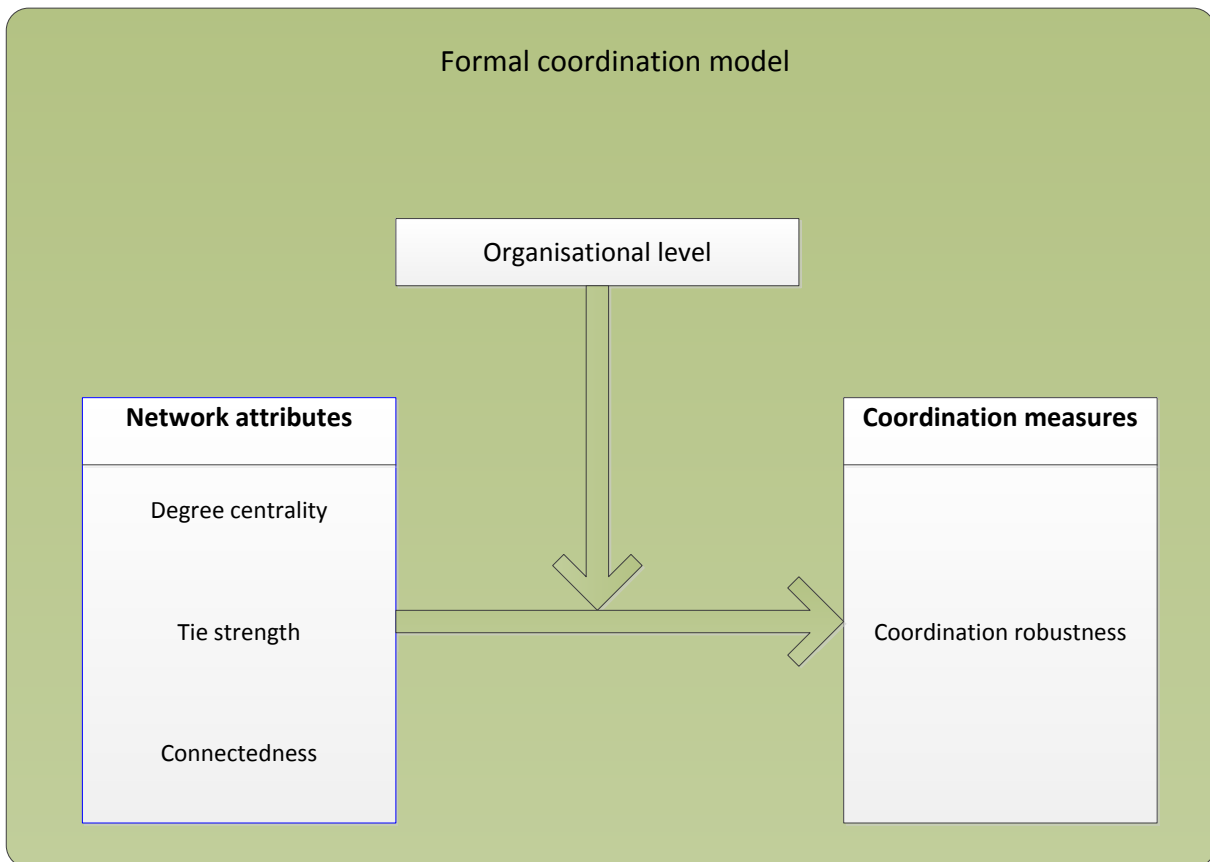


Figure 2-18: Coordination model

The same measures and concepts can also be applied to the network of informal coordination where the same network measures apply, since the ego will be initiating communications. The dependent variable is still communication robustness, but this robustness is defined in relation to the main reason for initiating informal coordination from the very beginning: bridging coordination gaps. Hence as the dependent variable, coordination robustness is considered to be the perception of respondents as to the importance of informal coordination to bridge any gaps left by formal coordination. How effective was this form of coordination in bridging structural holes? (Burt, 1992). Structural holes give the node that is bridging them competitive advantage, because nodes at the edges of the chasm do not communicate directly with each other, as explained by Burt. In the context of coordination, and especially disaster coordination, it is important to cover those holes as effectively as possible during the emergence of the network structure. Hence the informal coordination model will use the ability of informal coordination to close these gaps, as elaborated in Figure 2-19.

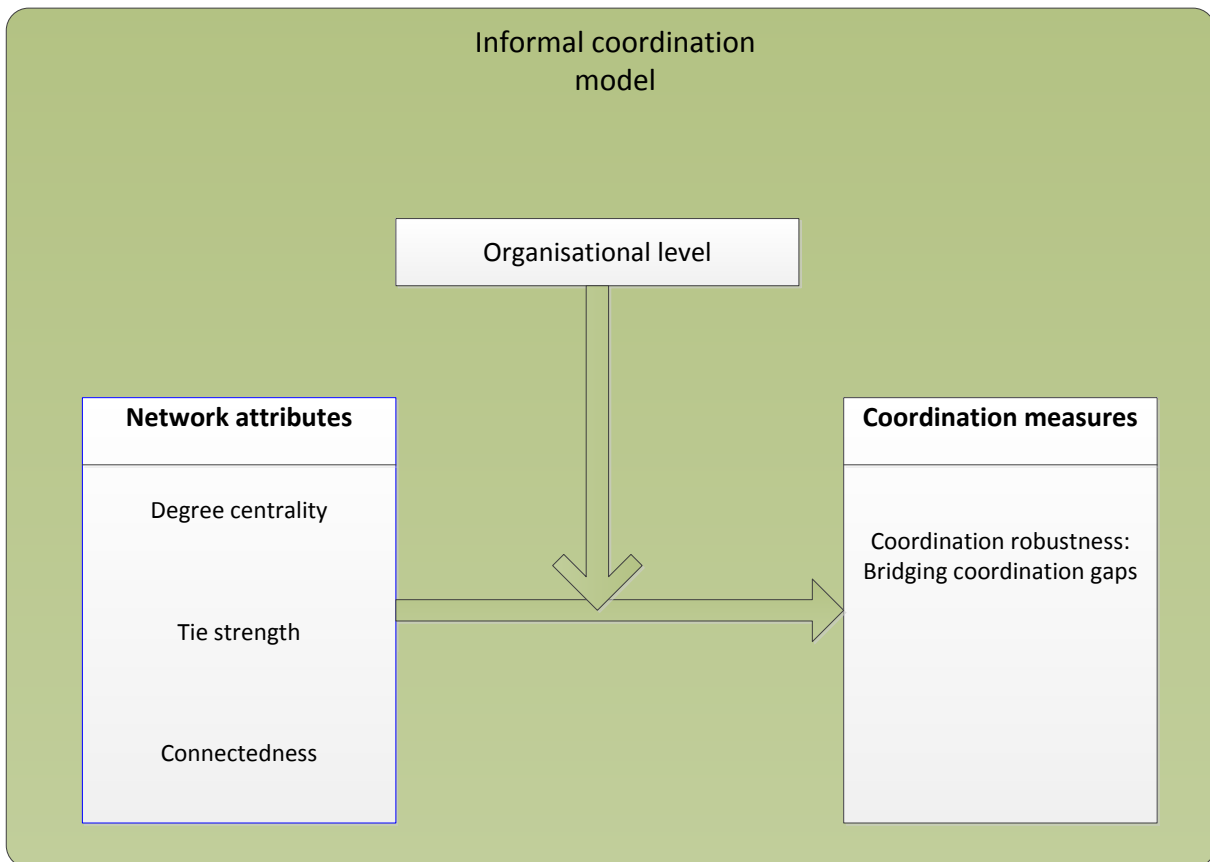


Figure 2-19: The informal coordination model.

2.6.2. Coordination phases

Coordination structures no longer rigid, as explained previously. They are dynamic and change in accordance with the crisis on hand. Hence it was necessary to study the pandemic coordination during two main phases, before and during the outbreak.

Usually pandemic management agencies participate in constant exchanges of information such as details of new cases, confirmed lab results as part of surveillance, or horizon scanning activities. These are normally constant bureaucratic activities that most public health related agencies routinely engage in as part of their standard practices. This information gathering and exchange process is an integral and important part of pre-pandemic administration that will also lead to a proactive management model. This communication should all lead, theoretically

at least, to better management and coordination efforts during the outbreak itself, as the agencies are familiar with each other's roles and communication protocols.

Hence this research was designed in a way to capture the pre-pandemic communication lines and then also capture those lines during the pandemic itself. This could facilitate understanding of the coordination lines and how they change with phase change.

Moreover, it was desirable to investigate coordination more comprehensively during the outbreak. Thus I planned to capture both formal and the informal coordination during the outbreak management. This represented a unique opportunity to examine the process from both facets, which has not previously been undertaken, as elaborated in previous sections.

Researching informal communication before the outbreak will be done qualitatively. The main reason is that before the outbreak, coordination is neither intensive nor demanding. The model will be as illustrated in Figure 2-20.

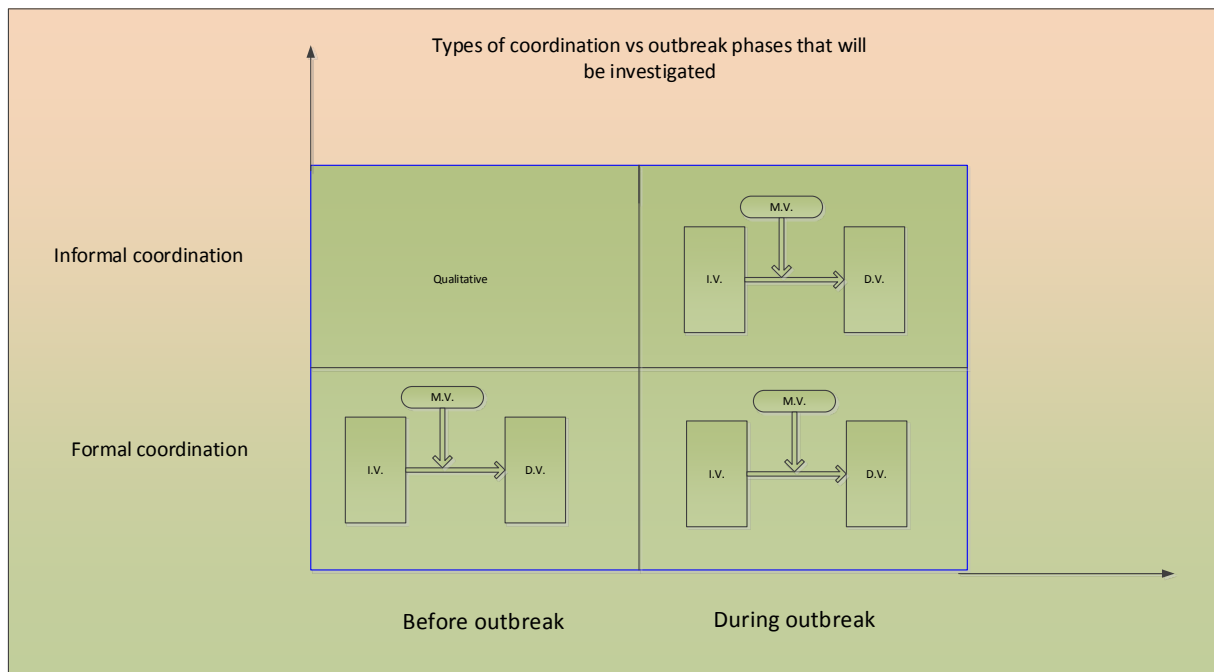


Figure 2-20: The three phases of coordination considered in the research

2.6.3. Research Hypothesis

In this section hypotheses are proposed that will be either validated or disproved in analyses.

2.6.3.1. Hypothesis 1 (H1)

There is significant relationship between the network positions of the agency (node) in the formal structure of the disease outbreak coordination network that exists before the outbreak coordination officially starts and the perceived level of performance regarding how long it took for the coordination to be optimal. To assess this hypothesis, three sub-hypotheses are used to evaluate the principal theory. They are:

Hypothesis 1a. Degree centrality in formal structure is positively correlated with the perceived coordination robustness before and during the outbreak.

In an organisational environment, an actor with high degree centrality would be ‘in the thick of things’ (Freeman, 1978). Hence it is expected that when a node is well connected to other nodes it will be better equipped and prepared to start the coordination process or join an emerging coordination process due to its high number of links that are expected to expedite the transfer of information from that node to others.

Hypothesis 1b. Tie strength in formal coordination is positively correlated with coordination robustness.

It has been shown in coordination preparedness that the greater the strength of the relation of an actor in the network, the more frequently it can share information with others (Uddin and Hossain, 2009). Tie strength defines the quality of a relationship and is a source of different kinds of information required for information exchange. Weak ties represent relationships that might be less efficient and might not be well maintained, whereas strong ties depict frequent and stable relationships. It is expected; therefore, that if a network has already forged strong ties between its nodes then it will better prepared to initiate the coordination process when needed, and is better equipped to meet coordination challenges that might arise later.

Hypothesis 1c. Tier connectedness in formal coordination is positively correlated with coordination robustness.

Tier connectedness is considered a measure of the variance of the nodes to which an agency is connected during the event (before and during the outbreak). Hence it is used as a measure of a node's multi-tiered relationships. For example, if an organisation operating at the local level can establish and maintain relationships with agencies at different jurisdictional levels (international, federal, state, etc.), that organisation will then have access to diverse sources of information and resources. It is originally anticipated that the collaboration network will operate at different jurisdictional levels, creating an interconnecting mesh that crosses tiers, as well as the cliques that usually exist within the network greater structure (Hossain and Kuti, 2010). By moving away from standard centrality definitions, how can such interconnectedness be interpreted? Does it correlate with an increase in coordination capability due to this multi-jurisdictional outreach? Will these diversified links locate the ego-nodes in a preferred position in relation to others that produce a more effective coordination performance? These are some of the questions to which the inter-connectedness analysis is expected to provide answers.

2.6.3.2. *Hypothesis 2 (H2)*

Hypothesis 2 investigates the informal structure of the coordination during the outbreak. As described previously, informal networks are formed when nodes (agencies or individuals) find it mutually beneficial to outreach each other to build shared understandings about issues that are important to the group. These networks grow spontaneously to satisfy personal needs. (Atkinson et al., 2005). In particular, these networks grow when there is need for information to deal with the task at hand; they are fast and surprisingly accurate and efficient vehicles for news and information (Waldstrøm, 2001, Mintzberg, 1979). Such information needs grow when there is insufficient or inaccurate information at times of uncertainty or crisis (Krackhardt and Stern, 1988), and thus such networks try to arbitrate information to cover these structural holes (Burt, 1992). Hence the coordination robustness or performance indicator for the informal network in this research is the perceived ability of these informal links to bridge the gap and cover those holes.

Hypothesis 2a. The degree centrality of informal coordination is positively correlated with its ability to bridge coordination gaps.

It is very likely that the more informal links that a node creates, the more it will be able to obtain novel information otherwise unavailable via formal links. Firstly there must be a premeditated intention to create these links and secondly there must be awareness of the number of these needed links. In other words, the person occupying a particular organisational position reaches out to satisfy his or her information needs so as to facilitate coordination capability, hence limiting or extending the number of those links and thus controlling outbound centrality.

Hypothesis 2b. The tie strength of informal coordination is positively correlated with its ability to bridge coordination gaps.

Tie strength is related to the frequency of communication between two parties. Since the main reason for initiating an informal link is to obtain some required information, therefore, it is anticipated that the more the two parties communicate, the more they will share needed information and the more they will be able to coordinate common tasks, especially those that need extensive information sharing.

Hypothesis 2c. Tier connectedness in informal coordination is positively correlated to information sharing and bridging coordination gaps.

Novel information needs to be obtained from diverse resources that exist in different repositories, which are not necessarily defined in the standard operating procedures or able to be obtained via established links. Therefore, informal links need to extend beyond the pre-established cliques and spread to cross-jurisdictional and hierarchical levels to satisfy the need for novel information. The more a node is connected across tiers, the more it will be able to acquire varied information to coordinate complex and demanding tasks.

2.6.4. Moderating variable

A moderating variable can be defined as one that affects the direction or strength or both of the relation between dependent and independent variables. In the proposed model, the moderating variable is considered as a third variable that affects the correlation between both variables. Moderating variables usually stem from the socio-demographic characteristics of actors such as their age, gender, locality or position. It is of interest to discover if a moderating

variable might exercise an influence on the dependent variable. Since this research deals with organisational nodes, it was decided to use the organisational tier level of the respondent as the moderating variable. This would further enable checking the influence of the organisation's tier on coordination performance. Introduction of the moderating variable gives rise to Hypothesis 3:

Hypothesis 3. The relations between H1 and H2 are mediated by the moderating variable being the tier level of the organisation that originates the link.

2.7. Introduction to next chapter

Having reviewed the literature that leads to the above-mentioned hypotheses, in the next chapter I present the social network measure that were selected to test those hypotheses. The chapter then details the data collection methodology, how it was constructed, its rationale, how it was carried out, and which constructs defined the hypotheses variables.

Chapter 3

3. Data Collection and Analysis

In Chapter Two, I discussed the theoretical background of the research. This chapter discusses social network methods, data collection and analysis techniques and how to employ them in the present research. This chapter moves from general to specific in presenting the material. It first briefly introduces network analysis, which took its name from social network analysis, and how and why it can be used to analyse inter-organisational coordination. This leads into the detail of the measures that can be used to gauge this coordination and the type of data that need to be collected to satisfy the measures. Since this is new research, it was decided to approach it quantitatively and qualitatively; hence both methods are overviewed. After this general overview the chapter moves into the specifics of data collection, zooming in to the research data collection techniques. This begins by introducing the geographical area and the particular pandemic that was sampled, and then presenting the designing of the qualitative and quantitative data collection instruments along with how they were administered. The chapter concludes with exploring data analysis procedures and data set exploration and description.

3.1. General Introduction to Social Network Analysis Methods

The origins of social network analysis (SNA) can be traced back to the 1930s when Jacob Moreno published his book “*Who Shall Survive?*” which is depicted by many scholars as the origin of SNA (Hummon and Carley, 1993, Leinhardt, 1977, Degenne and Forsé, 2004, Wasserman and Faust, 1995). Another important transition in the history of the SNA field began in early 1970 when Harrison White at Harvard started training graduate students in that field, producing an “amazing number of important contributions to social network theory and research such as ‘the block models theory for social structure’” (Mullins and Mullins, 1973, Hoffmann-Nowotny, 1984, Scott, 2007).

Beyond the historical timeline, SNA progressed theoretically in the field of social sciences with the interest in studying interactions among individuals. This went beyond the sample survey that used to dominate empirical social-research-based random sampling of individuals that were “tearing the individual from his social context and guaranteeing that nobody in the study interacts with anyone else”, as Allen Barton (1968) described mainstream research in social sciences. He also described that type of research as, “like a biologist putting his experimental animals through a hamburger machine and looking at every hundredth cell through a microscope; anatomy and physiology get lost, structure and function disappear, and one is left with cell biology... if our aim is to understand *people’s behaviour*... we want to know about primary groups, neighbours, organisations, social circles, and communities; about interaction, communication, role expectations and social control” (Barton, 1969). This statement marked the development of social sciences, the aim of which has been always to investigate the behaviour of individuals, to incorporate the interaction of social actors as major part of any ongoing research (Freeman, 2004).

Moreno collaborated with Helen H Jennings to support the social network theory with what they called “*sociometry*“, which Moreno defined as an “experimental technique... obtained by application of quantitative methods... which inquire into the evolution and organization of groups and the position of individuals within them” (Moreno, 1953). Social network theory, modelling and analysis soon began to penetrate different scientific disciplines and its methods were adopted in anthropology, communication studies, economics, biology, geography, information sciences, organisational studies, social psychology and sociolinguistics (Hummon and Carley, 1993, Leinhardt, 1977).

SNA can be defined as the relational data between actors, rather than the attribute data from a sample of individuals as in a general social survey (Chung et al., 2005). Those actors are called *nodes* and their relationships are called *ties*. The combination of nodes and ties can be presented in an array as the first step in visual representation.

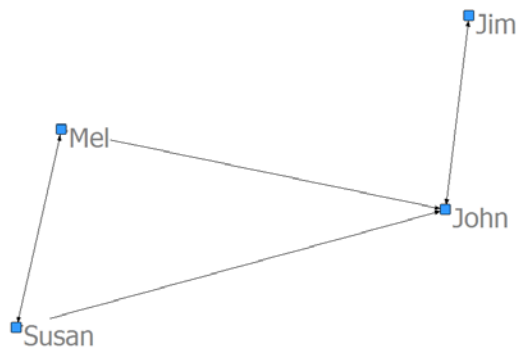
Table 3-1 is a simple array of “like” relationships that might exist between four individuals. Such data might be obtainable by asking the respondents – nodes – to answer a simple question such as: “Identify the ones you like from this set of individuals.”

Table 3-1: A simple matrix of “like” relationship between four individuals

Chooser	John	Jim	Mel	Susan
John	--	1	0	1
Jim	1	--	0	0
Mel	1	0	--	1
Susan	1	0	1	--

Visualisation is a powerful tool in SNA, which can provide investigators with new insights about network structures and help them to communicate those insights to others (Freeman, 2000). For example, visualising

Table 3-1 will result in Figure 3-1 below. This figure will easily suggest many assumptions about the network, such as that Jim is not popular within the group and the three other members maintain a close relationship among each other.

**Figure 3-1: A visual illustration of Table 3.1**

Yet SNA is not limited to social behavioural research; as mentioned previously, SNA has extended to other domains and established itself as an interdisciplinary field. One domain that uses SNA methodologies is inter-organisational relationships. Borgatti and Foster (2003) previewed some of the major research streams in organisational network theory. Their investigation began by looking at the use of network analysis in studying social capital, which is about the value of connections (Seibert et al., 2001, Adler and Kwon, 2002, Hansen, 1999b). Another branch was the study of embeddedness, which entails the notion that all economic behaviour is necessarily embedded in a larger social context, hence looking at economics as a branch of sociology (Ingram and Roberts, 2000, DiMaggio and Louch, 1998). In 1980s and 1990s, the use of organisational network terms was a fashionable way to describe organisational forms characterised by repetitive exchanges among semi-autonomous organisations that rely on trust and embedded social relationships to protect transactions and reduce their costs. It was argued in network organisation research that as commerce became more global, hypercompetitive and turbulent, both markets and hierarchies displayed inefficiencies as modes of organising production. In their place, a network organisational form emerged that balanced the flexibility of markets with the predictability of traditional hierarchies (Bradach and Eccles, 1989, Miles and Snow, 1986, Achrol, 1996, Borgatti and Foster, 2003, Van Alstyne, 2009). The study of board interlocks, which are ties among organisations that exist through a member of one organisation sitting on the board of another, also had its share of network analysis field and methods (Pfeffer, 1972, Pfeffer and Salancik, 2003). Network analysis has been used in public health studies, and some of that literature was reviewed in the paper titled “Network Analysis in Public Health: History, Methods, and Applications” (Luke and Harris, 2007). Network theory has been extensively used in epidemiological research such as tuberculosis (Klovdahl et al., 2001) and sexually transmitted diseases (Chen et al., 2003)

The SNA Data requirements are different from those of traditional social research in that SNA is capable of featuring rich information that analysts can use to understand social effects and trends.

3.2. Network Data Collection

Since it is relational data that is needed, social network analysts rarely use samples in their work. They usually identify some population and conduct a census by including all elements of the population – or as many as needed – as units of observation (Hanneman and Riddle, 2005). The two main approaches to collect relational social network data being the sociocentric and egocentric approaches are discussed next.

3.2.1. Sociocentric approach

The sociocentric approach is based on “whole network” or “whole population” method, assuming the availability of complete network information. In other words, it is based on a census approach for a certain predefined population with set boundaries. First, the researcher should define the network in question such as a classroom, school, board of directors for a certain company or mental care health providers in a certain city. Then a data collection method is used such as a network survey to investigate the ties between each node of this network to others, thus facilitating a complete understanding of the relationship matrix of the entire population investigated.

This approach is an ideal and desired situation for any researcher, since the information collected represents the saturation sample of interest and the results can be generalised for the population (Chung and Hossain, 2009) ; however, full network data can be very expensive and difficult to collect. Asking each and every member of a population to rank and rate every other member can be a very challenging task in all but small groups. This task can be made more manageable by asking respondents to identify a limited number of specific individuals with whom they have ties, based on the context of the study. Yet this problem might not be as severe as one expects, because many organisations, persons and groups tend to have a limited number of ties. This is probably because social actors can utilise only limited resources like energy, time, and cognitive capacity to maintain their ties, especially the strong ones (Hanneman and Riddle, 2005). This also contributes to the fact that social structures tend to self-balance and self-organise with relatively manageable connections.

Sociocentric approaches have been used in some inter-organisational coordination investigations that considered a particular type of health system in a bounded geographic area

such as a city (Provan and Milward, 1995, Tausig, 1987). This works well because there is a predefined and well-known set of organisations that deal, say, with mental care in a certain city, since they are usually institutionalised based on jurisdictions. In this environment it is rare to have new nodes joining or exiting the network dynamically. Actually, more often than not, such changes negatively affect the performance of the network, as Provan and Milward (1995) have demonstrated.

There are many challenges for using this approach in the context of pandemic coordination. To conduct a sociocentric study for pandemic coordination requires the collection of data from all the health workers, private and public, clinical and managerial, logistic and microbiological, within the geographic boundary of the state of NSW. This would literally create a list that includes tens of thousands of names, resulting in huge workload and data warehouse. Earlier research proposes that scrutinising through extensive lists of names and identifying the numerous kinds of links with each individual on the list leads to exhaustion and recall difficulties (Bernard et al., 1982). To overcome these problems, an alternative approach for social network data collection, which trades off respondent numbers with information richness and practicality, is the egocentric approach.

3.2.2. Egocentric approach

The egocentric data collection approach is another well-known method for collecting network data. Basically, this approach begins with the selection of focal nodes, “egos”, and identifies the nodes, “alters”, to which they are connected. Ego in the network parlance means the person being investigated, and alters are the people who are the ego’s affiliates or the “others” whom the ego is linked. In other words, it is the network of me (the ego). The researcher then decides which of those alters is interesting for the research and interviews those people. This progressively unveils the perspective network as we proceed to identify more alters in one step and change them to egos in the following one. The egocentric method is used when studying novel types of networks where nodes, affiliations and extent or boundaries cannot be predefined and which have not been previously investigated. Data collection will proceed by snowballing from one ego to another until no more actors are identified or the researchers decide to stop for other reasons like time and resource constraints or when practicality

suggests (Goodman, 1961). This method can be used to determine business contact networks or community elites and is used as name generator for further investigations and data collection.

When combined with an attribute-based approach, the egocentric method is effective for collecting relational data (Hanneman and Riddle, 2005). The egocentric network of a firm consists of its set of direct, dyadic ties and the relationships between these ties, with the firm at the centre of the network as the focal actor (Wasserman and Faust, 1995). When it comes to analysis, however, the egocentric network implies a dual level of network analysis that requires simultaneous focus on network dyads and the aggregation of dyads into the larger network. This simultaneous focus is necessary because changes in an organisation's egocentric network result from the aggregation of changes at the dyadic level. Thus, the evolution of a network necessarily includes and builds from the simultaneous evolution of the dyadic ties (Hite and Hesterly, 2001).

Knoke (1993) suggested four generic techniques to locate players within networks, these are:

- 1- Positional methods: persons occupying the key roles in the system, such as the ones with executive roles.
- 2- Decisional methods: actors that participate or influence the collectively binding decisions for the system.
- 3- Reputational methods: actors who have actual or potential power to "move and shake" the system.
- 4- Relational methods: actors who maintain important political relationships with other system members.

Knoke (1993) then states that it is hard to keep these methods separated as there will be always mix between incumbent and past involvements. In the inter-organisational disease outbreak data collection protocol, one noticeable condition was the different schemas of the parties involved, representing a wide spectrum of expertise, domains and bureaucracies. Hence data collection needs to be conducted through a diverse community of health professionals with various positions and skillsets to provide their linkage data. These positions could range

from emergency care provider to clinicians and epidemiologists. Table 3-2 shows some of those positions that could participate in the survey:

Table 3-2: Some of the positions that participated in pandemic coordination

Working Field	Position Examples
Clinical care	Doctors, nurses
Policy decision-makers	Senior public health officials
Emergency management	Emergency care professionals, intensive care unit professionals
Logistics	Ambulance services
Public health	Public health unit, epidemiologists
Detection and surveillance	Laboratories, GPs, infectious disease centres.

Interviews with such professionals were used to construct the network of the participating organisations in pandemic intervention and coordination. Interviews snowballed from one participant (ego) to that participant's interesting alters who were considered that have knowledge that could further extend the scope of information.

3.3. Social network measures

In any research, data collection is followed by data analysis and choosing the investigation approach. Network-based research is no exception. This section provides background of the calculation, interpretation, and some uses of various empirical formulas in the network analysis domain. For example, some of these measures define nodes that occupy an important role, like being in the central position of a network. The section also discusses some of the structural properties of the whole network. These empirical measures are a mean to quantify the position of nodes (being either individuals or organisations) within the structure as part of the sense making and enumeration of the coordination performance. There are numerous quantifying network measures that are usable by researchers, yet those used in each study depend on the structure of the network in hand and its associated level of data availability. For instance, in a star or wheel network where there is a central node connected to all other nodes,

using betweenness centrality is not applicable since it would not provide any significant or interesting information.

3.3.1. Degree centrality measure

When looking at network diagrams, viewers innately focus their attention on the nodes located in the centre. Typically, being at the centre of the network is viewed as a positive trait. These nodes enjoy positions of prestige and visibility, and may be influential in the spread of ideas, behaviour and information (Valente, 2010). Centrality measures for social networks were first developed in the 1950s by Bavelas, Sabidussi and many other scholars from many disciplines (Everett and Borgatti, 1999, Freeman, 1978). Freeman introduced the modern topology of network centrality measures by specifying that a centrality measure can have three properties (Valente, 2010):

- It can be calculated on individuals, referred to as point or node centrality.
- This point centrality measure can and often should be normalised by the size of the network so that calculations from different networks can be compared.
- A network-level centralisation score can be calculated indicating the degree of centralisation derived from a specific measure.

3.3.1.1. Degree centrality measure

The most frequently used, intuitive and easy to understand centrality measure is the degree centrality, being the number of links to and from a node. Degree centrality is a local centrality measure because it can be calculated without reference to the overall structure of the network. In an asymmetric (directed) network, *in-degree* is defined as the number of ties received and *out-degree* is the number of ties sent or initiated by the node outwardly. The following formulas define these types of vectored centrality:

$$C_{D_i}(\text{out} - \text{degree}) = \sum_j d_{ij} \dots \dots \dots (1.1)$$

$$C_{D_i}(\text{in} - \text{degree}) = \sum_j d_{ji} \dots \dots \dots (1.2)$$

Where d_{ji} Indicates the existence or non-existence of a link between nodes i and j . If there is any link between node i and node j then $d_{ji}=1$. If there is no link then $d_{ji} = 0$

In-degree counts the number of times a node (organisation) is needed or nominated by the others in the network. This node might be a resource distribution network, such as the authority that distributes vaccine or PPE (personal protective equipment) during the pandemic, and other agencies would be contacting it for such resources. It might also be a data collection agency such that all front line agencies and departments (pathology laboratories, emergency departments, etc...) are required to provide it with their daily statistics so that it can produce data for decision making and provide outbreak trends analysis.

To make the degree centrality comparable between networks of different sizes, the count is divided by $(N-1)$ being the maximum possible number of connections a particular node can have, hence a representation of the network size. This results in normalised centrality measurement that varies from 0 to 1 (Freeman, 1978):

$$C_{D_i}(\text{out - degree}) = \frac{\sum_j d_{ij}}{N-1} \dots\dots\dots(1.3)$$

$$C_{D_i}(\text{in - degree}) = \frac{\sum_j d_{ji}}{N-1} \dots\dots\dots (1.4)$$

Where N represents the number of nodes.

3.3.1.2. Closeness and betweenness centrality measures

Complementing degree centrality, which is a local centrality measure; other centrality measures have been developed to take into consideration the information pattern of the links in the entire network. Two of those are closeness and betweenness. *Closeness* measures the average distance of a node from all other nodes in the network. Totalling these distances and then inverting resulting the value changes the measure from a distance measure to closeness measure. Point closeness is then the inverted sum of all the distances, and normalised closeness is $N-1$ divided by the sum of distances, making it an average closeness measure. Normalised closeness is calculated as (Freeman, 1978, Valente, 2010) :

$$C_c = \frac{N-1}{\sum D_{ij}} \dots \dots \dots (1.5)$$

Closeness has intuitive appeal as a centrality measure, as someone who is closer to everyone else, on average, is in a central position. Yet social networks are non-Euclidian, meaning that the distance from node A to node B is not necessarily the same as the distance from B to A due to the asymmetric nature of the links. A path from one person to another follows a direction along the links, with the result that this path cannot be reversed if at least one link is asymmetric. Accordingly, closeness is directional. *In-closeness* refers to the links directed to a person and *out-closeness* to the links initiated from a person. The practical implication is that the person with the highest out-closeness is the person who can reach others in the fewest number of steps, whereas the person with the highest in-closeness is the person others can reach in the fewest number of steps (Valente, 2010).

The third centrality measure is the betweenness centrality proposed by Freeman (1979). It measures the frequency with which a person lies on the shortest path connecting everyone else in the network. The concept of betweenness is very appealing, as it measures the degree to which a node occupies a strategic position in a network, somewhat akin to bridging and centrality combined. Normalised betweenness centrality is calculated as:

$$C_b = \frac{\frac{g_{ij} P_k}{g_{ij}}}{n^2 - 3n + 2} \dots \dots \dots (1.6)$$

Where $g_{ij} P_k$ counts the number of times point k lies on the geodesic –shortest- path connecting all other nodes (i and j) and g_{ij} is the number of geodesics in the network. The maximum possible value that the numerator $g_{ij} P_k / g_{ij}$ can reach is $n^2 - 3n + 2$ so this is the normalisation factor (Linton, 1979). Since a geodesic path is directional, betweenness centrality is directional and hence separate calculations for in and out directions are needed. Freeman (1979) explained that betweenness centrality captures a gate-keeping function: if members high in betweenness oppose an idea, its diffusion to other segments of the group might be blocked. Closeness centrality captures a communication role such that people high in closeness can communicate an idea to many others rapidly (Valente, 2010)

3.3.2. Network-level measures

Network-level measures are those calculated on the whole network. These provide indicators of the network structure. These usually deal with the network's density and size and clusters within the network.

3.3.2.1. Network density

Density is the first measurement to be discussed. It is the number of connections in a network reported as a fraction of the total links, and is calculated as:

$$D = \frac{l}{N(N-1)} \dots \dots \dots (1.7)$$

Where l is the number of links in the network and n is the network size. Equation 1.7 is applicable to asymmetric networks, but the numerator must be multiplied by 2 for undirected (symmetric) networks. There is an inverse relationship between size and density: as size increases, density decreases. One of the reasons for this is that there are practical limits to the number of other people a person knows or can establish relationships with.

3.3.2.2. Tie strength

Tie strength expresses the excellence of connection between two nodes in a network. According to Granovetter (1973b), the strength of the relationship between two nodes can be expressed as a mixture of the amount of time and the mutual services that distinguish the link between them. Extending Granovetter's theoretical concept of tie strength, Marsden and Campbell (1984) established that "emotional closeness" was the most effective indicator of tie strength, in preference to the other indicators "frequency of contact", "reciprocity of services" and "intimacy" (mutual confiding). Besides emotional closeness, frequency of contact is extensively used as a measure of tie strength (Lin et al., 1978, Granovetter, 1995).

3.4. Forms of data collection

Research usually is associated with data collection and analysis. The researcher might newly collect some of the data or might use new methods to analyse and synthesise existing data.

Generally, these data are of two types, qualitative and quantitative, with a continuing debate on which is better to represent what type of research. A long trace of literature exists to support each group's point of view. Each method is briefly discussed here, since both were used in our research, and the subsequent section explains how these methods were used in the data collection when interviewing subjects.

3.4.1. Qualitative data

Qualitative research is used in inductive thinking to explore a new area or to develop hypothesis as well as testing whether the predictions of a certain hypothesis are valid or not valid. This is especially helpful when there is lack of an established theoretical basis in the specific area of research in hand.

Qualitative data has wrongly been associated exclusively with anecdotes and social sciences. This is because (a) it is usually in the form of words rather than numbers and (b) social science was the first domain that used it, notably anthropology, history, and political sciences. However, more researchers in basic disciplines and applied fields (psychology, sociology, linguistics, public administration, organisational studies, business studies, health care, urban planning, educational research, family studies, program evaluation, and policy analysis) have shifted to a more qualitative paradigm (Miles and Huberman, 1999).

The importance of qualitative data is that it is a source of rich descriptions and explanations that can help researchers to see precisely which events led to which consequences, to get beyond initial conceptions, and to use the opportunity to generate or revise conceptual frameworks. The objective of qualitative research is to obtain an in-depth understanding of human behaviour and the reasons that guide such behaviour. Qualitative research methods can also help in the development of a theory. They can lead to new findings and discoveries and improvement of existing practices. Qualitative research methods can also provide a closer view of the study case's culture, practices, motivations and emotions. Moreover, qualitative research can help test the bases for a science, examine the associated beliefs, and develop methods to specify how a theory should change in light of fresh information. Finally, qualitative research helps to answer questions such as: Where have we come from? Where are we? Who are we now? And where are we going?

Qualitative data is collected based on observation, interviews, reviewing available documents or audio-visual materials. Researchers collecting such data can use the following options:

- Observing: by directly observing the subject and recording the data. This can be with the observer concealing his or her role or revealing it as being a participant.
- Having face-to-face or telephone interviews with subjects. Also the observer can interview a focus group. These interviews are usually unstructured or semi-structured with open-ended questions.
- Collecting public or private documents or audio-visual material to be used for analysis.

Wolcott (1992) described qualitative investigation as “watching, asking or examining”. Such data emphasises people’s “lived experience” and is fundamentally well suited for locating the meanings people place on events, processes and structures in addition to the reasons and outcomes associated with them (Van Manen, 1977). It provides richness and holism, with strong potential for revealing complexity and “thick descriptions” nested in real contexts and naturally occurring, ordinary events in natural settings.

One prerequisite of qualitative data collection is purposefully selecting the sites or individuals for the proposed study. This helps the researcher to understand the problem of the research question, especially if the field of research is still immature. This will involve selectively choosing the sites and subjects to be interviewed rather than using random sampling or selecting a large number of participants and sites.

Qualitative data are not usually immediately accessible for analysis, but require some – or in most instances, “lots” of - processing, where raw field notes need to be corrected, edited, typed up and tape recordings need to be transcribed and corrected (Miles and Huberman, 1999). This information is then formed into categories or themes that are then developed into broad patterns, theories or generalisations that are then compared with personal experience or existing literature – if found – on the topic (Creswell, 2009).

Figure 3-2 shows how the theory becomes the end point in the qualitative research inductive method. The inductive process starts from information gathering and builds up through broad themes to a generalised model or theory (Creswell, 2009)

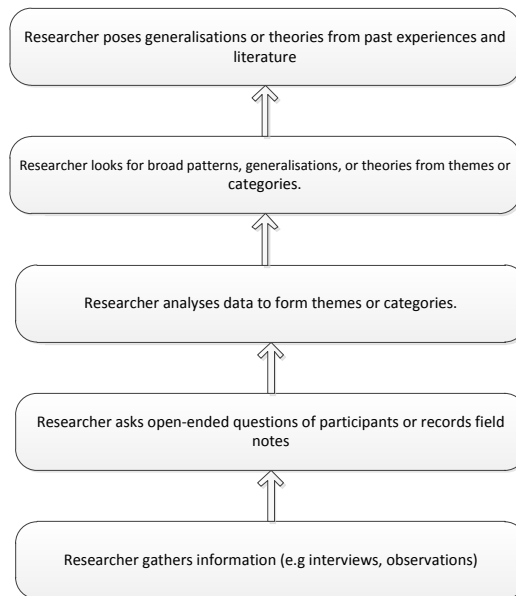


Figure 3-2: Inductive logic of Research in Qualitative stud; Adapted from Creswell: Research Design

In a disease outbreak, qualitative research can help us understand the culture and practices within health emergency management organisations and other agencies involved in disease outbreak incidents. It can provide an insight about how these organisations coordinate during disease outbreak and may answer important research questions, such as, “What are the characteristics of the organisations that will play central role during the coordination evolution?” Qualitative research methods can also help to identify the initiation point for the multi-agent coordination process and when it will be ended. It can also assist us to examine closely the flow of information within the large complex network formed by organisations responding to disease outbreak.

In the present study the qualitative approach enabled development of the following understandings:

- An exploration of the type of organisations that work together during infectious disease outbreaks
- Orientation to the types of communication that take place (case definition, case transport) etc...
- Discovery of some of the deficiencies that can manifest during the coordination process.

3.4.2. Quantitative Data

The objective of data collection and analysis is to test and verify the theory rather than developing it. Hence the theory becomes the framework for the entire study (Creswell, 2009).

Quantitative data is predominantly collected by either laboratory experiment or through surveys. It provides a numeric description of trends, attitudes, or opinions of a population by studying a sample of that population and then generalising to the whole population. The quantitative approach uses closed-ended questions and numeric data and employs statistical procedures to analyse the data.

The survey should be constructed around the theory in question. The researcher identifies the characteristics of the population to be targeted and then selects the sample to be surveyed. Then different statistical techniques are applied to generalise the results, usually with an estimated error.

The aim of quantitative research is to apply and develop mathematical models, theories and/or hypotheses referring to phenomena. Whereas qualitative research methods develop information only about the particular cases studied, and more general conclusions are only hypotheses, quantitative research methods are used to validate which of such hypotheses are true. Quantitative methods makes it is possible to give accurate and testable expression to qualitative views. Figure 3-3 shows the use of the quantitative method deductively to test and verify a theory.

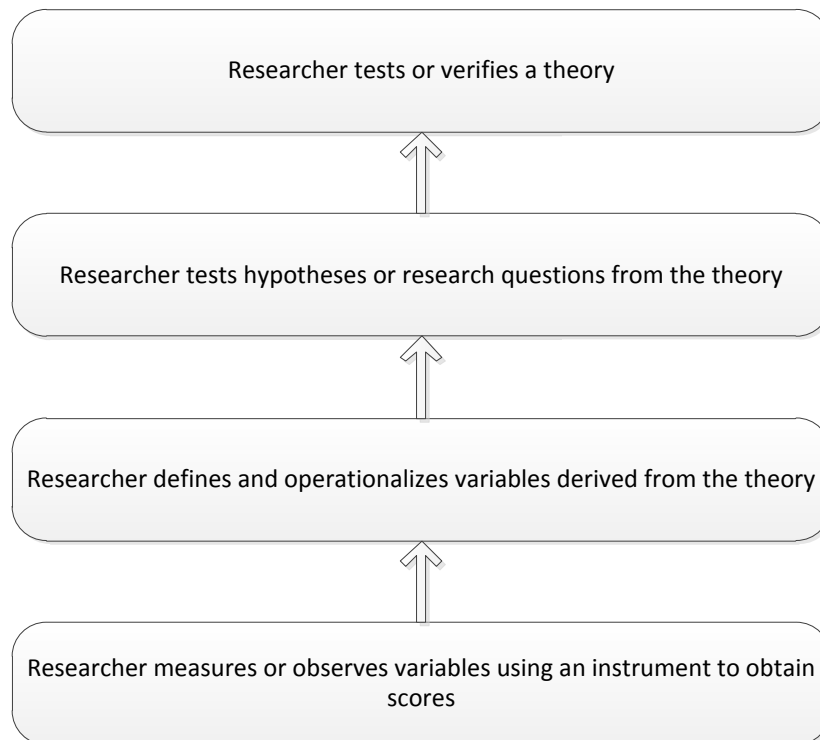


Figure 3-3: the deductive approach typically used in quantitative research. Adapted from Creswell: Research Design

Quantitative researchers rely on a positivist approach to social science as they apply reconstructed logic using the language of “variables and hypotheses”. They use the variables to test the hypotheses that are linked to general causal explanation (Neuman and Kreuger, 2003).

The form of quantitative data is usually numerical, and the data is analysed statistically to show significance, patterns and frequencies. It does not go as far as providing the meaning of the experience. This data is collected through surveys, which use closed-ended questions. The answers might be in the form of “yes” and “no” or “0” and “1”, as some call them. Hence, it is easy to use modern software systems to sort the data and analyse it to search for relationships. Statistical analysis is an important phase of analysing data to correlate any statistically significant results.

In researching disease outbreak, quantitative methods can help verify and validate theories developed about the inherent relationship between coordination structure and performance in a dynamic environment. Quantitative research methods can also help us develop performance

indicators to measure the efficiency of the disease outbreak coordination process. From the data collected, it is possible to perform statistical analysis for hypothesis testing as defined in the disease outbreak coordination model. For example, correlation and regression analysis can help to determine which network measures are used to predict disease outbreak coordination preparedness.

In longitudinal studies of disease outbreak, quantitative research methods can help to monitor certain variables over time and to examine the percentage of change of these variables, to understand the cause of these changes and whether the changes have an effect on other variables. For example, it is possible to monitor the time of response to a certain disease outbreak case over time and see whether different coordination structures have an effect on the response time.

By beginning this type of data collection in the present study, it will be possible to develop some insights about the following:

- Resource needs during the outbreaks.
- Types of inter-organisational links and how or why they are established – activation criteria.
- Measurement of node location and network performance during different outbreak phases.

3.4.3. Linking qualitative and quantitative analysis

Mixing both quantitative and qualitative methods is referred to as triangulation (Jick, 1979). Triangulation has been broadly defined by Denzin (2000, Denzin, 1978) as “the combination of methodologies in the study of the same phenomenon”. Hence, organisational researchers can improve the accuracy of their judgement by collecting different kinds of data bearing on the same phenomenon. (Jick, 1979). The use of triangulation can be traced back to Campbell and Fiske (1959) who developed the idea of “multiple operationism “. They argued, “more than one method should be used in the validation process to ensure that the variance reflected that of trait and not of the method”. (Jick, 1979). Hence, mixed method is a tool of cross validation to examine the same dimension of research. Both numbers and words are needed to provide

better understanding of the world, hence, "Quantities are of qualities, and a measured quality has just the magnitude expressed in its measure" (Kaplan, 1998). Howe's analyses (HOWE, 1985, Howe, 1988) shows that quantitative and qualitative methods are "inextricably intertwined", not only with regard to specific data sets but also on the level of study design and analysis. In deeper reflection, Salomon (1991) points out that the issue is not a qualitative–quantitative one; rather it is the approach that the specific research is taking: Whether is an analytical approach to understand a few controlled variables, or a systematic approach to understand the interaction of variables in complex environment (Miles and Snow, 1986).

“The question, then, is not whether the two sorts of data and associated methods can be linked during study design and analysis but whether it should be done, how it will be done and for what purposes” (Miles and Huberman, 1999). But what is the benefit of linking qualitative and quantitative data?

Rossmann and Wilson (1985) suggest three reasons:

- To enable confirmation and validation of each other by triangulation.
- To elaborate or develop analysis by providing richer detail.
- To initiate new lines of thinking, tuning ideas around or providing fresh insight.

Similarly, Firestone (1987) suggests that quantitative studies lead to more precise and generalizable results to convince the reader by disregarding individual judgment and by the use of formal standardised procedures. On the other hand, qualitative research overcomes the abstraction "inherent in quantitative studies" and persuades through rich depiction and strategic comparison.

Relating both to data collection and theory building, qualitative approaches can aid the quantitative side during design by helping with conceptual development. They can also help during data collection by making access and data collection easier. During analysis, qualitative approaches can help validating, interpreting, clarifying, and illustrating quantitative findings, as well as strengthening and revising theory.

Combining both the above methods is a challenge. In mixed methods research the researcher collects diverse type of data to present better understanding of the research problem. The results from qualitative and quantitative methods can be used side by side to reinforce each other. The mixed method neutralises or cancels any biases of either method. With mixed methods, the results from one method can help identify participants to study or questions to ask for the other method.

However, how can we link both methods together?

Miles and Huberman (1999) suggest four methods to provide such linkage, as illustrated in Figure 3-4.

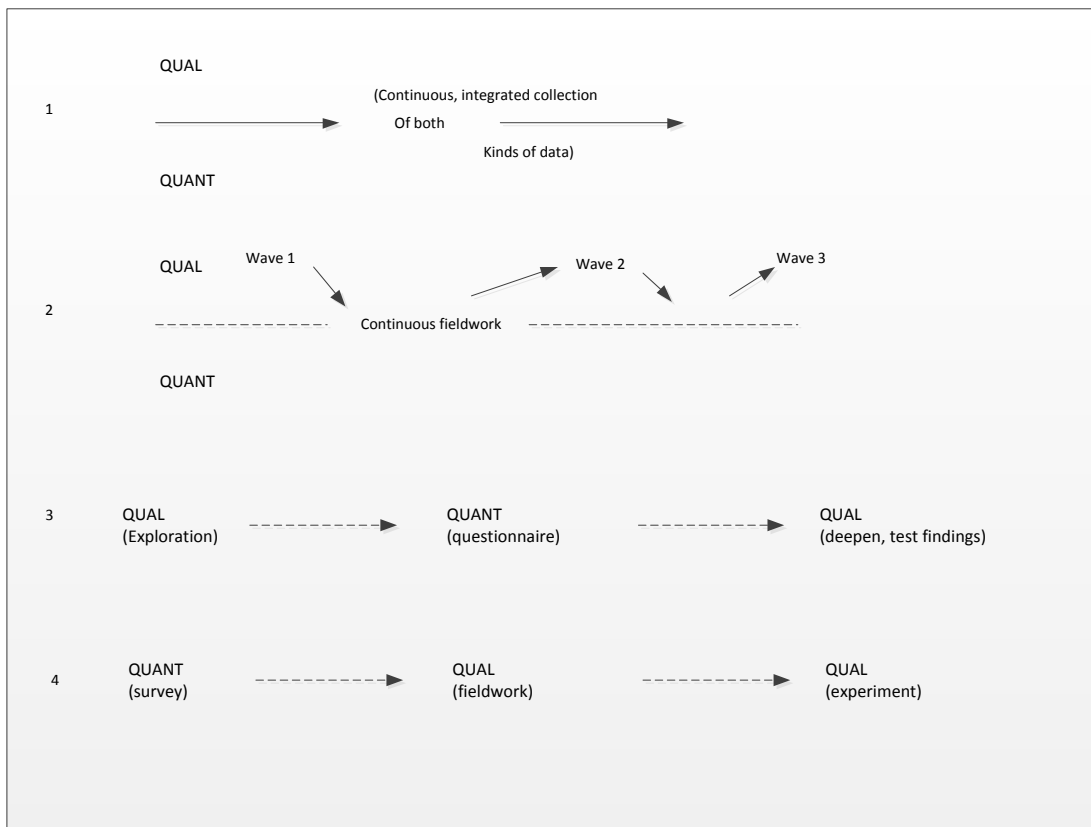


Figure 3-4: Illustrative designs linking qualitative and quantitative data. Adapted from Qualitative Data Analysis (Miles and Huberman, 1999)

In design one; the two methods are integrated throughout the whole track to understand the case in hand.

Design two is a multi-wave survey method. The first survey wave may draw attention to things the field worker should look for, and the fieldwork carried out after that might lead to revisions in wave 2, and so on.

Design three alternates the two kinds of data collection, beginning with exploratory fieldwork leading to the development of a quantitative instrument by means of which findings can be deepened and tested systematically in the next round of data collection.

Design four shows another alternating style: An initial survey helps to point the researcher to phenomena of importance. Then the researcher moves to develop a close-up, strong conceptual understanding of how things work; and then a qualitative experiment is designed to test the results.

3.4.4. On purposeful sampling and mixed methods

Determining the number of samples in any research is often a question with many answers. This applies for both quantitative and qualitative researches as well as in the mixed methods one. Especially in the qualitative research, “determining adequate sample size ...Is ultimately a matter of judgment and experience” (Sandelowski, 1995). Hence, Margarete (1995) continues “...students with whom I have worked that beginning qualitative researchers often require more sampling units than more experienced researchers” since the experienced ones can recognise “what is there and what can be made of the data already collected”.

One of the main differences between quantitative and qualitative approaches is the “purposeful sampling” (Kuzel, 1992, Patton, 1990) to the extent that Patton (1990) described 14 types of purposeful sampling involving the in-depth study of typical, atypical or exemplary information rich cases” (p169). Researchers in both domains have to resort in many studies to samples they know is less than ideal for their purposes (Sandelowski, 1995).

Beyond the misconception that sample size is not important in qualitative research, yet sample size has to be adequate to support informational redundancy or theoretical saturation. This will permits deep “ case oriented analysis that is a hallmark of all qualitative inquiry, and results in – by the virtue of not being too small- a new and richly textured understanding of experience” (Sandelowski, 1995). Data saturation is reached when “further data collection of evidence

provides little in terms of further themes, insights, perspectives or information.” (Suri, 2011). This saturation are factors of the nature of data source and the synthesis questions. Usually closed ended and focused questions result in faster data saturation while open-ended ones result in additional insights and extended data saturation point (Suri, 2011).

Patton (1999) discusses the misunderstanding about triangulation in that the researcher should expect and accept that different data sources or methods of enquiry would yield different results. However, this ought not to be viewed that it is weakening the “credibility of results, but rather as offering opportunities for deeper insight into the relationship between inquiry approach and the phenomenon under study”.

In order to enhance the quality and readability of data, Patton discusses one triangulation characteristic that is of interest to this research, which is “checking out the consistency of findings generated by different data collection methods”. (Patton, 1999). This involves comparing data collected through different methods such as qualitative and quantitative ones. It is often the case, as Patton argues, that one method is usually used a secondary role. Thus, observational data are used to generate hypothesis while quantitative data verify it, which combines them in a form of comparative analysis. That “often involves different operational measures of the same concept...This does not defeat comparison, but can strengthen its reliability.” (Fielding and Fielding, 1986).

Combining both qualitative and quantitative methods is also beneficial for new studies where researchers need to learn the domain literature from subject matter experts. In the present study it was decided to use mixed methods in data collection, where both qualitative and quantitative data were collected. This was first established by the questionnaire and survey design. Data gathering started with a qualitative questionnaire which was used to acquire domain knowledge from subject matter experts. This was followed by a survey designed to conduct wide-scale interviews. By combining the two methods it was possible to capture relationships and the reasons for those relationships, as well as the links beyond what the quantitative questionnaire could have provided. The method used to combine the two data-gathering techniques was continuous and integrated collection. This is further discussed in the next sections.

3.5. Disease Outbreak Network Data Collection

Data for this research was collected using qualitative and quantitative methods. The qualitative part was designed to enhance and enrich understanding of the coordination process itself and to enable the researcher to have a “look behind the scenes”. The quantitative part facilitated reconstructing the networked coordination structure, and hence it was possible to apply critical validation and testing of it. Since the H1N1 outbreak had occurred in 2009, the first practical step was to track the professionals who had a role in that outbreak. Then the qualitative questionnaire was administered to them for validation. After some interviews it was possible to design the quantitative questionnaire, and hence to conduct follow-up interviews with those professionals. With both data sets on hand, the opportunity was presented to compare the results and cross-validate them.

3.5.1. Qualitative data collection method

This section introduces the qualitative questionnaire, which was primarily motivated by the review of literature related to pandemic coordination.

3.5.1.1. Qualitative questionnaire content and design

As discussed, it was necessary first to qualitatively understand the outbreak criterion and activities. After a detailed examination of the research that has been conducted in disease outbreak coordination, a 'gap' in the research was identified there were some interesting questions yet to be answered:

1. How to identify the initiation point for this multi-agent coordination process and when it will be over?
2. What are the characteristics of the organisations that will play a central role during the evolution of coordination?

3. What are the effects of formal and informal structures on the total inter-organisational coordination process?
4. What are the performance indicators to measure efficiency of the disease outbreak coordination process and how should they be developed?

These initial questions were the foundation for developing the qualitative questionnaire, which in turn evolved to the final survey. The focal points that needed to be addressed were divided into four main ones:

1. Situational information
2. Actors
3. Processes
4. Determinants and resource management.

The next step was to dissect the research questions into tangible ones, which then were in turn allotted to the focal points. These questions are elaborated in Table 3-3:

Table 3-3: Summary of the main focal points and their relevant questions

Section:	Example Questions
<ul style="list-style-type: none"> • Situational information 	<ul style="list-style-type: none"> • How is an outbreak detected? • How is information routed? • What are the outbreak criteria? • What are the containment criteria?
<ul style="list-style-type: none"> • Actors 	<ul style="list-style-type: none"> • Which organisations are involved? • What are the organisations' characteristics? (Jurisdiction/domain/location...) • How and when do organisations become involved in the outbreak? • What is their communication plan and protocols? • What types of information are

	exchanged?
<ul style="list-style-type: none"> • Determinants 	<ul style="list-style-type: none"> • How can coordination gaps be measured? • What are the criteria to determine whether coordination is successful?
<ul style="list-style-type: none"> • Resource management 	<ul style="list-style-type: none"> • How are resources deployed? • Are resource storage and distribution centralised or distributed?

Expanding these mid-level questions resulted in the qualitative questionnaire as presented in Appendix A, which was intended to be administered in the first wave of interviews.

3.5.1.2. *Administering the questionnaire*

The interview questions were designed and planned carefully so that when they were executed, a systematic flow to the data collection process was achieved (Sudman and Bradburn, 1982, Miles and Huberman, 1999). The questions were constructed in a way to avoid resistance, suspicion, prejudice and any sort of negative forces within the interview environment. The qualitative questionnaire was designed to target decision-makers, coordinators and middle level managers within the public health system. These people usually act as gatekeepers for incoming and outgoing communication within their organisations. They also act as policymakers and determinants for any policy changes. Table shows the proposed matrix for each section of the questions, along with the proposed interviewees – the titles have been generalised to suit different health authorities' structures and names that might differ from one state or country to another.

Table 3-4: Matrix of proposed interviewees for the qualitative questionnaire

Section	Proposed Interviewee
A. Situational information	Policy and decision-makers/ biosecurity authorities/ emergency

	management authorities
B. Actors	Coordination units/ clinical managers/ logistics/ public health units/ emergency management authorities
C. Determinants	Policy and decision-makers/ coordination units
D. Resource management	Resource provision and distribution management

The responses to the qualitative questionnaire mainly established the following repositories:

1. Domain schema: A basic overview of the terminologies/ processes/ workspace environment and sphere of the outbreak management
2. Organisational matrix: A basic matrix of organisations/ units that were used as a pool from which to select interviewees during the following quantitative phase
3. An overview of the main determinants of the process, such as when and how an outbreak is announced.

This questionnaire was used in the first wave of interviews conducted between October and December 2010. Firstly I identified a group of experts, including academics and subject matter experts, with whom I engaged to capture information and obtain feedback about the survey.

The positions of the persons interviewed were:

1. Senior public health management professional
2. Senior epidemiologist
3. Midlevel disaster management professionals working in health services functional area coordinator (HSFAC) teams
4. Senior laboratory professional
5. Executive manager in GP division
6. Senior clinical pathology and medical research professor

7. Midlevel health media communication unit manager.

Interviewees were chosen who had participated in the H1N1 2009 outbreak. All the interviews were face-to-face; four of them were conducted in the Hunter New England Area Health Service (HNEAHS) and the rest were within the greater Sydney region. The time of each interview was intended to be one hour only, but three of the interviews extended to be about two hours each, due to the wealth of information from some of the respondents and their willingness to share this information. The interviews were semi-structured using the Appendix “A” questionnaire. The advantage of the semi-structured interview is that it uses the planned questionnaire template uses open-ended questions that allow the spontaneous flow of information. Semi-structured interviews have the benefit of flexibly adapting to suit the interviewee; they promote rich understanding of the data collected, which is a necessary prerequisite for building later surveys in less known research contexts (Miles and Huberman, 1999).

Some of the main findings of these questionnaire-based interviews were the understanding of coordination dynamics such as initiation and closure. The interviews provided valuable insights such as the different phases during which public health systems change their intervention procedures (delay, contain and protect). They also provided information about the different levels of intervention in Australia, at federal or commonwealth, state, and local levels. Understanding was built up of the types of communication that take place during outbreaks, such as case definitions which are the set of criteria used to classify patients as having a defined illness. As well I became aware of the use of the informal communication and its needs during outbreaks, and hence began to consider types of formal and informal communication, the context of these types of communication and their targeted audience and objectives. Finally, these interviewees provided the first seeds of contact details of further candidates and respondents in variety of organisations.

On the basis of the interview results, a quantitative survey was designed – discussed in the next section – and then most of those professionals were approached again to fill in the survey and provide some feedback.

3.5.2. Quantitative data collection method

In conjunction with qualitative interviews conducted with subject matter experts, the data collection framework was used to further develop and refine a valid and reliable survey instrument. The quantitative method included a non-traditional “networks” method of data collection and analysis to serve as a fine complement to traditional research methods in behavioural studies. Surveys are most useful when the actors are people and the relations that are being studied are ones that the respondent is reporting on.

The survey for this study was essentially designed to cover three broad constructs: (i) social networks, (ii) coordination, and (iii) performance. Importantly, the quantitative research method added further empirical weight to the disease outbreak coordination model by explaining with quantitative evidence how network properties were associated with coordination.

3.5.2.1. Survey design

Designing a quantitative survey based on the relational quality of network methods requires a shift in thinking when it comes to research methodology. The network approach focuses on relations between nodes (organisations in this case) rather than between subjects’ attributes. Hence study design, data collection, and data analysis incorporated this relational perspective, requiring unique approaches to each (Luke and Harris, 2007). Data collection focused on data about nodes and their relations with each other. The survey, “A national assessment of State and Local law enforcement preparedness” prepared by RAND Corporation was adopted as the basic structure for the survey developed for this research (Riley, 1995). Interestingly RAND’s survey and the dataset it generated has been used in much other researches and several papers (Davis et al., 2004, Hossain and Kuti, 2010, Fricker et al., 2002, Hossain et al., 2011). The RAND survey contained questions developed to investigate the relationships between organisations at different jurisdictional levels and how they communicated with each other during preparation for terrorism response planning. In the present research, it was customised to suit outbreak coordination in a multi-networked environment. The rationale of the design took into consideration many aspects, some of which were:

1. Coordination is not a process that evolves overnight. Yes, it intensifies during the crisis, but its seeds are well planted before that. It starts from policy development, followed by training and then standard coordination before the outbreak followed by evolving coordination during the outbreak. Figure 3-5 shows the stages through what is called the coordination train.

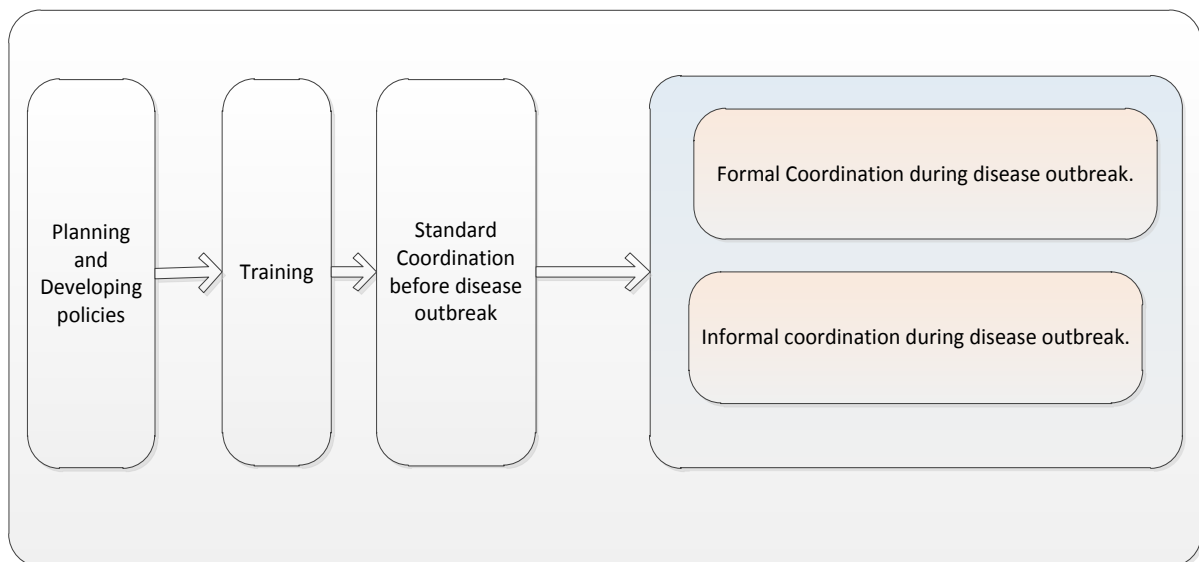


Figure 3-5: the coordination train: Coordination phases from policy development to outbreak coordination

Naturally it is not anticipated that the relationship will be as linear as in the figure, but the view represents a holistic approach to the coordination sequence and facilitates following up the network during its growth. Also the actual coordination during the outbreak is divided into two main sections:

- Before the outbreak: This usually covers the horizon scanning and surveillance phases discussed in Chapter Two, where a group of agencies exchange information and update each other on new or expected outbreaks.
- During the outbreak: This is when the evolving dynamic coordination structures are activated. Agencies refer to their plans or standard operating procedures and emergency manuals to work together. The coordination will materialise in different forms such as the provision of information or the exchange of resources.

2. The “during the outbreak coordination” part was further divided into three further phases: delay, contain and protect, in accordance with how the NSW health authorities divided the pandemic intervention phases.
 - Delay involved delaying admission of the pandemic to Australia by taking specific measures at airports, seaports, and any other borders.
 - Contain is when the authorities activate their plans to manage patients, limit contagion, and create awareness. This is the phase usually characterised by considerable tension, information collection and analysis, resources mobilisation, etc. It is the phase during which most of the fatalities occur.
 - Protect occurred is when the authorities activate their vaccination plans. Acquiring the needed resources, primarily the vaccine, usually precedes this. Then the authorities interpret the information collected in the contain phase to determine the most vulnerable communities and age groups. They then begin targeted or mass vaccination programs.

Moving from one phase to another is a decision made by the health authorities based on correlated information. Due to the different tasks in each phase, different organisations are needed. Capturing such micro-information would enhance understanding of the dynamics of each phase within the macro-structure and compare the main changes that occurred in the network when moving from one phase to another.

3. Formal and informal coordination. As part of capturing the whole coordination process, it was decided to use different questions for formal and informal coordination, each in its separate section. Both sets of questions were designed to obtain the details of the three main coordination phases (delay, contain, protect), and both contained separate questions about the organisations that respondents “[did not] normally coordinate with but needed to create (formal/informal) communication channel during the outbreak.” It was of interest to know how the informal coordination helped the respondents during the outbreak. Hence, the survey contained in its last section a question about the “most three important factors that informal coordination facilitated [in their] work”. Respondent were asked to list these from the most to the least important, to add perceptual weight the

answers. The last section also contained perceptual questions about the effectiveness of the informal coordination in “getting things done” and its importance in bridging coordination gaps.

4. Communication methods: It was presumed that health professionals in different locations of the network would use different communication methods to communicate with others. Hence, they were asked to rate communication methods from most to least important. These were landline phone, mobile phone, fax, mobile text messaging, email, and web portal.
5. Resources: Different types of resources are used during an outbreak. Some questions were included to capture the types of resources that were needed and how these were usually transferred.
6. Who sends the notification out: To identify initiation point, questions were included about who notified different parties that an outbreak was declared or finished, and which methods of communication were used in both cases.
7. Errors or mistakes: To identify the perceptions of respondents about errors or mistakes that could have happened to them, and at the same time trying to identify some performance measures, a question was added, asking what were the three main errors or mistakes that could happen during the outbreak. Respondents were asked to list those errors or mistakes from the most to least important to identify the perceptual weight of each response.

3.5.2.2. *Survey structure*

Any survey design is necessarily an iterative process. In most cases the first version of the survey is large and ambitious one, but it needs to go through a weight loss program after some iterations. This survey was no exception. The first version of the survey was a considerable 62 questions within 30 pages, a time-consuming booklet to manage by all means. This iteration was first used to interview eight respondents, the average interview lasting one hour and 45 minutes, nearly double the time that was originally agreed to by the respondents. Indeed, most of the eight respondents tended to rush through the remaining questions after the first hour, something they could not be blamed for. Hence the survey was reviewed to make it leaner and more attractive cosmetically. The number of questions was cut to 37 and the number of pages

to a mere 14. During the course of interviews, question 30 was found unnecessary and deleted, as discussed below. The questionnaire was then a manageable 36 questions. Then it went into second iteration by obtaining valuable feedback from highly experienced subject matter experts, such as professors in the Centre of Infectious Diseases and Microbiology. After this the survey was ready to be rolled out.

The survey was composed of eight sections, reduced to seven after dropping question 30. The survey itself is presented in Appendix B. Here I present the main questions and some discussion of them.

1. Section 1: “About your organisation”, 10 questions: This section sought necessary information about the organisation, the respondent’s position within it, and the activities that it handled during the outbreak. The pandemic management and coordination tasks explained in section 2.5.2 were summarised under the following tick boxes:

- Leadership and guidance
- Collecting information
- Information analysis and dissemination
- Training other organisations
- Epidemiology
- Detection (including surveillance)
- Community education
- Emergency care (emergency department and intensive care unit)
- Providing resources to others (more information was required about the types of resources and to whom they was provided)
- Using logistics to transport disease outbreak related equipment.

The aim of questions 7 to 10 was to capture how and who notified the respondent’s department when an outbreak was announced, and how and who notified them when it was over. Hence the attempt to determine the initiation and closure points for the coordination process in accordance with the design questions in section 3.3.3.1 above.

- 2- Section 2: Planning and developing polices: In this section perceptual questions were asked about the importance of developing policies, rated on a six-point scale ranging

from not important to very important. Networking questions were included, asking respondents about collaboration with other agencies during policy development and how often it occurred (weekly, monthly, semi-annually or annually), so as to measure tie strength during policy development.

- 3- Section 3: Internal training: this small section was used to gauge preparedness within the organisation to use as an outcome construct if need be.
- 4- Section 4: Trans-unit training: This was a networking section, the main focus of which was to capture the ego's training and exercises relationships before outbreaks and how often they occurred. A four-point scale question measured the perception of preparedness after the training compared to before it.
- 5- Section 5: Formal coordination: three questions all focused on networking. The first question asked with whom the respondent exchanged information about outbreaks before they occurred. Here is where networking information of the respondent was captured. More meta-information questions were included about each link, so as to capture:
 - Tie strength as the frequency of communication (daily, weekly, monthly, semi-annually, and annually).
 - Tier connectedness by asking about the jurisdictional level of the organisation with which the respondent communicated (international, federal, state, local, private, and other). The federal, state and local categories were used for public agencies (education department, health departments, etc.) and private was for non-public corporations.
 - Type of communication: The aim was to capture the context of the communication itself, whether it was exchanging information, exchanging resources, or conducting fieldwork together.

The above three points were repeated in all the subsequent questions about coordination. This section then proceeded into coordination during the outbreak itself, and the last question-concerned organisations that the respondent had not anticipated needing to coordinate with during the outbreak and hence were not part of the coordination plan, yet needed to be involved. Here missed parts of the structure could be captured, which do not usually show up until needed.

- 6- Section 6: Informal coordination: This section captured nearly the same information as the previous one, but applied to informal coordination during the outbreak and to the agencies that respondents did not anticipate needing, yet found they needed to extend organisational reach to them and create informal links with those agencies. Informal coordination was not captured before the outbreak because we assumed such interaction would be minimal in that phase, consisting just of passing and receiving surveillance and protocol information. Those contexts do not usually stimulate the creation of informal coordination links since there is no need for them. This section contained a further three questions. One asked about the stage at which the respondent realised the need for informal coordination. The second was a scaled question about the efficiency of the informal coordination in getting things done compared to the formal coordination, rated from *not efficient at all* to *very efficient*. The last question in this section was also a scaled one, asking about the importance of informal coordination in bridging coordination gaps, rated from *not needed at all* to *it is essential*. This question could be used as a dependent variable for the informal coordination model.
- 7- Section 7: Intra-organisational informal coordination. Many departments were small, containing five to ten workers and making it infeasible and uninformative to collect such information because in such small environments everyone talks to everyone. Therefore any information would be insignificant and not representative. Thus this question was discarded.
- 8- Section 8: Coordination measure: Besides capturing coordination measures, i.e. dependent variables, this section also contained some miscellaneous questions. One question asked how up-to-date the coordination plan was (relating it to the policy development section). Respondents were also asked to rate the most effective communication methods on a scale from 1 to 6, ranging from landline phone to web portal such as wiki sites or intranets. An important question asked how long it took for coordination to begin after the outbreak was announced, hence an important indication of coordination robustness; and how long it took for the coordination to reach the optimal point. The section ended by asking about additional resources that the respondent had needed during the outbreak, and the three main errors or mistakes that

occurred during the outbreak as well as the most important ways in which informal coordination facilitated the respondent's work. These questions could be used as further indicators for the success or robustness of coordination, besides the questions already detailed.

Figure 3-6 presents a cumulative graphical view of the relationship between different components of the survey. The survey itself is presented in Appendix B.

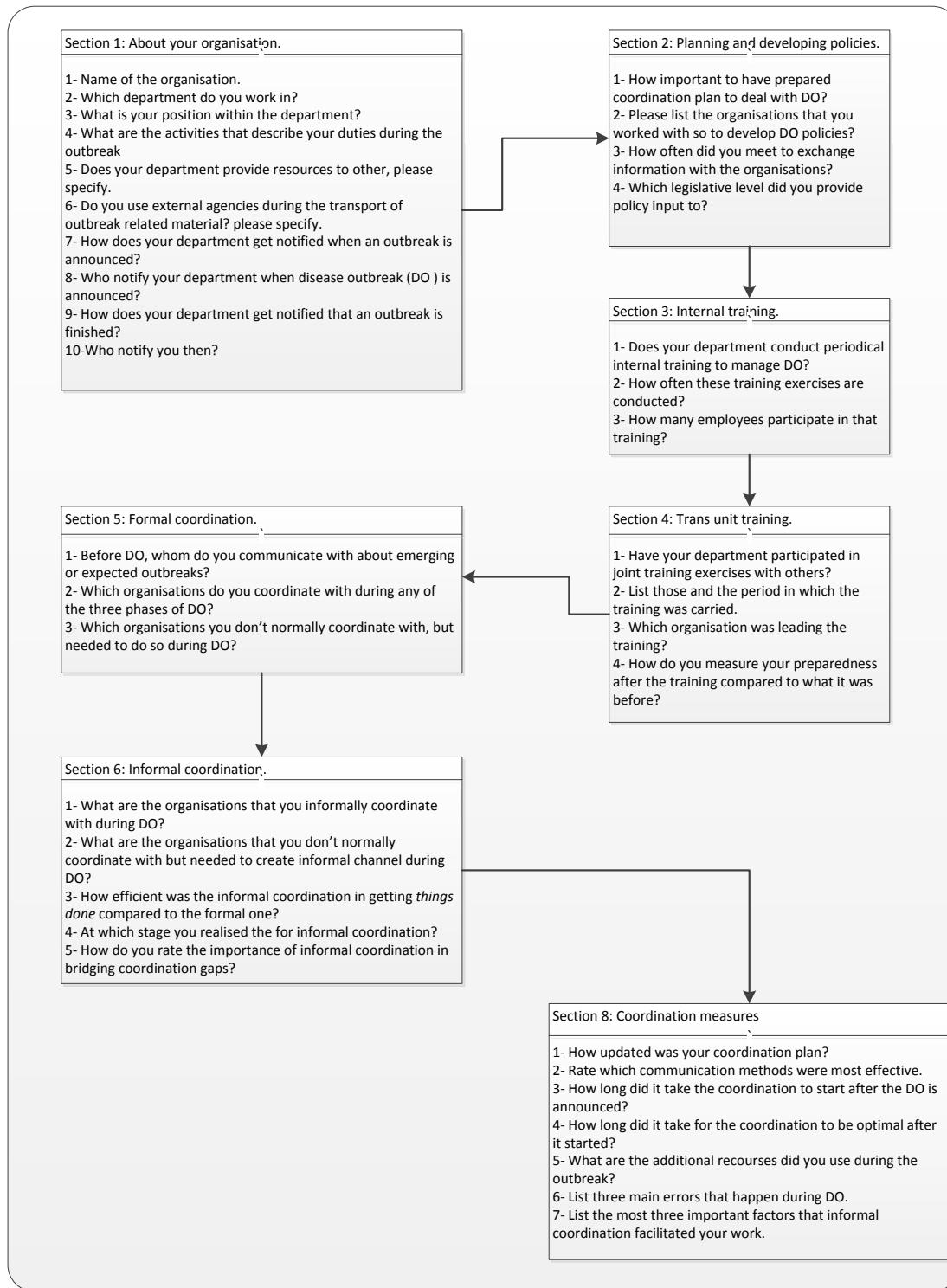


Figure 3-6: Flow chart of the survey flow and components

3.6. Ethics approval

For this research, that dealt with health issues and needed to collect information from health professionals, it was necessary to apply for health ethics approval before releasing the survey to health officials. Ethics approval had to be obtained from the NSW Ministry of Health (NSW Health) via a newly established online system www.ethicsform.org/au. The process started in October 2010, where the survey and many other forms were submitted. Fortunately, the survey was deemed a low and negligible risk survey, and NSW Health at that time had a new expedited process for reviewing research that involved low and negligible risks. Approval was sought from the Hunter New England (HNE) ethics committee, and luckily again, the HNE Human Research Ethics Committee (HERC) was a lead HERC under the NSW Health systems for single Ethical and Scientific Review of Multicentre research. Thus, all other NSW HERCs would accept ethics approval granted from this committee and for any multisite (i.e. involving more than one Area Health Service). The approval, once obtained, could be used throughout NSW rather than needing to file a separate application for each AHS. This was beneficial since the research involved many AHSs within the state and overall approval saved the hassle, time and effort to seek new approval for each one.

The approval letter was received on March 10, 2011, with the lifetime of three years on condition that progress report was filed each year (HNEHREC number 11/03/16/5.13). Any changes in the survey would need to be notified to the committee and re-evaluated. Hence with the latest version of the survey was supplied, with no intention for subsequent change.

Email correspondence and copy of the approval letter are in Appendix C.

3.7. Administering the survey:

Conducting a sociocentric network study would have been relatively new for research of this scope (Dantas and Dalziell, 2005) because it involves the entire population in disease outbreak (Bharosa et al., 2010). The researcher would have to form a roster of all disease outbreak personnel and colleagues (alters) and then present it to the ego who would be asked to identify known alters, so as to determine the relationships between different alters. This would be a massive, practically impossible exercise since tens of thousands of personnel were involved in

the H1N1 2009 outbreak. For this reason, the egocentric network approach was more practical, less expensive, and hence adopted for the study. Furthermore, it also allowed the ego to freely recall alters and could include alters not conceived of by the researcher. This would not have been possible with the sociocentric approach. So the first step was to utilise the information that had been acquired through the first round of qualitative data collection to build an understanding of what tasks were performed during the outbreak, and then target officials working within these tasks. The second step was to discuss with them introducing their alters to the research so that they might participate in the survey, based on the criteria that they participated in the 2009 H1N1 outbreak. The matrix of expertise targeted is shown in Table 3-5.

Table 3-5: Overview of the positions surveyed

Working Field	Positions Example
Clinical care	Doctors, nurses
Policy decision-makers	Senior public health officials
Emergency management	Emergency care professionals, intensive care unit professionals, clinicians
Logistics	Ambulance services
Public health	Public health unit, epidemiologists
Detection and surveillance	Laboratories, GPs, infectious disease centres, intensive care units

This was also accompanied by constructing an abstraction of the tasks and high-level communication scheme between organisations involved in outbreaks. This is illustrated in Figure 3-7. It is divided into four quadrants to emphasise the leading agencies within each quadrant. These tasks start from surveillance and detection, to communication and management and logistics. These groups do not reflect any sequential division of the tasks;

rather they reflect general categories. The scope of this research was limited to NSW state within Australia; hence the focus was on the tasks that were performed within this scope.

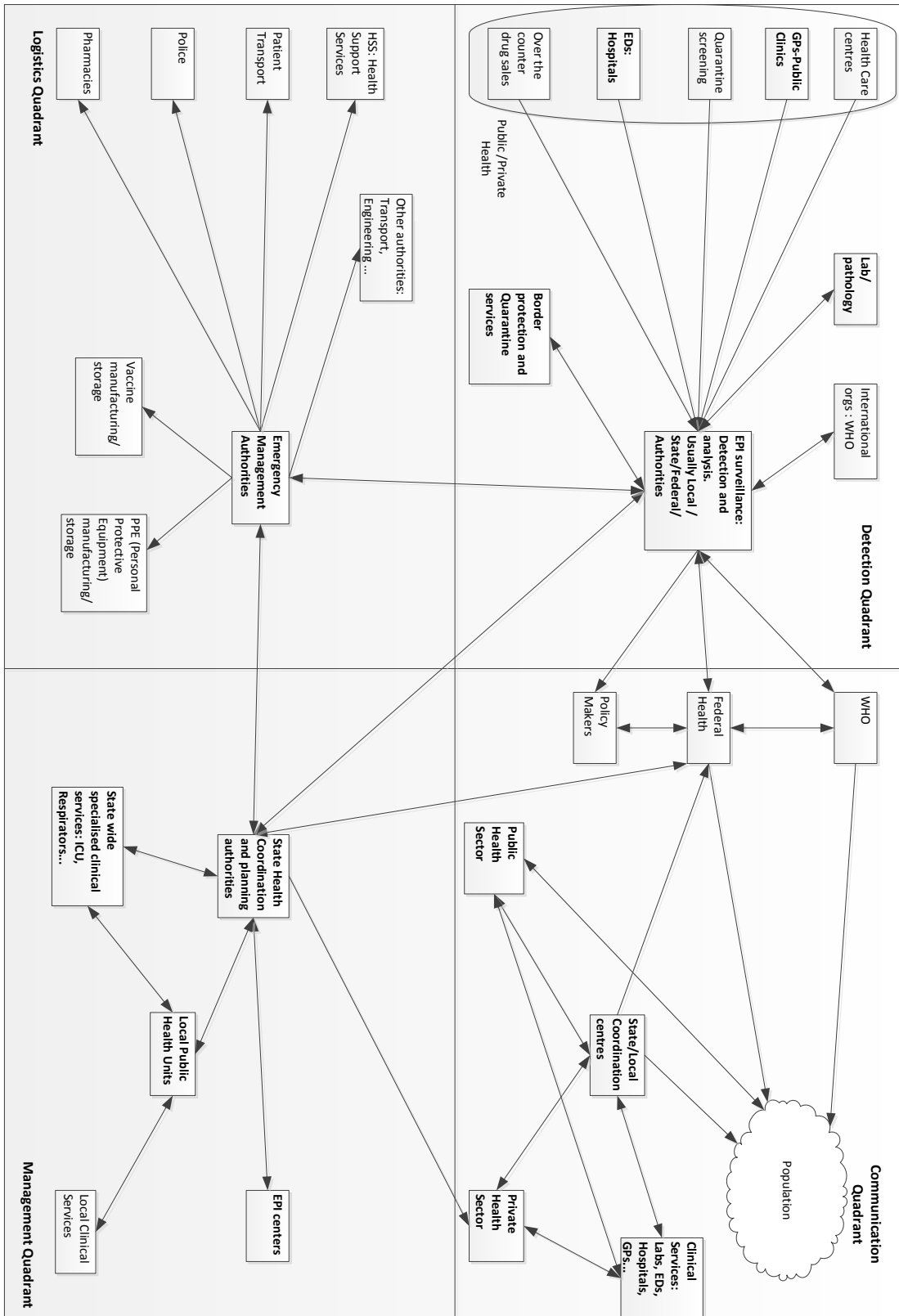


Figure 3-7: Abstraction of the tasks that are performed during the outbreak

The next step was to superimpose Table 3-5 and Figure 3-7 to define the targeted audience and hence approach individuals working within these organisations or performing such tasks to complete the survey and provide a list of their contacts. This will be used to further build up the data corpus. Those targeted are shown in bold in Figure 3-7

The plan was to approach most of the health professionals who had been interviewed for the qualitative questionnaire to obtain their comments on the survey. This resulted in fixing some cosmetic and grammatical errors, but most importantly, it was reduced from a voluminous 30 pages with 64 questions to 14 pages and 37 questions, focusing on the main streams discussed above. Since this was considered health-related research, the next step was to apply for ethics approval before rolling the survey out to health professionals.

Approval was received with HNEHREC reference No: 11/03/16/5.13, NSW HREC reference No: HREC/11/HNE/78 and NSW SSA Reference No: SSA/11/HNE/79. This meant that data collection in NSW could begin. Thus the main data collection phase started.

3.7.1. Sample population targeted.

An online version of the survey was created using smart-survey.com. A test link is still available and can be accessed via:

[https://www.smart-survey.co.uk/v.asp?i=40603sjrvk&preview=THIS IS A PREVIEW LINK DO NOT SEND](https://www.smart-survey.co.uk/v.asp?i=40603sjrvk&preview=THIS_IS_A_PREVIEW_LINK_DO_NOT_SEND)

Data collection for this phase began by utilising contacts and establishing new ones with support from the Sydney Infectious Diseases and Biosecurity Institute (SEIB) to generate names that could participate in the survey. The initial intention was to send introductory emails with the supporting documentation attached to potential respondents, asking them to use the link to fill out the survey online. Follow-up emails would then be used as per the survey's standard procedures. It soon became apparent, however, that since health workers were extremely busy, they paid little heed to the survey and this method generated zero results. Hence, the technique needed to be changed if any results were to be obtained. Potential respondents were then telephoned, and I went through a brief introduction about the

research then asked for a one-hour appointment. This personal approach created trust and interest, and many agreed to meet and go through the survey. Most of the health professionals were so busy that some meetings were scheduled one month after the initial contact. Others had to reschedule the interviews due to unexpected circumstances. Some respondents were far from Sydney, and I had to travel more than three hours to do an interview. Meeting the respondents face-to-face provided a unique opportunity to extend the information captured by obtaining in-depth details with the respondents, and hearing their personal insights, reflections, perceptions, criticisms, and anecdotes. These proved to be valuable information during the data analysis phase, especially as these interviews were tape-recorded, allowing transcription for further analysis. Moreover, many personnel volunteered valuable documentation such as situational reports, policies, influenza plans and the like. These proved to be invaluable to build a structural layer of familiarity and understanding of the formal methods for operating procedures.

In seeking to widen the base of the interviewed people, the snowballing method was followed to elicit contacts details for others to be interviewed. Some interviewees were helpful by initiating the communication with the contacts that were deemed interesting. This was capitalised on the trust and working relationships between contacts and proved exceptionally helpful to gain access to other health workers with busy schedules. I found that even in initiating the first contact with potential interviewees, the phone was much more efficient than email. People chose to ignore or shelve non-urgent third party and non-work-related emails, whereas phones and voice created trust and a sense of importance.

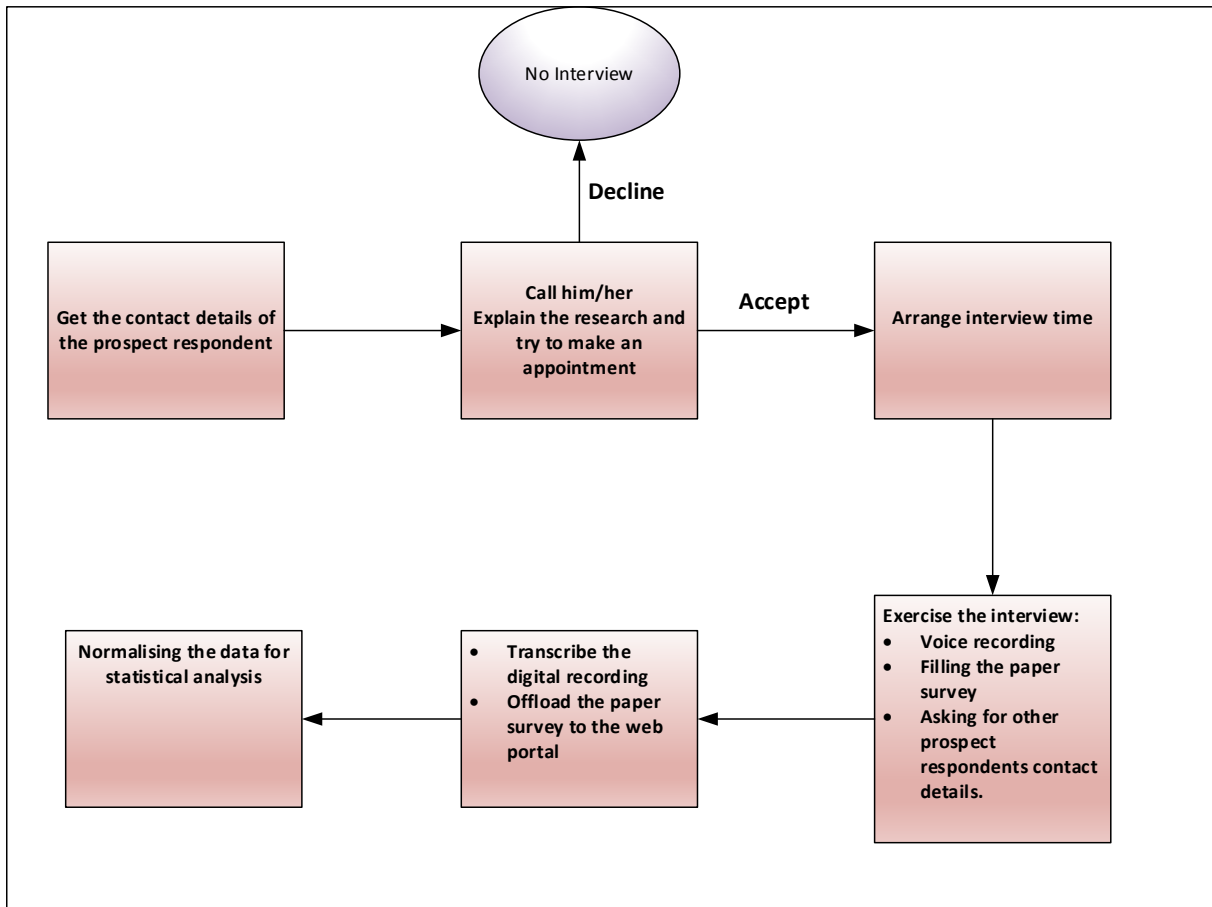


Figure 3-8: flowchart of the interview process.

Figure 3-8 above shows a flow chart of the interview process that I followed during the data collection phase.

This phase lasted about four months. By the end of this period, about 70 professionals, health workers and bureaucrats from a broad spectrum of the health industry had been interviewed. During the interview process, the respondents were asked on behalf of their department during the formal communication part in accordance of the standard formal procedures especially if these respondents worked in small departments or they were managing their departments. However when the interview turned to the informal part, the respondents talked about themselves as individuals who have waived these informal relationships.

Appendix E lists the general positions interviewed, along with general task descriptions. These have been intentionally generalised to reduce the possibility of identifying the personnel interviewed. Appendix E reflects the diversity of the interviewees, which stems from the

diversity of tasks that were undertaken in outbreak management and coordination. This further elaborates the discussion in Chapter Two of the wide expertise needed for such a complex system of coordination and communication.

Appendix E also shows the different AHSs that were targeted, suggesting the wide geographical area covered. It extended from Wagga Wagga and Albury in southern NSW to Lismore in the northern part of the state.

Only one respondent completed the survey online, but even then I had a face-to-face interview with her later. There were also three purely qualitative interviews, which are not reflected in Appendix E, one of them with very senior public health official.

Only one person declined to be recorded. One other respondent could not be recorded since the interview was conducted over that respondent's mobile phone. All the other interviews were either face-to-face or by phone (only if they worked in remote places that required more than six hours travel each way) but even those interviews were recorded. Finally 66 surveys were completed, and more than 80 hours of recordings had to be transcribed.

During the interviews, responses were written on paper rather than recorded online since internet access was not guaranteed at all locations and to allow the researcher to stay focused on the interviewee discussions. In more than 90% of the interviews, the researcher filled in the survey while the respondent dictated the answers. This created an interactive session, as the researcher was able to reflect on the answers and guide the discussion if more details were thought to be of importance. Also it facilitated taking field notes as an elaboration to some answers.

While the interviews were still occurring, transcribing began as well as copying the details from the paper surveys to the online system, as recommended by Miles and Huberman (1999). This was important for following up some of the information in further interviews or even for contacting recently interviewed respondents to clarify some topics.

Transcribing was an interesting task because the researcher began to draw conclusions and discover similarities and deficiencies within the information. It was also an extremely time-

consuming task. Finally, the survey data was all standardised by moving the paper data to the online system and standardising the entries, making it ready for synthesis and analysis.

3.8. Data analysis procedure

Data analysis technique is dependent on number of factors ranging from the research questions to data distribution. In most cases it is not a one-step process, as the raw data collected from the field must be standardised, synthesised and then organised to suit the selected software and testing methodology. Statistical analysis provides a plethora of algorithms to apply to datasets, depending on the aim of each test and the type of the data on hand.

3.8.1. Dataset description

For the dataset that was used, the first step was to export it from the online system. Unfortunately the online survey provider had only few options for filtering the data before exporting it. Also there were very limited options for structuring the exported data to make it most suitable for further analysis. Therefore data was exported as a raw .csv file that was best opened by the MSEXCEL program. Figure 3-9 shows a screenshot of how part of the raw data looked when imported to Excel.

The image shows a screenshot of an Excel spreadsheet with a grid of data. The columns are labeled with letters A through AH, and the rows are numbered from 56 to 116. The data includes various codes, abbreviations, and text descriptions. At the bottom of the spreadsheet, there is a status bar that reads 'RawData - 40603-121154-14-11-201'.

Figure 3-9: Data screenshot in Excel

One of the first tasks was to extract the questions and answers that would be used as constructs for the independent, moderating and dependent variables, in a structure that could be used for further analysis. At the same time, this structure should elicit the ego network of each participant, enabling further calculation of the variables discussed previously. Figure 3-10 shows a screenshot of the structure from question 25.

Organisation	Department	Position	Type of Communication	Frequency	Org level	end org
Centre for Infectious Diseases	Clinical Virology	Clinical Research	IP, IR	W	S	NSW DoH
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	F	dept of primary industry
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	S	dept of premier and cabinet
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	S	senior people SES
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	S	senior people of Ambulance
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	S	ministers office
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	F	dept of health and aging
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	F	food authority
Sydney South West PHU (part	PHU	Acting director of the PHU	IP	D	S	CDB
Sydney South West PHU (part	PHU	Acting director of the PHU	IR/IP	D	L	Local LABS
Sydney South West PHU (part	PHU	Acting director of the PHU	IP	D	S	Ref Labs (SEALS, ICPMR)
Sydney South West PHU (part	PHU	Acting director of the PHU	IP	W	S	Food Authority
Sydney South West PHU (part	PHU	Acting director of the PHU	IP	Ad hoc	L	EDs
Sydney South West PHU (part	PHU	Acting director of the PHU	IP	Ad hoc	L	GPs
Western Sydney Area Health	ICPMR - CIDMLS (Centre of	Public Health Liaison officer	IR/IP	D	L	PHUs
Western Sydney Area Health	ICPMR - CIDMLS (Centre of	Public Health Liaison officer	IP/IR	M	F	Department of Health and aging
Western Sydney Area Health	ICPMR - CIDMLS (Centre of	Public Health Liaison officer	IP/IR	Vairable	S	Labs (PHLN)
Sydney West Public Health Ur	PHU	Manager	IP/IR	ad hoc	L	EDs
Sydney West Public Health Ur	PHU	Manager	IP/IR	ad hoc	L	GPs
Sydney West Public Health Ur	PHU	Manager	IP/IR	ad hoc	S	Department of Health
Sydney West Public Health Ur	PHU	Manager	IP/IR	ad hoc	L	Infection control in hospitals
Sydney West Public Health Ur	PHU	Manager	IR	ad hoc	L	Labs
Sydney West Public Health Ur	PHU	Manager	IP	ad hoc	L	Schools
Sydney West Public Health Ur	PHU	Manager	IP	ad hoc	L	Department of Education
Sydney West Public Health Ur	PHU	Manager	IP	ad hoc	P	Catholic Education Corp
Nepean Blue Mountains Local	PHU / Health protection te	Senior infectious disease surv	IP/IR	Y	L	Infection control in hospital
Nepean Blue Mountains Local	PHU / Health protection te	Senior infectious disease surv	IP/IR	Y	L	Divisions of GPs
Nepean Blue Mountains Local	PHU / Health protection te	Senior infectious disease surv	IP/IR	Y	L	Community health
NSW health	project officer in the Biopre	principle project officer and r	IP/IR	A	L	PHUs
Centre for Infectious Diseases	Clinical Virology	Clinical Research	M	M	L	Other Reference Labs
Centre for Infectious Diseases	Clinical Virology	Clinical Research	M	M	L	Public Health Unit
South Eastern Sydney Local H	Public Health Unit	Director & Medical Officer of	IP	M	L	EDs
South Eastern Sydney Local H	Public Health Unit	Director & Medical Officer of	IP	M	L	Labs
South Eastern Sydney Local H	Public Health Unit	Director & Medical Officer of	IP	M	L	Infectious disease physicians
South Eastern Sydney Local H	Public Health Unit	Director & Medical Officer of	IP	M	L	Micorbiologists
South Eastern Sydney Local H	Public Health Unit	Director & Medical Officer of	IP	M	L	Infection control
NSW ministry of Health	Center for Health Protectio	Public Health Laboratory Sur	IP/IR	Real Time	L	PHU
NSW Minister of Health	Center for Health Protectio	Medical Epidemiologist	IP	M	L	PHU

Figure 3-10: Screenshot of how the ego network data was structured after extracting it from the raw file

At this stage, each question had its own entity and represented one of the stages and phases of the outbreak coordination (formal: before and during; and informal: during the outbreak).

3.8.2. Survey questions and variables

Referring to the model in section 2.6.1 and Figure 2-18, the questions and constructs of the survey could be linked to the model as follows:

Formal coordination before the outbreak was addressed through question 22: Prior to disease outbreak, did your department communicate with other organisations/departments about outbreaks?

This question designated the phase of coordination before the outbreak, which included daily routine communication according to the standard operating procedures as well as during horizon scanning in anticipation of outbreaks.

As well as giving the name of the organisation that he or she communicated with, the respondent indicated the jurisdictional level of that organisation using an ordered series of categories:

I: International, F: Federal, S: State, L: Local (operating at Area Health Service Level), P: Private, O: Other.

These constructs were used to calculate the tier connectedness for the respondent's organisation in that phase.

Also the respondent was asked to state the frequency of communication based on these codes:

W: Weekly, M: Monthly, S: Semi-annually, A: Annually, AN: As needed.

The "as needed" category indicated a domain context in which organisations decide to initiate many communications based on need that they perceive at specific times. Such communications usually occur between monthly and the semi-annual frequencies.

Another construct that was collected was the communication type: whether it was information providing, information receiving, resource request, and resource supply. Those results are not included in this research.

Formal coordination during the outbreak was addressed through question 23: Which organisations/departments/units did you coordinate during the outbreak?

Informal coordination during the outbreak was addressed in question 25: Which organisations/departments/units did you informally coordinate with during the outbreak?

The same construct information was collected as for question 22.

The dependent variable for the formal coordination, as discussed in Chapter Two, was how quickly coordination began after the outbreak was announced. This topic was addressed in question 33 of the survey.

The moderating variable, being the actual tier of the respondent's organisation, was deduced from questions 1 and 2, asking for the name of the respondent's organisation and the department or unit he or she worked in. By combining those responses with the organisational

chart information from the NSW Ministry of Health, it was possible to deduce the organisational tier of the respondent's organisation, whether it was federal, State, local, or other (which includes organisations that are not part of the public health system).

Still remaining was the task of changing these variables to numerals that could be used as in subsequent calculations.

3.8.3. Changing letters to numerals, Ridit analysis

Ridit analysis was first suggested by Bross in 1958 as a missing link in data analysis in biological and behavioural sciences, specifically when response variables fall in the "borderland" between dichotomous classifications (e.g. "lived"- "died", "yes"- "no") and redefined measurement systems (i.e. measurements that are highly reproducible at different times or at different places). Bross explained that sometimes the response variable is a subjective scale (e.g. a well ordered series of categories such as "minor", "moderate", "severe"). These borderland response variables may not be adequately analysed by the chi-square family of statistical methods, but at the same time the *t*-test family of techniques may not be appropriate. In such cases the "Ridit analysis" may provide the missing link between the two traditional families of statistical methods. Ridit procedure is also safe to use because it is "distribution free" (Bross, 1958).

The name "Ridit" was chosen because of the analogy with "Probits" and "Logits". Like other members of the "it" family, Ridit represent a type of transformation. However, whereas Probits are relative to a theoretical distribution (the normal distribution), Ridit is relative to an empirical distribution. The first three letters stand for Relative to an Identified Distribution. In other words, Ridit is based on the observed distribution of a response variable for a specified set of individuals. Ridit represent a new application of a very old idea ("the probability transformation") and are closely related to distribution-free methods based on ranks (especially the Wilcoxon Test). The technique grew out of efforts to apply the rank *t*-test to Cornell Automotive Crash Injury Research Program (ACIR) data (where the number of subseries was large) (Bross, 1958)

The calculation method for Ridit values begins by giving ascending scores to the answers or values. Once this is done, the calculation of Ridit is a simple routine process, the mechanics of which are shown in Table 3-6 which uses the ACIR data to exemplify the calculations (Bross, 1954). Column 1 of Table 3-6 gives the distribution (with respect to a subjective injury scale) of the individuals in the "identified distribution" of the ACIR study. Thus of 179 persons, 17 were reported as not injured and 14 were fatally injured. The Ridits are calculated from the numbers in column 1 according to the instructions listed below the table. The Ridit for a given category is simply the proportion of individuals injured to a lesser degree plus one-half the proportion of individuals in the category itself.

Table 3-6: Using ACIR data to exemplify Ridit calculations

	A	B	C	D	E
	Frequency of occurrence	1/2 Column A	Cumulative frequency	Column B+C	Ridit Value (D/Sum)
None	17	8.5	0	8.5	0.047
Minor	54	27	17	44	0.246
Moderate	60	30	71	101	0.564
Severe	19	9.5	131	140.5	0.785
Serious	9	4.5	150	154.5	0.863
Critical	6	3	159	162	0.905
Fatal	14	7	165	172	0.961
Total	179				

The calculations of the columns are done as follows:

Column A: The frequency distribution in the identified distribution (reference class).

Column B: One-half of the corresponding entry in column A.

Column C: The cumulative of column A (displaced one category downward).

Column D: Column B + column C.

Column E: The entries in column D divided by the grand total (179). The numbers are the Ridits.

The operation in Table 3-6 can be viewed as a method of assigning a number (or weight) to the graded categories of the data. For example, a person whose degree of injury was previously described by a name or category (i.e. “severe”) now has a degree of injury described by a number (i.e. 0.785) (Bross, 1958). Also Ridits are by design close to distribution-free methods. (Jansen, 1984)

Ridits have been used in the network analysis context for classification of fraudulent car accident injury claims (Brockett et al., 2002). In another study Ridits were used along with SNA to create an expert system for detecting automobile insurance fraud (Šubelj et al., 2011). Redit and network analysis have been used in studying emerging coordination during a disaster by focusing on the structural positions of the organisations within the network structure. In the present research, Redit was used to calculate tie strength, degree centrality, and ego betweenness as continuous numerical score values by converting the respondents’ answers from ordinal ones such as for the frequency of coordination meetings held (Hossain et al., 2011). The exact question being; how often does your department meet or exchange information on terrorism with other STATE AGENCIES?

Responses could use these values:

- 1) Once a week or more
- 2) Two or three times a month
- 3) Once every month or two
- 4) A few times a year
- 5) Annually

6) Never

These responses were given values representing the weight of each answer, depending on its frequency among the total responses. Such score values looked like those in Table 3-7

Table 3-7: Ridit values for balanced scores of preparedness survey response (Adopted in part from (Hossain et al., 2011)).

Ridit value	1	2	3	4	5	6
Tie strength	0.194	0.402	0.491	0.712	0.92	0.991

Hence Ridit is a viable and feasible analysis to calculate the score tie strength, centrality and tier connectedness when changing responses to scores and values, to allow use of these values in further calculations. The details of these calculations are discussed in Chapter Four.

3.9. Statistical tests used

The choice of data analysis techniques to be used on any dataset is dependent on a variety of factors ranging from the research questions to data distribution and dataset structure. The hypotheses proposed (H1 – H3) and their sub hypotheses examined the relationships between independent and dependent variables of the proposed coordination models. The first phase of preparing the data after exporting the survey responses from the online survey system was to use Microsoft Excel and begin filtering responses for the required rows and columns. Then Ridit analysis was applied to change the ordinal values to numeral-weighted ones. In the last phase, all the variables were placed into the SPSS statistics program to implement certain statistical tests so as to test correlation between the relevant variables.

3.9.1. Correlation: Partial correlation and zero-order correlation

Correlation is a statistical measurement of the relationship between two variables (Field, 2009). It has the value range from +1 to –1 for the relationship between two variables where a zero value indicates that there is no relation between those two variables. A “-1” value implies

a perfect negative relation between them, which means that when one variable increases, the other variable decreases. On the other side, a “+1” value reflects a perfect positive relation between the variables, indicating that both variables move in the same direction together.

Partial correlation is defined as the measure of the association between two variables after removing the common effects of one or more control variables (Hinton, 2004, Levin, 2006). When there is no control variable in the measurement of correlation between two variables, it is called a zero-order correlation. If there is one control variable then it is called a first-order correlation. This means that a zero-order correlation is the correlation between two variables which does not include any control variable (Hinton, 2004, Field, 2009).

For example, in Figure 3-11a, the third variable (i.e. *third*) is correlated with both the *first* and *second* variables. In this case, we must choose *partial correlation* to determine the correlation between the *first* and *second* variables. However, in Figure 3-11b, there is no need to use partial correlation in measuring the correlation between the *first* and *second* variables – a *zero-order correlation* can calculate the correlation between those variables appropriately.

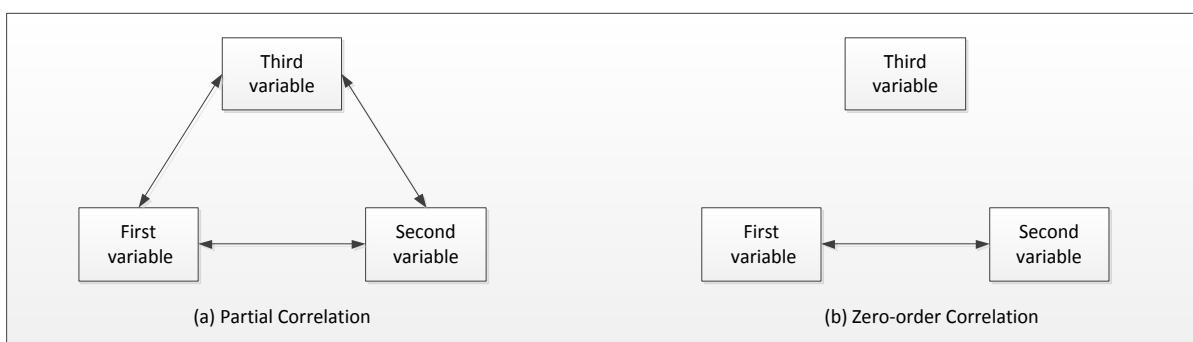


Figure 3-11 Illustration of (a) partial and (b) zero-order correlation.

To measure zero-order correlation between any pair of independent and dependent variables of the proposed hypotheses, both parametric and non-parametric tests are applied.

3.9.2. The Moderating Variables

Moderating variables are those that conspire with the independent variables to affect the dependent ones. These variables take into consideration some of the characteristics of the nodes (gender, ages, organisational level...) in order to measure the influence of these on

performance. In this research, the organisational tier level was discussed to be the moderating variable. This section presents the calculation methodology that was used for the moderating variables, and the results are presented in Chapter Four.

To test the effects of the moderating variable over the independent and dependent variables, the moderating variable (tier level of the originating organisation) had to be changed to numerical values using Ridit analysis following the same procedure as for tier connectedness when calculating the independent variable in section 3.8.3. This time, however, it was done for the originating organisation – the one that the respondent represented – rather than the one that the link was directed to. Then a linear regression model was used to determine whether this moderating variable had an effect on performance. Regression is a way of predicting the outcome variable from one or more predictive variable(s) (Healey, 2011). In simple regression, a predictive variable is used to quantify the outcome variable, whereas in multiple regressions more than one predictive variable is used. In regression analysis the following mathematical equation is used to predict the value of the dependent variable (denoted by Y) on the basis of the independent variable (denoted by X):

$$Y = aX_1 + bX_2 + c(X_1 * X_2) + e$$

where a denotes a baseline amount given to all dependent variables, b denotes the coefficient of the moderating variable, and c is the interaction term which defines the role of the moderating variable. This is the term usually calculated to estimate whether the role of the moderating variable is significant or not. Also e is called error terms or disturbance terms.

Hence the mathematical method combines the effect of the independent and moderating variables in calculating the regression significance of this effect on the dependent variable. If the result proves to be significant then the coefficient of the moderating variable exists in the linear equation. Table 3-8 provides an overview of how this is done:

Table 3-8: Methodology and interpretation of effect of moderating variable

Number	Independent variable	Moderating variable	Interaction	Result interpretation (linear regression)
1	Connectedness	Tier level	Connectedness*Tier	If significance <0.05

			Level	
2	Degree centrality	Tier level	Degree Centrality*Tier level	then the moderating variable affects the dependent variable; otherwise it does not.
3	Tie strength	Tier level	Tie strength*Tier level	

3.10. Data Limitations

The first data limitation in this study, as in most quantitative studies, is that the sample might not be generalizable to the complete population of staff involved in health. Second, it should be appreciated that participants were asked to remember incidents that in some cases might have occurred a year or more earlier. It is consequently conceivable that there are inaccuracies in the data basically because individuals' memory of what occurred was incomplete. The responses might be prejudiced through the recollection and the motivations of the individuals who took the time to complete the survey. Third, the survey on which the analysis is based was not set up to undertake research into social networks. For this purpose, it was demonstrated that the processes undertaken did extract what were believed to be useful proxies of network relations. From this perspective, it is vital to review the results carefully and to reflect on directions they might show for additional research validation.

Chapter 4

4. Findings from the network enabled coordination for disease outbreak

This chapter presents the results for the data collected, without interpretation or discussion, which will be provided in Chapter 5. The chapter initially presents descriptive statistics about the personnel interviewed, without revealing their identity. This is followed by the storyline of how the data was synthesised for analysis, and finally the correlation results for each of the hypotheses presented in Chapter 2.

4.1. Descriptive Statistics

This section provides descriptive statistics of the data gathered from the respondents during the 4-month interview period. This section focuses on the demographics and functional descriptions, leaving the network-based statistics to the second section.

4.1.1. Functional areas of the participants

The interviews were conducted with widely diversified group of actors whose diversity of positions and functions demonstrates the complexity of coordinating disease outbreaks. The information from Table 3-5, positions and tasks of the respondents, was further condensed into 19 generalised functional categories, with the number of respondents identified in each category. Table 4.1 shows those categories and the number of respondents in each.

Table 4-1: Number of respondents in each functional category

Respondents' functional categories	Occurrences
Microbiology	5

Area Health management	6
Laboratory management	2
Epidemiology	13
Coordination	3
Surveillance	2
Emergency management	9
Clinical management	5
Policy development	2
Pharmacies	1
Logistics	1
Immunisation	3
Nursing	4
General management	2
Community Health	1
Health management	2
Informaation Technology (ICT)	1
Bio-preparedness	3
Public communication	1
Total	66

Also Figure 4-1 below provides a visual representation of these numbers.

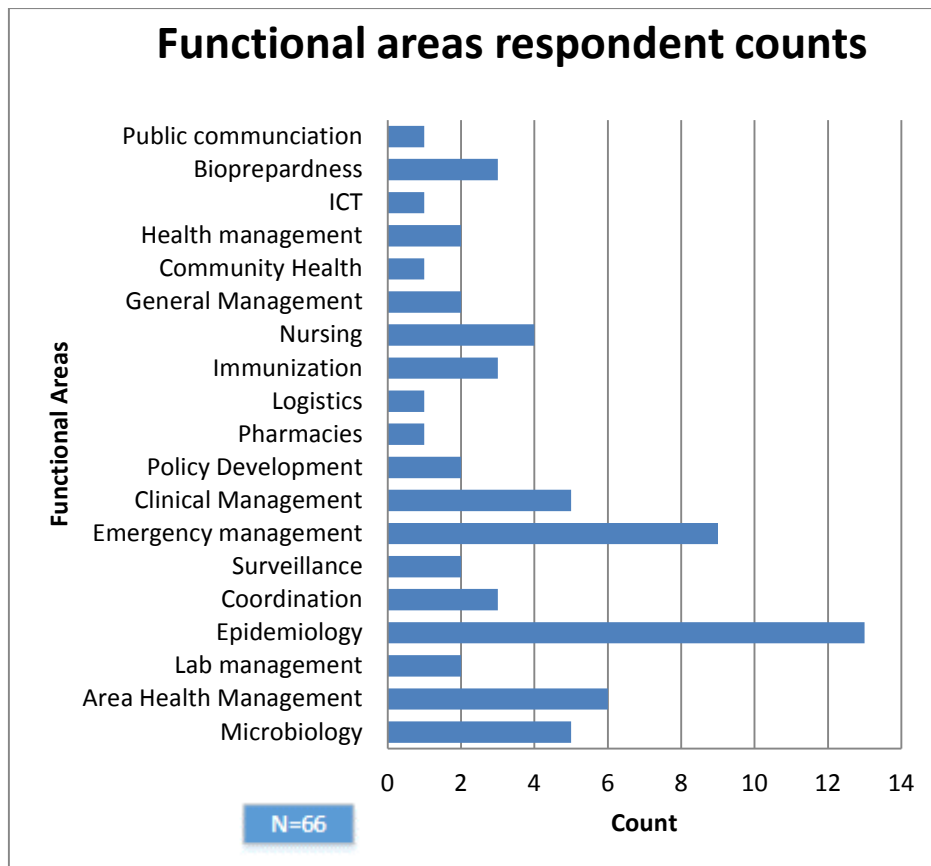


Figure 4-1: Number of respondents in functional areas

4.1.2. Task matrix of the respondents

Question 4 in the questionnaire asked respondents to mark the types of tasks in which they had been involved. The standard tasks listed were the following:

- Leadership and guidance.
- Collecting information.
- Information analysis and dissemination.
- Training other organisations.
- Epidemiology.
- Detection (including surveillance).
- Community education.
- Emergency care (Emergency Department and Intensive care unit).

- Others: please specify.

This question was designed to define an inter-organisational-tasks relationship matrix, giving weight to the tasks most performed during the outbreaks. Figure 4-2 shows the percentage distribution of these tasks.

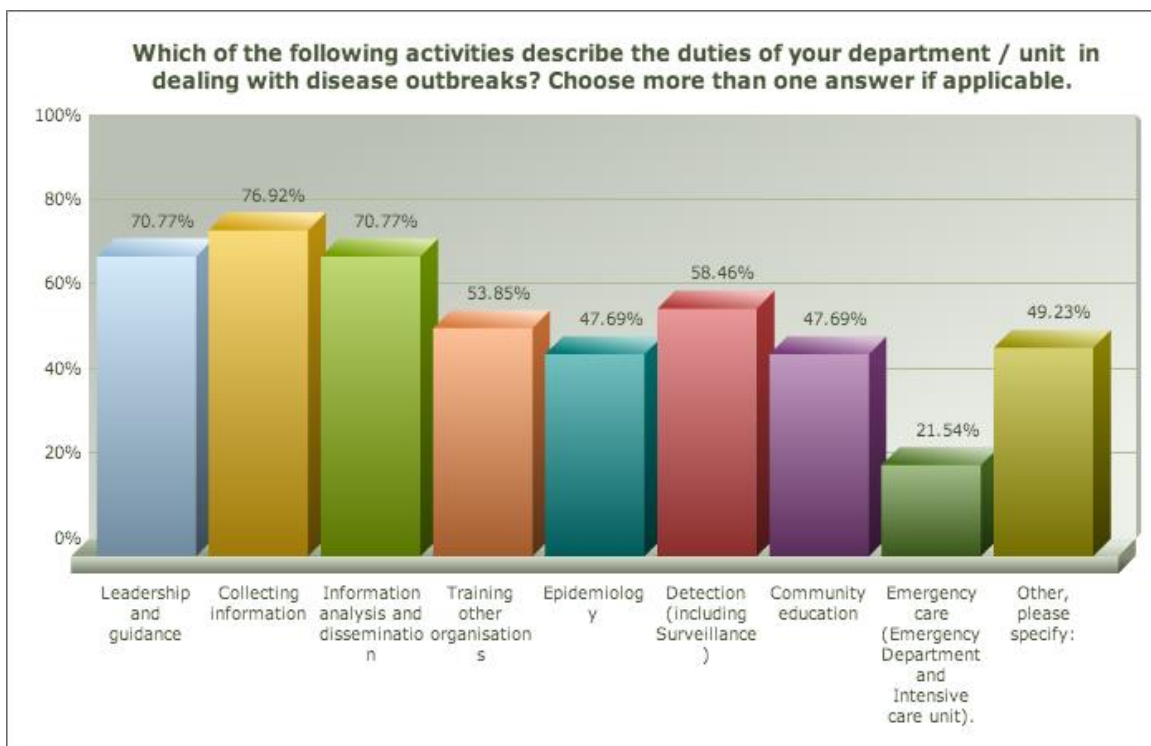


Figure 4-2: Tasks performed during the outbreak (N=66)

For the “others” category (the last column in the chart), the individual results were:

Response to individual cases and contact management

1. Communication to public (NSW health site) / fact sheets
2. Public Health Alerts (Community, GPS, Hospital)
3. Liaison between Labs and Public Health epidemiologists
4. Data entry NCIMS (state-based system for notifiable diseases)
5. Implementation of NSW Dept. of Health Communicable Disease protocol
6. Emergency management coordination, provide information to other government agencies on how to protect their staff
7. Supply of medications

8. Logistics – distribution of quarantine packs
9. Emergency management
10. Liaising personal protective equipment (PPE) and patients’ isolation management
11. Deploying National and State stockpile of equipment and drugs
12. Support the GP network and Aboriginal Medical Services (AMS's)
13. Surveillance at Sydney airport
14. Planning/coordination
15. Testing samples and reporting back
16. Support and advice to Public Health Units (PHUs)
17. Hospital staff education
18. Assistance to Department of Health
19. GP-level care facility
20. Liaison with State Emergency Management services (SEMC)
21. Liaison with other organisations
22. Policy, resource allocation, protocol development, strategic planning for critical care
23. Source of communication for people
24. Taking care of phone call/courier/isolation packs
25. Logistics / internal communication
26. Resource development, public and internal communication
27. Policy development, management and external liaison services
28. Coordinate home isolation and provision of services for isolated people
29. Offer vaccine
30. Helped in rolling information to schools

It should be noted that for about only 21% of the health workers responded that they work in emergency care since these are the ones that work in the intensive care or clinical care in hospitals while other epidemiologists and health workers considers themselves working in pandemic management rather than emergency management.

4.1.3. Geographical distribution of respondents

In trying to cover coordination patterns across different response groups, the intention was to interview respondents from different geographical and demographic spectrums, whether they were suburban, urban or rural. This required selective targeting of both respondents' tasks and geographical locations. Some interviews were also conducted with health workers who worked on jurisdictional boundaries between NSW and two other states, Victoria and Queensland. For this cross-jurisdictional experience, the public health centres in Albury and Lismore were targeted. The NSW Ministry of Health was located in North Sydney. All the statewide management services were located there, representing the hub for most of the health communication within the state. The complexity and intensity of tasks decreased as one moved from suburban to rural areas due to the simplicity of social structures in the rural context. The red drop pins on the map below represent the offices of the interviewed participants. Their offices manage large areas within their local area health service geographical location.

Figure 4-3 provides a mapped projection of the interview locations.

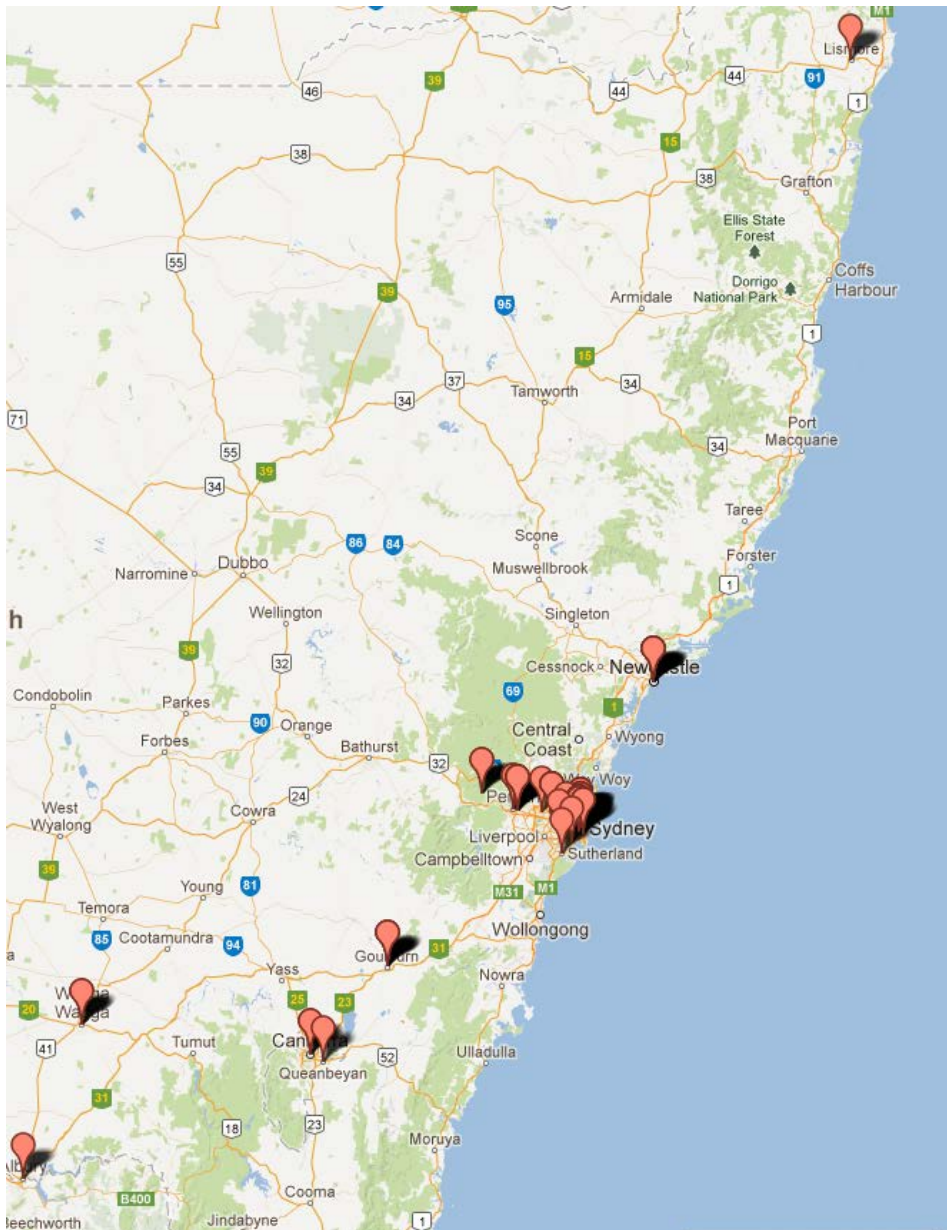


Figure 4-3: Base work locations of interviewed respondents (N=66)

4.2. Network descriptive statistics

This section briefly highlights some of the network-based information, such as the percentages of links.

4.2.1. Comparison of number of formal links before and during the outbreak

It is to be expected that organisations tend to initiate more links during a time of crisis as part of their effort to acquire more information or resources from others. Table 4-2 compares the number of links of each respondent before the Swine flu (H1N1) outbreak to the number during the outbreak. It also shows the percentage increase of these links for each respondent.

Table 4-2: Number of links before and during the outbreak, along with percentage of increase

Respondent ID	4313734	4288732	4029068	4284390	4821701	4236514
Links before outbreak	3	3	2	2	4	1
Links during outbreak	4	9	3	13	10	2
% Increase	33.3	200.0	50.0	550.0	150.0	100.0
Identifier	3593163	3343240	4045418	4366750	3686788	3583350
Links before outbreak	1	6	3	1	1	4
Links during outbreak	4	14	4	12	8	4
% Increase	300.0	133.3	33.3	1100.0	700.0	0.0
Identifier	3285663	5038035	3910135	3496016	3304691	4000864
Links before outbreak	4	5	9	3	3	6
Links during outbreak	4	7	12	21	10	14

% Increase	0.0	40.0	33.3	600.0	233.3	133.3
Identifier	4821260	3532293	5047656	4016687	4245128	4001052
Links before outbreak	4	3	2	2	2	3
Links during outbreak	6	8	3	4	6	15
% Increase	50.0	166.7	50.0	100.0	200.0	400.0
Identifier	4301022	3313606	3687181	3338107	3701510	3567155
Links before outbreak	1	8	1	1	5	1
Links during outbreak	1	21	6	21	14	5
% Increase	0.0	162.5	500.0	2000.0	180.0	400.0
Identifier	4016687	4245128	3480594	3268758	5024149	3333690
Links before outbreak	2	2	7	4	3	8
Links during outbreak	4	6	9	12	12	13
% Increase	100.0	200.0	28.6	200.0	300.0	62.5
Identifier	3285663	5038035	3910135	3496016	3304691	4000864
Links before outbreak	4	5	9	3	3	6

Links during outbreak	4	7	12	21	10	14
% Increase	0.0	40.0	33.3	600.0	233.3	133.3
Identifier	4420907	3701781	3797036	3764761	3255980	3486586
Links before outbreak	1	3	3	2	5	3
Links during outbreak	4	6	5	4	6	10
% Increase	300.0	100.0	66.7	100.0	20.0	233.3
Identifier	3977276	3850879	3701613	3653416	4573390	3683064
Links before outbreak	4	2	3	4	7	2
Links during outbreak	11	3	3	6	15	6
% Increase	175.0	50.0	0.0	50.0	114.3	200.0
Identifier	3662303	4259129	5047656	3296106	5011784	4380610
Links before outbreak	6	3	2	8	4	1
Links during outbreak	15	5	3	17	6	10
% Increase	150.0	66.7	50.0	112.5	50.0	900.0

Identifier	5011784	4380610	3259726	3553658	4181107	4250528
Links before outbreak	4	1	1	0	0	0
Links during outbreak	6	10	4	8	4	2
% Increase	50.0	900.0	300.0	NA	NA	NA
Identifier	4324305	5038216	4292861	3259726	3644246	3157803
Links before outbreak	0	8	0	1	2	3
Links during outbreak	1	13	6	4	11	4
% Increase	NA	62.5	NA	300.0	450.0	33.3
Identifier	5024264	4285907	4856713	4821704	4948099	5024264
Links before outbreak	6	3	3	9	2	6
Links during outbreak	9	13	11	19	6	9
% Increase	50.0	333.3	266.7	111.1	200.0	50.0

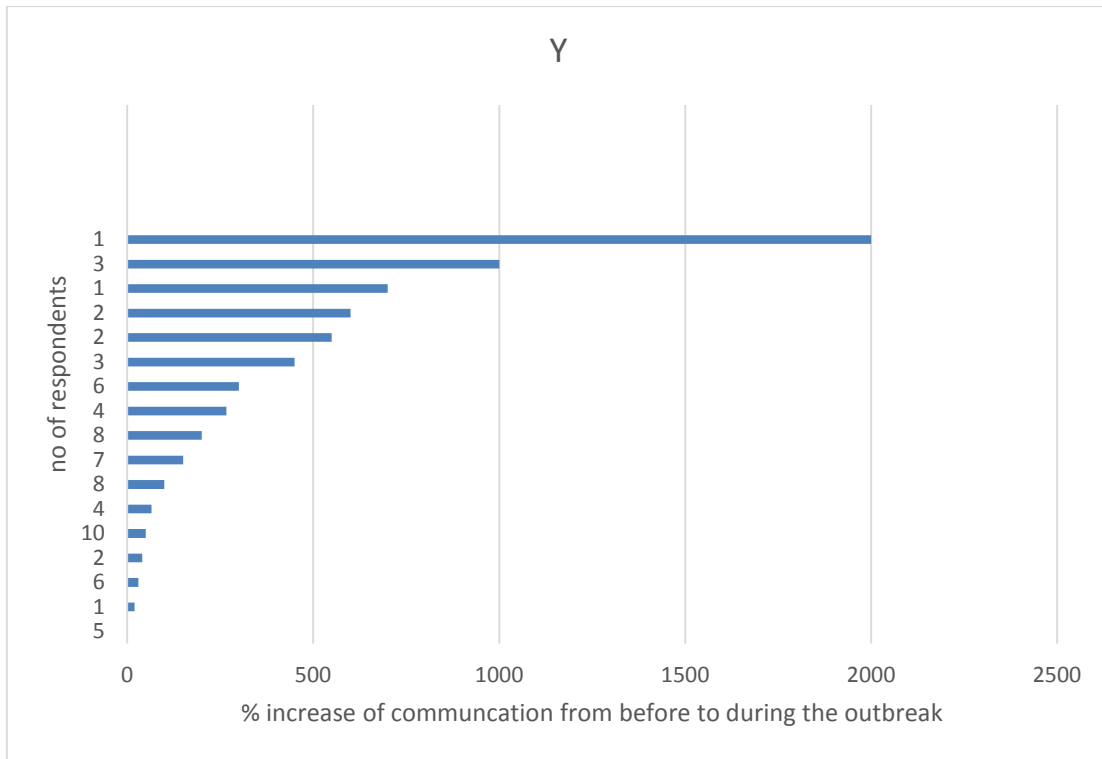


Figure 4-4: Graphical view of the percent increase of communication aggregated per number of respondents from before to during the outbreak.

The average link increase for all respondents was 232%, demonstrating a major shift towards increasing new communication during the outbreak. Figure 4-4 shows the percent increase in communication against number of respondents compared before to during the outbreak. It is noticed that most of the respondents reported between 50% (10 respondents) and 300% (4 respondents) fold increase in the communication.

4.2.2. Comparison of informal and formal links during the outbreak

Table 4-3 presents the comparative statistics between the formal and informal links during the outbreak.

Table 4-3: Comparative descriptive analysis between numbers of formal and informal links during the outbreak

Respondent ID	Formal links	Informal links	Difference in number	Total number	% Formal	% Informal

	during	during	of links	of links		
3157803	4	3	1	7	57%	43%
3255980	6	6	0	12	50%	50%
3259726	4	2	2	6	67%	33%
3268758	12	7	5	19	63%	37%
3285663	4	4	0	8	50%	50%
3296106	17	4	13	21	81%	19%
3304691	10	8	10	10	56%	44%
3313606	21	20	21	21	51%	49%
3333690	13	3	10	16	81%	19%
3338107	21	13	8	34	62%	38%
3343240	14	3	11	17	82%	18%
3480594	9	9	0	18	50%	50%
3486586	10	10	0	20	50%	50%
3496016	21	10	21	21	68%	32%
3532293	8	0	8	8	100%	0%
3553658	8	1	7	9	89%	11%
3567155	5	4	1	9	56%	44%
3583350	4	5	-1	9	44%	56%

3593163	4	1	3	5	80%	20%
3644246	11	2	9	13	85%	15%
3653416	6	8	-2	14	43%	57%
3662303	15	8	15	15	65%	35%
3683064	6	4	2	10	60%	40%
3686788	8	5	8	8	62%	38%
3687181	6	1	5	7	86%	14%
3701510	14	11	3	25	56%	44%
3701613	3	3	0	6	50%	50%
3701781	6	3	3	9	67%	33%
3764761	4	3	1	7	57%	43%
3797036	5	4	1	9	56%	44%
3850879	3	1	2	4	75%	25%
3910135	12	12	0	24	50%	50%
3977276	11	4	7	15	73%	27%
4000864	14	4	10	18	78%	22%
4001052	15	11	4	26	58%	42%
4016687	4	6	-2	10	40%	60%
4029068	3	1	2	4	75%	25%
4045418	4	7	-3	11	36%	64%

4181107	4	1	3	5	80%	20%
4236514	2	1	1	3	67%	33%
4245128	6	2	4	8	75%	25%
4250528	2	3	-1	5	40%	60%
4259129	5	5	0	10	50%	50%
4284390	13	3	10	16	81%	19%
4285907	13	4	13	13	76%	24%
4288732	9	8	1	17	53%	47%
4292861	6	0	6	6	100%	0%
4301022	1	1	0	2	50%	50%
4313734	4	1	4	4	80%	20%
4324305	1	0	1	1	100%	0%
4366750	12	4	8	16	75%	25%
4380610	10	3	7	13	77%	23%
4420907	4	0	4	4	100%	0%
4573390	15	4	15	15	79%	21%
4821260	6	2	4	8	75%	25%
4821701	10	2	8	12	83%	17%
4821704	19	4	15	23	83%	17%
4856713	11	12	-1	23	48%	52%

4948099	6	1	5	7	86%	14%
5011784	6	2	4	8	75%	25%
5024149	12	10	2	22	55%	45%
5024264	9	0	9	9	100%	0%
5038035	7	3	4	10	70%	30%
5038216	13	5	8	18	72%	28%
5047656	3	9	-6	12	25%	75%
3147843	3	1	2	4	75%	25%

It is noticed that 92.54% of the respondents, that is, the overwhelming majority, used both formal and informal forms of coordination during the outbreak. Only 7.46% of them remained faithful to formal coordination only, showing strict adherence to the hierarchical structure. Two of those respondents, 5024264 and 4420907, expressed their commitment to the standard operating procedures and directly indicated that they did not branch to any other communication channels. Respondent 5024264 worked in the NSW ministry of health, whereas all the other respondents stated openly that they used informal communication. Respondent 4420907 worked in the NSW state disaster emergency management centre, health section. This centre, which hosted the ambulance and other disaster management facilities, was structured on a hierarchical basis and hence informal coordination was not part of the organisational culture. Nevertheless, informal coordination was widely used across environments during the disease outbreak, alongside the formal coordination.

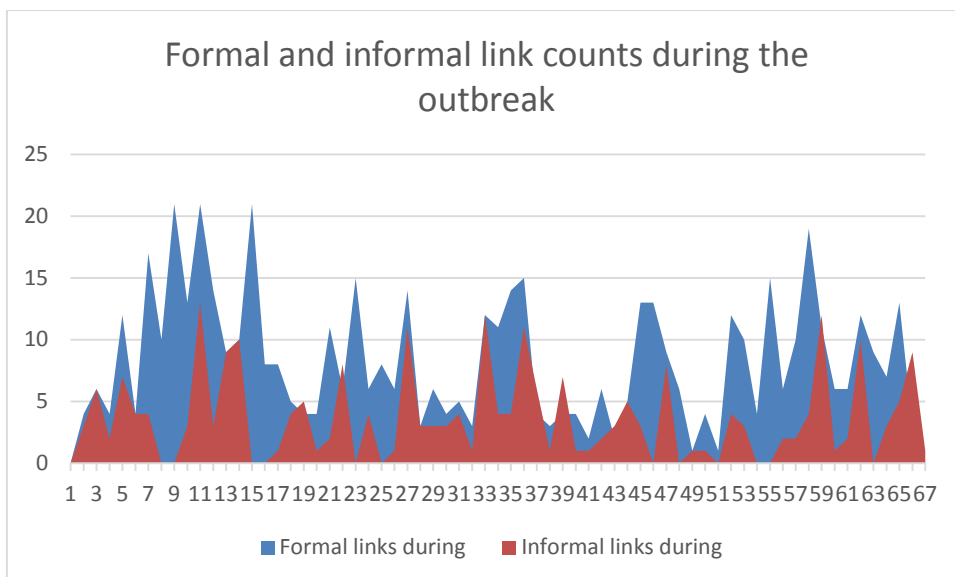


Figure 4-5: Formal and informal links during the outbreak.

Figure 4-5 shows both formal and informal links counts plotted from table 4-3. An important reading from this graph is that formal and informal links are not inversely proportional. It is not the case that if the formal links increase, then informal ones will decrease. Rather this graph shows that in many cases that even when the number of formal links is high, so is the number of informal and vice versa. Hence, one form of communication does not substitute the other.

4.2.3. Additional descriptive statistics

This section contains some additional descriptive statistical graphs of data obtained from several questions that were not used for model analysis, but nevertheless shed light on the mechanics of the coordination process.

Q7: “How does your department get notified when a disease outbreak is announced?”

The results are charted in Figure 2-9.

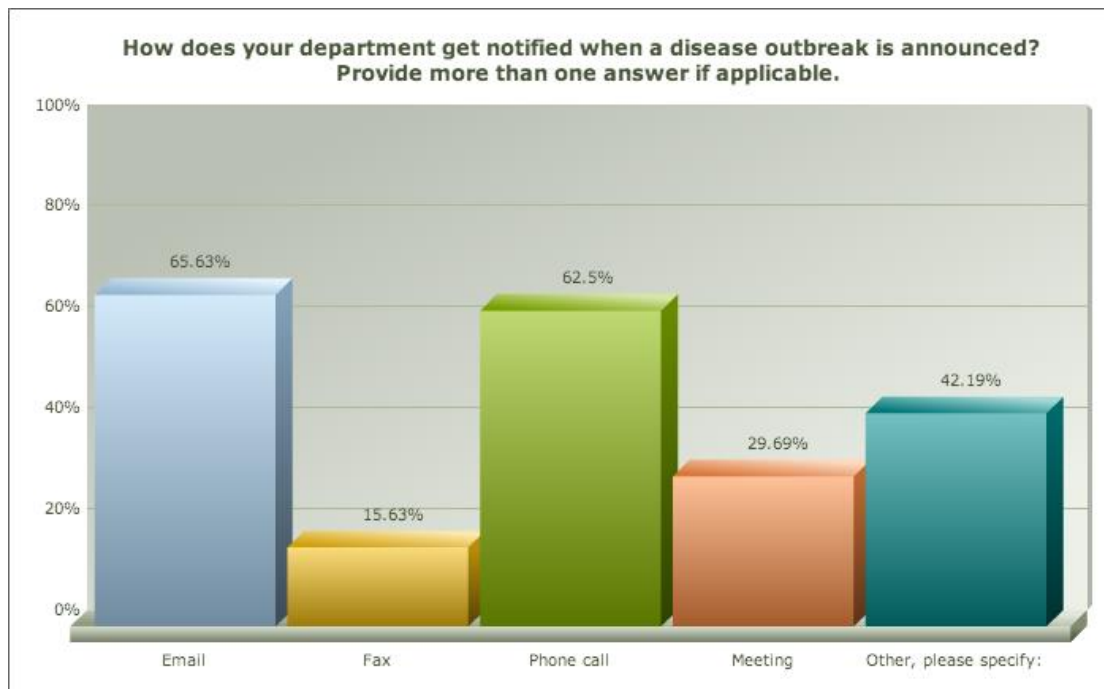


Figure 4-6: How does your department get notified when a disease outbreak is announced?

Q9: “How does your department get notified when a disease outbreak is finished?” The responses are charted in Figure 4-7.

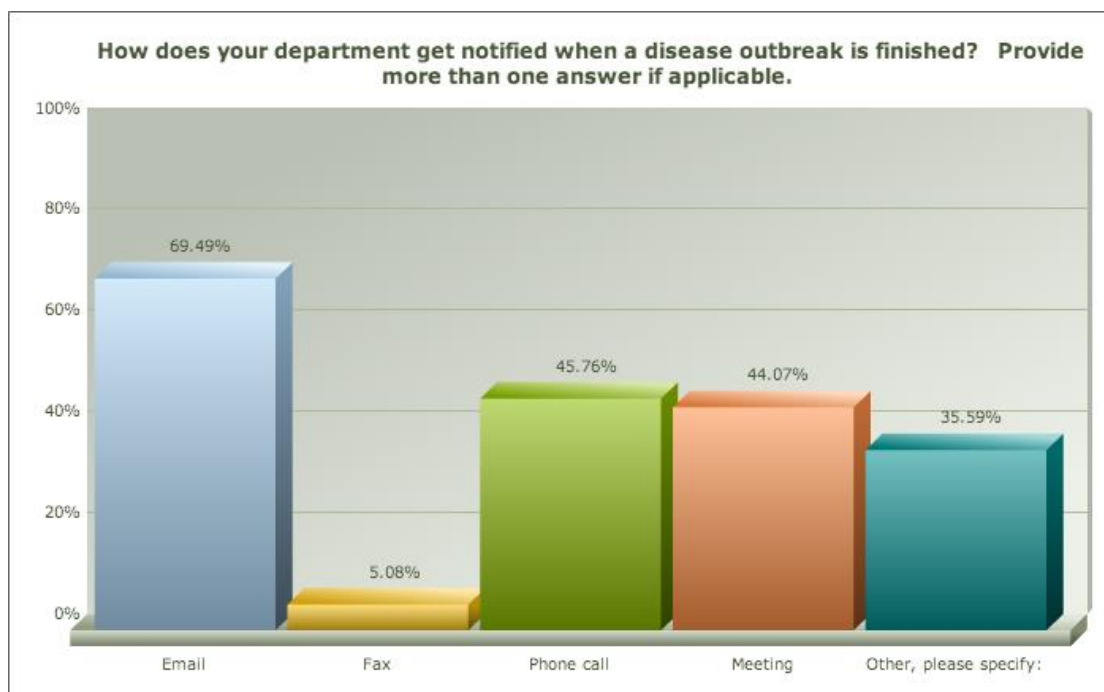


Figure 4-7: Notification methods when a disease outbreak is finished

Q11: “In your opinion, how important is it to have a prepared coordination plan?” Figure 4-8 depicts the results.

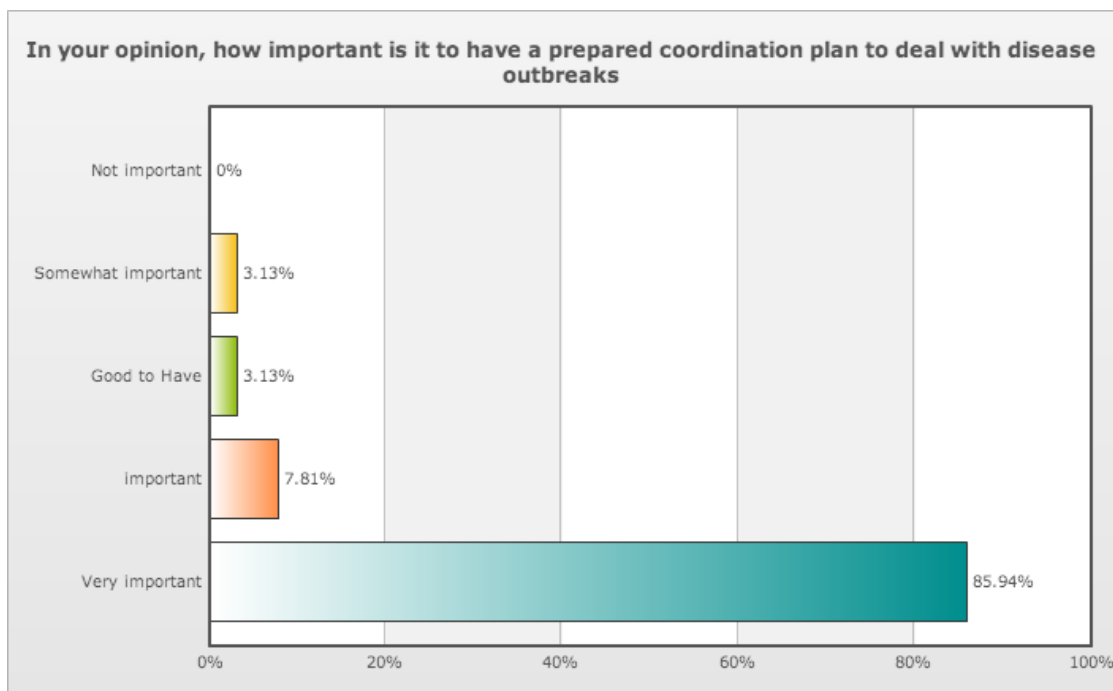


Figure 4-8: Importance of having a prepared coordination plan.

Q14: “In case you provide input to policy development for other departments/units/organisations, which levels do you provide that input to?”

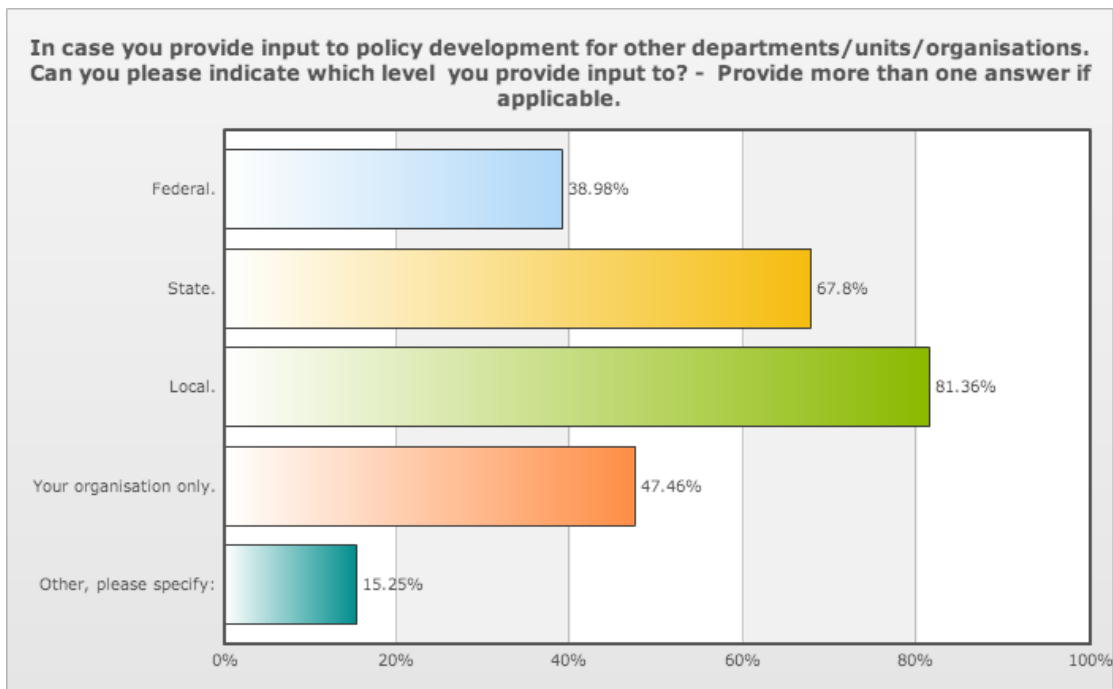


Figure 4-9: Policy input to other jurisdictional levels

Question 21 asked about participation in training with other organisations; and Question 24 followed this: “How do you measure your preparedness after the training comparing to what it was before?”

The results are charted in Figure 4-10 and Figure 4-11 respectively.

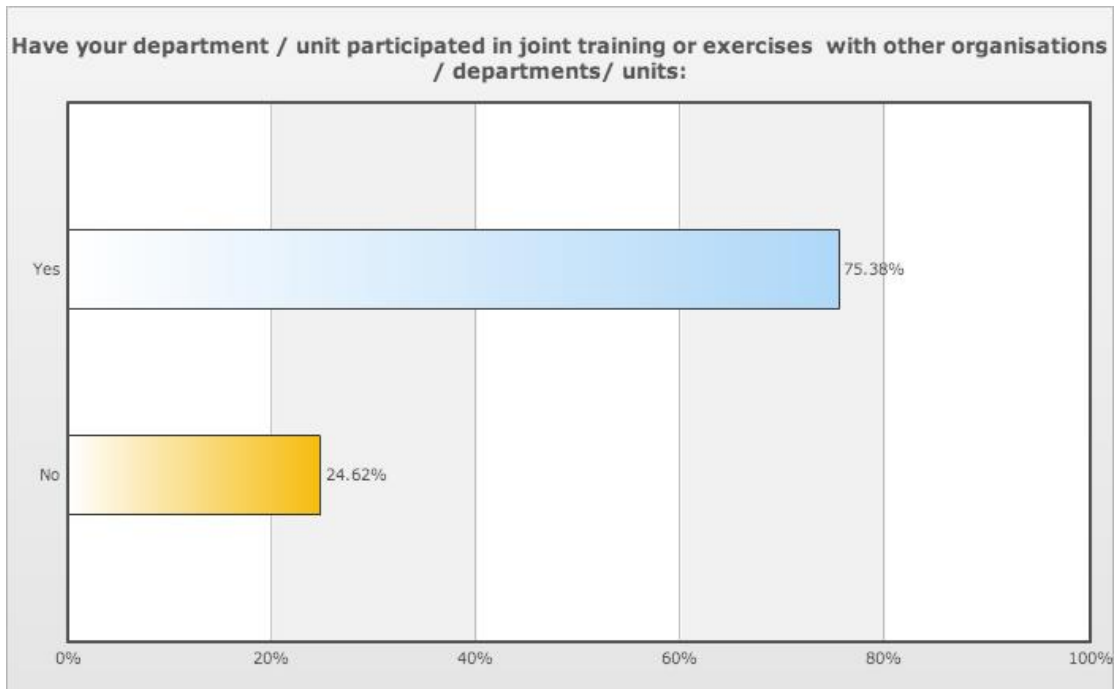


Figure 4-10: Percentage of organisations that participated in joint training with others.



Figure 4-11: Preparedness after training

4.3. Normalising the data

This section details how the data was normalised from text responses to numeric values using the Ridit method described in Chapter 3.

4.3.1. Organising data

The data was downloaded in raw csv files, hence it was first necessary to re-organise it along each respondents' contacts to create an ego star network for each respondent. In other words, each respondent had to be isolated along with her contacts. An example is shown in Figure 4-12. This figure warrants some discussion, as much later information is built on top of such networks. The number in the middle, 3296106 represents the respondent or ego. All the links branching out are the communications that respondent had with targeted organisations during the outbreak.

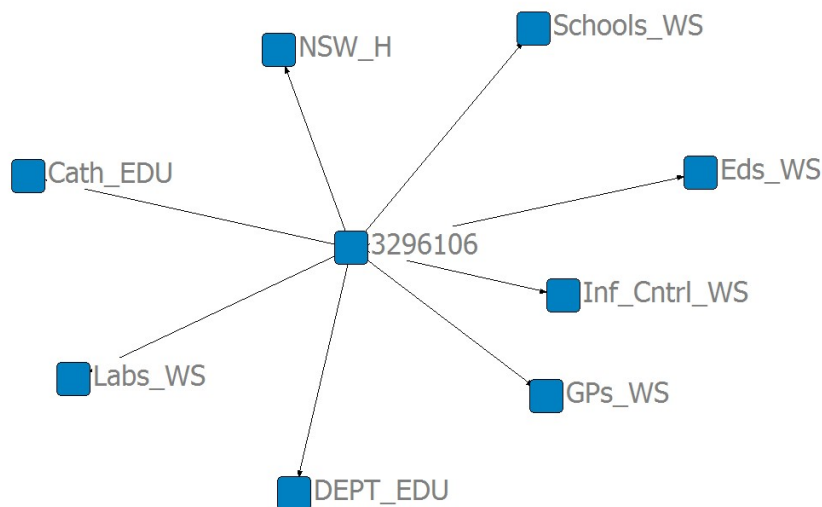


Figure 4-12: Ego network of respondent 3296106.

From such a star network, network measures such as centrality can be easily deduced. To provide a broader perspective of the network, Figure 4-12 shows how the respondent's network above was linked to those of other respondents.

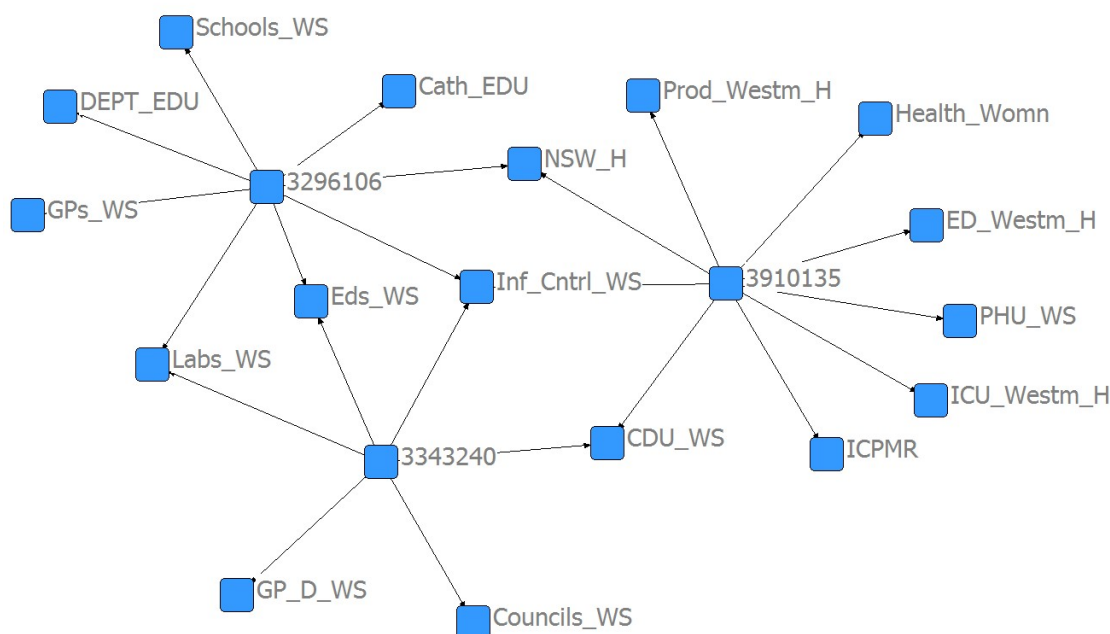


Figure 4-13: The extended network of three respondents

It also important to realise that each of these links has a metric associated with it. This metric is how often the communication happened (daily, weekly, monthly...). Those metrics are discussed in the Redit analysis section.

4.3.2. Normalising organisations

In the interviews, most of the data was raw and not normalised. Many respondents used acronyms and often referred to organisations broadly, without using the formal name. A simple example is “The Ministry of Health”, which is the main health body in NSW. Sometimes the respondents called it by its official name, but at other times, they used “NSW Health” or referred to it as the “Health Department”.

If these names were left as is, then three separate nodes would have been created in the network structure referring to one entity. This would create not only confusion and inconsistency but also inaccuracies when calculating the measures. Therefore the researcher had to refer back to the industry literature, manuals and organisational charts in order to normalise all organisations and codify them, deciding on a single code for each entity. This normalisation had to take into consideration several factors:

1. The codes should be distinctive so as not to be confused with each other.
2. The codes should give a brief idea of each entity that facilitates the process of reading tables and diagrams and reduces the need to refer back to the key table.
3. The codes should take into consideration different organisational levels and services of each entity and embed those in the code. It was particularly important here to differentiate between organisations that operated at federal, state, and/or local level longitudinally, and to try to understand which of these levels a respondent interacted with, so as to refer to it accurately in the name code.

Each entity name was thus manually revised and codified, which produced the code names shown in Figure 4-13 above.

Table 4-4 below presents some of these codes and their original meanings.

Table 4-4: Some code interpretations from the respondents' network in Figure 4-13

Code	Organisation
NSW_H	New South Wales Ministry of Health
Schools_WS	Schools in the Western Sydney Area Health Service (WSAHS)
Eds_WS	Emergency departments in WSAHS hospitals
Inf_Cntrl_WS	Infection control unit in WSAHS hospitals
GPs_WS	General practitioners in the WSAHS geographic region
DEPT_EDU	Department of Education

Labs_WS	Medical laboratories (public and private) in the WSAHS geographic region
Cath_EDU	Catholic Education Office (private educational organisation) in the WSAHS geographic region
Councils_WS	Local councils (local government areas) in the WSAHS geographic region
ICPMR	The Institute for Clinical Pathology and Medical Research at Westmead Hospital
CDU_WS	Counter Disaster Unit in the WSAHS geographical area
ED_Westm_H	Emergency Department in Westmead Hospital

4.3.3. Using Ridit to calculate tie strength

Tie strength was the first independent variable to be calculated using the Ridit method. This section details how a value was calculated for each link of the respondent, as a prerequisite for calculating the tie strength value for the whole respondent as a normalised value.

The survey asked respondents to list the frequency of their communication with other agencies, a measure that represents tie strength as discussed in Chapters 2 and 3. The answers were coded as annually, semi-annually, quarterly, monthly, as needed, weekly, and daily. Table 4-5 shows some of these responses taken from Question 25 of the survey about the coordination before outbreak. These forms of response were repeated for Questions 26 and 28 (formal and informal coordination during the outbreak respectively).

	A	B	C
1	Org-originate	Org-end	Frequency
2	ICPMR	LABS_ref	M
3	ICPMR	PHU	M
4	PHU_SES	EDs	M
5	PHU_SES	Labs_pub	M
6	PHU_SES	Inf_D_Phys	M
7	PHU_SES	Micro_P	M
8	PHU_SES	Inf_Cntrl	M
9	CDB	PHU	D
10	CDB	PHU	M
11	CDB	CDNA	W
12	CDB	DPI	S
13	CDB	Hospitals	M
14	ICPMR	NSW_H	D
15	PHU_SWS	DPI	As needed
16	PHU_SWS	DEPT_EDU	As needed
17	PHU_SWS	CDB	W
18	PHU_SW	CDU	Q
19	PHU_SW	Inf_Cntrl	M
20	PHU_SW	GP_D	M
21	PHU_SW	Councils	A
22	PHU_SW	Labs_pub	As needed
23	PHU_SW	EDs	M
24	HEMU	WHO	W
25	HEMU	NSW_H	D
26	HEMU	SEMC	D
27	HEMU	AMB	W
28	HEMU	Health_M	W
29	HEMU	HSFAC	W
30	HEMU	Health_Comm	W
31	Westmead_child_ED	Hosp_Westm	Q
32	Westmead_child_ED	CDU	Q
33	Westmead_child_ED	EDs	Q
34	CHP	Schools	As needed
35	CHP	AMB	As needed
36	CHP	DoHA	As needed
37	RPAH_ED	NSW_H	Q
38	RPAH_ED	PHU	Q
39	RPAH_ED	SWSAHS	Q
40	RPAH_Phrm	PHU	M
41	PHU_SW	CDB	W

Table 4-5: A sample of the responses indicating the frequency of communication

Table 4-5 above also illustrates the communication frequencies in action. These were divided into “*as needed*”, meaning that the respondents would communicate when they need to, then *daily*, *weekly* and *monthly*, up to *quarterly*. The frequency of the communication reflects the importance and urgency of the collaboration task as well the strength of the relationship between both nodes.

Ridit analysis was used to convert these frequencies (A, S, M, As Needed, W, D) to numbers following; the procedure discussed in section 3.8.3 above. First, the number of occurrences of each of the responses was counted. Then the Ridit values were calculated using the standard calculation method for this procedure. The tie strength Ridit calculation and values for Question 25 are shown in Table 4-6

Table 4-6: Tie strength calculations using Ridit analysis

Tie strength-Q25	A	B	C	D	E
Ridit analysis	No. of occurrences:	1/2 column A	Cumulative B	Add C+B	Ridit value: D/Total
Annually: A	14	7	0	7	0.032
Semi-annually: S	5	2.5	14	16.5	0.076
Quarterly: Q	22	11	19	30	0.139
Monthly: M	40	20	41	61	0.282
As needed	81	40.5	81	121.5	0.563
Weekly: W	28	14	162	176	0.815
Daily: D	26	13	190	203	0.940
Sum:	216				

Table 4-6 shows that the network had 216 total links. The last column, E, is the final Ridit value for tie strength. The tie strength value was low when the connection was made only annually (0.032), and increased as the connection grew stronger for organisations that communicated weekly (0.815) and daily (0.94).

These values were then introduced to the Question 25 table to replace the frequency-coded answers. Table 4-7 shows these values in place in the Ridit value column.

Table 4-7: Sample of tie strength values

Org-originate	Org-end	Frequency	Ridit Value
PHU_SW	Councils	A	0.032
CDB	DPI	S	0.076
PHU_SW	CDU	Q	0.139
Westmead_child	Hosp_Westm	Q	0.139
Westmead_child	CDU	Q	0.139
Westmead_child	EDs	Q	0.139
RPAH_ED	NSW_H	Q	0.139
RPAH_ED	PHU	Q	0.139
RPAH_ED	SWSAHS	Q	0.139
ICPMR	LABS_ref	M	0.282
ICPMR	PHU	M	0.282
PHU_SES	EDs	M	0.282
PHU_SES	Labs_pub	M	0.282
PHU_SES	Inf_D_Phys	M	0.282
PHU_SES	Micro_P	M	0.282
PHU_SES	Inf_Cntrl	M	0.282
CDB	PHU	M	0.282
CDB	Hospitals	M	0.282
PHU_SW	Inf_Cntrl	M	0.282
PHU_SW	GP_D	M	0.282
PHU_SW	EDs	M	0.282
PHU_SWS	DPI	As needed	0.563
PHU_SWS	DEPT_EDU	As needed	0.563
PHU_SW	Labs_pub	As needed	0.563
CHP	Schools	As needed	0.563
CHP	AMB	As needed	0.563
CHP	DoHA	As needed	0.563
CDB	CDNA	W	0.815
PHU_SWS	CDB	W	0.815
HEMU	WHO	W	0.815
HEMU	AMB	W	0.815
HEMU	Health_M	W	0.815
HEMU	HSFAC	W	0.815
HEMU	Health_Comm	W	0.815
CDB	PHU	D	0.940
ICPMR	NSW_H	D	0.940
HEMU	NSW_H	D	0.940
HEMU	SEMC	D	0.940

Table 4-7 is sorted by tie strength in ascending order. The values indicate that before the outbreak was detected, low-tier organisations like Public Health Units (PHU_SW, PHU_SWS) had lower than average communication frequency specifically with clinical units like Pathology laboratories (ICPMR, Labs_pub) and with emergency departments (RPAH_ED). On the hand, communication occurred daily between bureaucracies and emergency

management organisations, such as between the Health Emergency Management Unit (HEMU) and the Ministry of Health in NSW (NSW_H) and the State Emergency Management Coordination Centre (SEMC). The reason for this frequent communication was that, even in a situation where no outbreaks are detected, there were daily situational updates between the State Emergency Management centres.

The same calculation is performed for Questions 26 and 28. The tie strength results for Question 26 are in Table 4-8 and for Question 27 in Table 4-9.

Table 4-8: Tie strength calculations for Q26 (Formal coordination during the outbreak)

Tie Strength-Q26	A	B	C	D	E
Ridit analysis	No. of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: E/Sum
Annually: A	0	0	0	0	0.000
Semi-annually: S	2	1	0	1	0.002
Quarterly: Q	1	0.5	2	2.5	0.005
Monthly: M	8	4	3	7	0.013
As needed	152	76	11	87	0.157
Weekly: W	117	58.5	163	221.5	0.399
Daily: D	275	137.5	280	417.5	0.752
Sum	555				

Table 4-8 shows tie strength during the disease outbreak. Interestingly, there is no annual communication, as everyone now is engaged in actively communicating with others, rather than passively waiting for communication to occur. Note that there are 555 links in this network compared to only 216 links before the outbreak; that is, there was more than 100%

increase in the number of links after the intervention plans were activated and new agencies became part of the evolving network.

Table 4-9: Tie strength calculations for Q28 (Informal coordination during outbreak)

Tie Strength- Q28	A	B	C	D	E
Ridit analysis	No. of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: N/Sum
Annually: A	0	0	0	0	0.000
Semi-annually: S	0	0	0	0	0.000
Quarterly: Q	0	0	0	0	0.000
Monthly: M	18	9	0	9	0.037
As needed	66	33	18	51	0.211
Weekly: W	54	27	84	111	0.459
Daily: D	104	52	138	190	0.785
Sum	242				

There are 242 links in this network. Note that the number of informal links is nearly half that of the formal links (242 compared to 555). This shows that nearly one third of the communication during the outbreak was informal, representing a significant amount and at the same time revealing the real necessity and importance of informal communication. Another observation is that informal communication occurs at intervals between monthly and daily, since it was motivated by the direct need to coordinate quickly and to attend to urgent and pressing situations, rather than to long-term matters.

4.3.4. Using Ridit to calculate tier connectedness

Tier connectedness is the second independent variable. In this section a value is calculated for each tie as a prerequisite to calculating the normalised tier connectedness value for the respondent as a whole. Tier connectedness represents the value of the link and how the ego is connected across different tiers and jurisdictions. These values were expressed as follows in the survey:

International: I

Federal: F

State: S

Local: L (at the Area Health Service level)

P: Private (such as private health care)

O: Other

The numbers of these tiers were also calculated using Ridit. However, when adding the numbers, it was noted that the contributions of international, private and “others” were each negligible (numbers were 2, 4, and 1 respectively). Hence, the three categories were merged into one, called “Others”.

The calculations for Question 25 (formal coordination before the outbreak) are shown in Table 4-10.

Table 4-10: Tier connectedness calculations for Question 25

Connectedness -Q25	A	B	C	D	E
Ridit analysis	No. of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: D/Sum
Other: O	7	3.5	0	3.5	0.016

Federal: F	18	9	7	16	0.074
State: S	82	41	25	66	0.306
Local: L	109	54.5	107	161.5	0.748
Sum	216				

The calculations for Question 26 (formal coordination during the outbreak) are shown in Table 4-11.

Table 4-11: Tier connectedness calculations for Question 26

Connectedness-Q26	A	B	C	D	E
Ridit analysis	No. of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: D/Sum
Other: O	54	27	0	27	0.049
Federal: F	34	17	54	71	0.128
State: S	179	89.5	88	177.5	0.320
Local: L	288	144	267	411	0.741
Sum	555				

The calculations for Question 28 (informal coordination during the outbreak) are shown in Table 4-12.

Table 4-12: Tier connectedness calculations for Question 28

Connectedness-Q28	A	B	C	D	E
Ridit analysis	No. of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: D/Sum
Other: O	39	19.5	0	19.5	0.064
Federal: F	22	11	39	50	0.165
State: S	96	48	61	109	0.360
Local: L	146	73	157	230	0.759
Sum	303				

Table 4-13 below shows a sample of these values when they are substituted back into the original tables of the survey to quantify the tiered connectedness in question 28.

The three tables above (Table 4-10, Table 4-11, and Table 4-12) in combination provide an important result, which is that the lower the specific organisational tier level, the higher the tier connectedness. Hence, there is an inversely proportional relationship between the tier level of the origination and its tier connectedness. One reason for this is that local organisations seek links with upper-level organisations (e.g. state and federal) since such links are usually needed by virtue of hierarchical considerations. Another reason is that local organisations seek to connect to upper-level ones since they have to feed them with information and elicit resources from them.

Table 4-13: The Ridit values for tier connectedness populated for part of the data in Question 28

	A	B	C	D
1	Org-originate	Org-end	Level of Org end	Ridit value
2	HSFAC_HNE	LABS_HNE	L	0.75
3	AMB_SOU	NSW_H	S	0.31
4	AMB_SOU	AHS_A	S	0.31
5	AMB_SOU	DoHA_sockplie_coord	F	0.07
6	AMB_SOU	AMB	S	0.31
7	AMB_SOU	AQIS	S	0.31
8	AMB_SOU	Customes	S	0.31
9	NSW_H_Epi_Rsrch	CHP	S	0.31
10	NSW_H_Epi_Rsrch	PHU_A	S	0.31
11	NSW_H_Epi_Rsrch	EDs	S	0.31
12	NSW_H_Epi_Rsrch	AMB	S	0.31
13	RPAH_ED	NSW_H	S	0.31
14	RPAH_ED	PHU_SWS	L	0.75
15	RPAH_ED	SWSAHS	L	0.75
16	CDU_WS	PHU_WS	L	0.75
17	PHU_SW	CDU_WS	L	0.75
18	PHU_SW	Inf_Cntrl_WS	L	0.75
19	PHU_SW	GP_D_WS	L	0.75
20	PHU_SW	Councils_WS	L	0.75
21	PHU_SW	Labs_WS	L	0.75
22	PHU_SW	Eds_WS	L	0.75
23	HEMU_CDU	NSW_H	S	0.31
24	HEMU_CDU	AHS_A	L	0.75
25	HEMU_CDU	AMB	S	0.31
26	HEMU_CDU	SEMC	S	0.31
27	HSFAC_SWS	PHU_SWS	L	0.75
28	AGPN	DoHA_NIC	F	0.07
29	PHU_SW	CDB	S	0.31
30	PHU_SW	NSW_H	S	0.31
31	PHU_SW	Councils_WS	L	0.75
32	PHU_SW	GP_D_WS	L	0.75
33	HSFAC_HNE	PHU_HNE	L	0.75
34	HSFAC_HNE	NSW_H	S	0.31
35	GP_D_SW	PHU_WS	L	0.75
36	GP_D_WS	NSW_H	S	0.31
37	GP_D_WS	DoHA	F	0.07
38	PHU_GS	Councils_GS	L	0.75

Table 4-13 further emphasises the results and discussion for Table 4-10, Table 4-11, and Table 4-12 showing that organisations on the lower tier levels had higher connectedness. For example, compare the connectedness value of 0.75 for South West Sydney Public Health Unit (PHU_SW) with the value of only 0.07 for the Australian General Practitioners Network (AGPN). These results indicate that the lower the tier level of the organisation, the more it would try to connect to other tiers of organisations.

4.3.5. Calculating centrality

Centrality is the third independent variable used in the model. It is also one of the easiest measures in the ego networks since it is merely the number of ties that the ego has with alters. Hence, the procedure was to produce a count of each respondent' reported links for each of the three questions. Table 4-14 shows some of these measures for Question 26.

Table 4-14: Some of the centrality values for Question 26

	A	B
	Department-originate	Degree centrality - number of Links
1		
2	GP_NSW_imm	4
3	PHU_GS	9
4	Hospital_Bal_GP	3
5	NSW_H_Develp	13
6	PHU_GS_Inf_Surv	10
7	WS_Comm_H	2
8	HSFAC_HNE	13
9	Epid_WS	8
10	AMB_SOU	15
11	NSW_H_Epi_Rsrch	6
12	RPAH_ED	8
13	CDU_WS	4
14	Bankst_ICU	4
15	PHU_SW	14
16	HEMU_CDU	4
17	HSFAC_SWS	12
18	AGPN	8
19	PHU_SW	4
20	HSFAC_HNE	6
21	GP_D_SW	5
22	PHU_GS	1
23	NSW_H_Bio	21
24	ICPMR_CIDMLS	4
25	CHP	7

The sample of centrality in Table 4-14 shows that high centrality was not constrained to certain types of organisation. High centrality existed for state organisations such as the NSW

Ministry of Health bio-preparedness Unit (NSW_H_Bio) with centrality of 21, South West Public Health Unit (PHU_SW) Unit with centrality of 14, and Ambulance AMB_SOU with centrality of 15. This generally means that centrality is diversified based on the unit's need rather than its position in the hierarchy.

4.3.6. Calculating the independent variables

After the numerical calculations for each link and node were completed, it was necessary to normalise these values by calculating the value of each per respondent rather than per link, as was done in the previous sections.

Hence each of the tie strength and connectedness values for all the links of an ego were totalled, and the total was divided by the number of links of the ego. The formulae were:

$$Tie\ Strength = \frac{\sum_{n=1}^n link\ score}{N}$$

$$Tier\ Connectedness = \frac{\sum_{n=1}^n Tier\ connectedness\ score}{N}$$

Where N is the number of links for each ego.

A sample result after the calculations were performed for the three questions 25, 26 and 28 is shown in Table 4-15.

Table 4-15: A sample of the final calculations for Q28 showing the three independent variables sorted by ascending centrality

	A	B	C	D	E	F
1	number	org-originate	org-end	Degree centrality	Tie Strength	Connectedness
2	3147843	ICPMR	Lab_Hospt_O	1	0.541	0.356
3	3553658	RPAH_ED	Comm_serv	1	0.541	0.757
4	3593163	PHU_SW	Councils_WS	1	0.252	0.162
5	3687181	POP_H_WS	GPs_WS	1	0.252	0.757
6	3259726	CDB	Labs_A	2	0.681	0.557
7	3644246	PHU_SW	GPs_WS	2	0.252	0.557
8	3157803	ICPMR_CVR	NSW_H	3	0.820	0.624
9	3333690	NSW_H_Bio	PHU_A	3	0.727	0.624
10	3343240	PHU_SWS	Labs_SWS	3	0.541	0.356
11	3701613	PHU_NC	Immu_provi	3	0.252	0.490
12	3701781	AMB_Retriv	ICUs	3	0.252	0.526
13	3285663	CDB	AMS	4	0.750	0.508
14	3296106	PHU_SWS	HSFAC_SWS	4	0.681	0.557
15	3567155	RPAH_ED	RPAH_Pharm	4	0.678	0.508
16	3683064	AMB_SOU	Pharm_GUILD	4	0.539	0.410
17	3583350	RPAH_Phrm	Conc_H_Pharm	5	0.480	0.319
18	3255980	PHU_SES	Resp_dept	6	0.202	0.757
19	3268758	RPAH_Phrm	Liverp_H_Pharm	7	0.658	0.429
20	3653416	CDU_WS	Inf_Cntrl_WS	8	0.501	0.284
21	3480594	PHU_SW	PHU_O	9	0.694	0.414
22	3486586	HEMU_CDU	AQIS	10	0.738	0.597
23	3701510	POP_H_WS	Councils_WS	11	0.279	0.332
24	3338107	PHU_SWS	Councils_SWS	13	0.562	0.650

A quick deduction from

Table 4-15 shows that the three independent variables, centrality, tie strength and connectedness, were independent and not correlated with each other. This means that high centrality, for example, did not correlate with high tie strength or connectedness, and vice versa. As an example, compare respondents 3296106 and 3338107: the first had 4, 0.681 and 0.557 for centrality, tie strength and connectedness respectively, whereas the latter had 13, 0.562 and 0.650 for the same three values. This variability provides a good basis for using such variables and obtaining interesting outcomes.

After calculating the values for the independent variables, the next step was to do the same for the dependent variables.

4.3.7. Calculating the dependent variables for formal coordination (H1)

As discussed in Chapter 3, the dependent variable used as an outcome measure for Hypothesis H1 was Question 33 in the survey, which asked, “How long did it take the coordination to start after the outbreak was declared?” This was considered as an indication of the speed and robustness of the initiation of the coordination process.

Respondents were asked to respond in the framework of time, with options like “same day” (some chose “immediately”), “within one week”, “between one and two weeks” or “more than two weeks”. A small sample of the raw responses is given in Table 4-16.

Table 4-16: A sample of the answers to Q33 about the time before the coordination started.

Respondent	Answer to q33
3296106	1-2 days
3304691	Anzac day - same day
3313606	Same day we heard the news
3333690	Same day
3338107	Two days
3343240	About a week

3480594	A while
---------	---------

It was also necessary to change those responses to numerals and then use the Ridit analysis to define their final values.

The first step was to assign a numerical value to each time period, as shown in

Table 4-17 below:

Table 4-17: The numerical values assigned to time-period answers for Question 33.

Q33: Answers	Values
Same day	1
Immediately	1
Straight away	1
Within 24 hours	1
More than 1 day but less than week	2
1–2 weeks	3
More than 2 weeks	4

These numerical values were then used to calculate the Ridit value for each category of the responses (each time period).

Table 4-18: Ridit values for Question 33

Q33	A	B	C	D	E
Ridit	Frequency	1/2 column A	Cumulative frequency	Column B+C	Ridit: D/Sum
4	3	1.5	0	1.5	0.024
3	3	1.5	3	4.5	0.073
2	8	4	6	10	0.161
1	48	24	14	38	0.613
Sum	62				

Therefore, these values were assigned to each ego as per their answer. A sample is shown in Table 4-19.

Table 4-19: Ridit values for Question 33

Respondent	Ridit Q33
3296106	0.615
3304691	0.615
3313606	0.615
3333690	0.615
3338107	0.164
3343240	0.074
3480594	0.025

4.3.8. Calculating the dependent variable for informal coordination (H2)

Hypothesis 2 used Question 32 as the dependent variable to measure the effectiveness of the informal coordination. The question used a five-scale answer. The response categories are presented along with the number of answers in Table 4-20.

Table 4-20: The number of responses in categories for Question 32 in the survey

Q32	No of occurrences
Not needed at all	0
Can be used sometimes	2
Useful	9
Needed most of the time	13
It is essential!	32

Numerical values were assigned to these answers, as shown in Table 4-21.

Table 4-21: Numerical values for Question 32.

Q32: Rate imp of informal in bridging coordination gaps	q_32
Not needed at all	1
Can be used sometimes	2
Useful	3
Needed most of the time	4
It is essential!	5

The Ridit values for Question 32 are shown in Table 4-22.

Table 4-22: Ridit values for Question 32, the dependent variable for H2

Q32	A	B	C	D	E
Ridit	No of occurrences	1/2 column A	Cumulative B	Add C+B	Ridit value: N/Sum
Not needed at all	0	0	0	0	0.000
Can be used sometimes	2	1	0	1	0.018
Useful	9	4.5	2	6.5	0.116
Needed most of the time	13	6.5	11	17.5	0.313
It is essential!	32	16	24	40	0.714
Sum	56				

The results presented in Table 4-22 show that more than half of the respondents consider informal coordination to be essential (32 out of 56), hence resulting in the high Ridit score for this answer. These results are another indication of the ubiquitousness of the informal coordination.

4.3.9. Normality and statistics of data distribution

Table 4-23 lists some of the descriptive statistics for the social network variables, including means and standard deviations.

Table 4-23: Descriptive statistics for dependent and independent variables

	Range	Minimum	Maximum	Mean	Std. Deviation	Variance

Before outbreak						
Degree centrality	8	1	9	3.57	2.235	4.995
Tie strength	.907	.032	.940	.49376	.246068	.061
Connectivity	.674	.074	.748	.49631	.204253	.042
Formal during outbreak						
Degree centrality	20.000	1.000	21.000	8.52308	5.108534	26.097
Tie strength	.669	.083	.752	.51535	.201005	.040
Connectivity	.591	0.0150	.0.741	.0.5078	.0.19081	.036
Informal during outbreak						
Degree centrality	12	1	13	4.57	3.357	11.268
Tie strength	.79	.03	.82	.43408	.2635	.038
Connectivity	.60	.16	.76	.5158	.16347	.027

As part of the statistical analysis, it is important to investigate the distribution of data by visualising the graphs (e.g. histograms) and conducting statistical tests. This can also determine whether the distribution of variables of interest is normal or not. Besides inspecting the data via the histogram visual inspection, the Kolmogorov-Smirnov test of normality was conducted, and the results are shown in Table 4-24.

Table 4-24: Kolmogorov-Smirnov normality test

	Kolmogorov-Smirnov test			
	Measure	Statistic	df	Significance

Formal before	Degree centrality	.217	60	.000
	Tie strength	.143	60	.004
	Connectivity	.157	60	.001
Formal during	Degree centrality	.182	65	.000
	Tie strength	.119	65	.022
	Connectivity	.118	65	.025
Informal during	Degree centrality	.216	54	.000
	Tie strength	.178	54	.000
	Connectivity	.097	54	.200

Since the significance was less than 0.05, it seems that, in the tests where the distribution of the variable of interest was not normal, non-parametric tests should be applied. However, such results from the Kolmogorov-Smirnov tests are quite common (where $n > 60$). Also the histograms for the independent variables “degree centrality” ($mean=3.57$, $std. dev. =2.235$), “tie strength” ($mean=0.49376$, $std. dev. =0.246$), “connectivity” ($mean=0.496$, $std. dev. =0.2402$), as well as those for formal and informal coordination during the outbreak as per Table 4-23 are fairly normally distributed. Given these results, parametric tests such as t-tests, Pearson’s product-moment correlations and regression analysis may still be run, as there are no obvious outliers or extreme irregularities in the data distribution for these variables. Moreover, these parametric tests are robust enough to handle the variations in normality observed in the histograms in Appendix D.

4.4. Formal coordination hypotheses

This section reports the results relating to the hypotheses about formal coordination before and during the outbreak. Pearson’s correlation is a measure of how the variables are related and it shows the linear relationship and the direction of the relationship between the two variables. This was discussed in Section 3.9

4.4.1. Hypothesis 1a – Degree centrality and coordination

Hypothesis 1a. Degree centrality in formal structure is positively correlated to the perceived robustness of coordination before and during the outbreak.

4.4.1.1. Before the outbreak

To test Hypothesis 1a, a partial correlation test was applied to explore the relationship between the independent variable (degree centrality) and the dependent variable (coordination robustness). In addition, a t-test was applied to test for the significance between these variables. The results for coordination before and during the outbreak are presented separately. As discussed, Pearson's test was used in the correlation analysis. The calculated Redit values for both degree centrality and coordination start-off were used for the analysis. Table 4-25 shows the correlation results for before the outbreak.

Table 4-25: Correlation between degree centrality and coordination, for formal coordination before the outbreak

Control Variables		Coordination
Degree centrality before outbreak	Correlation	-0.147
	Significance (2-tailed)	0.262

The results from Table 4-25 show a negative but non-significant correlation ($\rho=-0.0147$, t-test significance two tailed $=0.262 > 0.05$ – the significance level). Hence, initially it can be said that there was no direct relationship between the centrality of an actor and its coordination robustness before the outbreak, as per H1a.

4.4.1.2. During the outbreak

The second correlation to be tested against H1a was for the period during the outbreak. The same tests were applied for the set of data derived from Question 26. The results are provided in Table 4-26.

Table 4-26: Correlation between degree centrality and coordination for formal coordination during outbreak

Control Variables		Coordination
Degree centrality during outbreak	Correlation	0.019
	Significance (2-tailed)	0.891

The results again show that no correlation existed (Pearson's coefficient $\rho = 0.019$, t-test = 0.0891 for 2 tailed). Hence, the centrality measure of the respondents either before or during the outbreak did not result directly in their initiating the response when the outbreak was announced. Therefore, H0 is still valid for both scenarios.

4.4.2. Hypotheses 1b – Tie strength and coordination

Hypothesis 1b. Tie strength in formal coordination is positively correlated with robustness of coordination

4.4.2.1. Before the outbreak:

Tie strength was calculated based on the frequency of communication between different nodes. The same Pearson's correlation and t-test as above were applied to test whether there was any correlation between the independent and dependent variables. Ridit derived values were again used. Table 4-27 shows the results of those tests for the phase before the outbreak.

Table 4-27: Correlation and t-test between tie strength and coordination before the outbreak

Control Variables		Coordination
Tie strength before outbreak	Correlation	0.065
	Significance (2-tailed)	0.621

The results from Table 4-27 ($\rho = 0.065$ and $t\text{-test} = 0.621$) again show no correlation between coordination and tie strength before the outbreak. This means that the null hypothesis is still valid, and tie strength with others before the outbreak did not indicate that coordination would be more effective during the outbreak.

4.4.2.2. *During the outbreak:*

Hypothesis 1b also predicted a relationship between tie strength and coordination during the outbreak. Pearson's correlation and t-test results are shown in Table 4-28.

Table 4-28: Correlation and t-test between tie strength and coordination during the outbreak

Control Variables		Coordination
Tie strength during outbreak	Correlation	0.288*
	Significance (2-tailed)	0.036

The tie strength correlation value ($\rho = 0.288$ and $t\text{-test} = 0.036 < 0.05$) indicates the significance and association between tie strength and robustness of coordination during the outbreak, and hypothesis H0 is invalid. In other words, the more frequent communication was with other organisations, the faster coordination was achieved.

4.4.3. Hypotheses 1c – Tier connectedness and coordination

Hypothesis 1c. Tier connectedness in formal coordination is positively correlated with robustness of coordination.

Tier connectedness measures the variance of a node's links between different jurisdictional and tier levels. The results are given here for the hypothesis before and during the outbreak.

4.4.3.1. *Before the outbreak:*

Correlation and t-test analysis were performed for tier connectedness before the outbreak and the results are shown in Table 4-29.

Table 4-29: Correlation and t-test between tier connectedness and coordination before the outbreak

Control Variables		Coordination
Tier connectedness before outbreak	Correlation	0.117
	Significance (2-tailed)	0.372

The results ($\rho = 0.117$ and t-test $0.372 > 0.05$) do not indicate any correlation between connectedness and coordination performance for formal coordination before the outbreak.

The same tests were performed for tier connectedness during the outbreak. The results are shown in Table 4-30.

Table 4-30: Correlation and t-test between tier connectedness and coordination during the outbreak

Control Variables		Coordination
Tier connectedness during outbreak	Correlation	0.387*
	Significance (2-tailed)	0.01

The correlation result ($\rho = 0.387$ and t-test $= 0.01$) shows that there was a significant and positive correlation between tier connectedness and coordination performance. This invalidates the null hypothesis and consequently validates Hypothesis 1c; meaning that during the disease outbreak tiers connectedness positively affected coordination performance.

4.4.4. Informal coordination hypotheses

This section discusses the second hypothesis H2 and its sub-hypotheses, concerning informal coordination during the outbreak.

Hypothesis 2a. Degree centrality of informal coordination is positively correlated with the ability to bridge coordination gaps.

This hypothesis predicts that the higher the number of informal connections of the actor, the more robust that actor's coordination will be, since these links will enable the actor to bridge coordination gaps or structural holes. Pearson's correlation analysis and the t-test results are shown in Table 4-31.

Table 4-31: Correlation and t-test results between degree centrality and informal coordination during the outbreak

Control Variables – informal		Coordination
Degree centrality during outbreak	Correlation	0.422*
	Significance (2-tailed)	0.006

The correlation and t-test results ($\rho = 0.422$ and $t\text{-test} = 0.006$) indicate that there was a direct correlation between the number of links and the ability to bridge across structural holes, as in trying to acquire more information and resources.

Hypothesis 2b. Tie strength of informal coordination is positively correlated with the ability to bridge coordination gaps.

This is where tie strength, as in the frequency of communication, was tested for any correlation. Table 4-32 presents the results.

Table 4-32: Correlation and t-test between tie strength and informal coordination during the outbreak

Control Variables – informal		Coordination
Tie strength during outbreak	Correlation	0.319*
	Significance (2-tailed)	0.019



The result shows that a correlation ($\rho = 0.319$ and t-test = 0.019) between tie strength and coordination performance in informal coordination. This means that the null hypothesis is invalid.

Hypothesis 2c. Tier connectedness in informal coordination is positively correlated to information sharing and bridging coordination gaps.

Would the existence of informal links to diverse organisations at different jurisdictional levels help to bridge the gaps? This is what this hypothesis addressed. Again, correlation was checked between the independent and dependent variables. The results are presented in Table 4-33

Table 4-33: Correlation and t-test between tier connectedness and informal coordination during the outbreak

Control Variables – informal		Coordination
Tier connectedness during outbreak	Correlation	0.417*
	Significance (2-tailed)	0.07

The result indicates a direct correlation ($\rho = 0.417$ and t-test 0.07), which means that the null hypothesis is invalid. Hence, there is an association between the ego initiating links with nodes at different jurisdictional levels and the use of these links to overcome gaps that might occur during formal coordination.

4.5. Effect of moderating variables on coordination

The organisational tier level was used as the moderating variable, as discussed in Chapter 2. The calculations were performed according to the methodology elaborated in Section 3.6 after using the Redit calculation technique to change the values from the original tier level as follows:

S=State

L=Local

O=Other (private/NGO/...)

After these calculations were completed, the moderating variable regression results were calculated only for those hypotheses, which had indicated a correlation between dependent and independent variables. All the results are presented in Table 4-34

Table 4-34: Moderating variable significance calculations

	Hypothesis against which moderating variable (MV) is tested	Standardised coefficient	T-test	Significance
1	Formal tie strength during outbreak (<i>H1b</i>) *MV	-0.357	-2.499	0.015
2	Formal connectedness during outbreak (<i>H1c</i>) *MV	-0.325	-2.025	0.047
3	Informal degree centrality during outbreak (<i>H2a</i>) *MV	0.432	2.089	0.042
4	Informal tie strength during outbreak (<i>H2b</i>) *MV	1.146	16.236	0.000
5	Informal connectedness during outbreak (<i>H2c</i>)	0.239	1.821	0.074

	*MV			
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The results show that for the following hypotheses the moderating variables were significant (significance <0.05) and affected coordination as the dependent variable:

***H1b* ($\rho =0.015$), *H1c* ($\rho =0.047$), *H2a* ($\rho =0.042$), and *H2b* ($\rho =0.000$).** On the other hand, the result for *H1c* ($\rho =0.074$) showed that the impact or effect of the moderating variable was insignificant.

Table 4-35 summarises the results for the moderating variables. These results are discussed further in Chapter 5.

Table 4-35: Hypotheses affected by the moderating variable

Theory	Details	Significance
H1b	Formal coordination, tie strength, during outbreak	0.015
H1c	Formal coordination, connectedness, during outbreak	0.047
H2a	Informal coordination, degree centrality, during outbreak	0.042
H2b	Informal coordination, tie strength, during outbreak	0.000

Table 4-35 indicates that the organisational tier level, such as whether a state or local organisation is concerned, when combined with tie strength and connectedness influenced formal coordination. With regard to informal coordination, tier level influenced coordination performance when combined with degree centrality and tie strength.

4.6. Forward to next chapter

Table 4-36 below summarizes the results of Hypotheses 1 and 2.

Hypotheses	Independent variable	Formal/Informal	Before /During	Coloration coefficient	Correlated
Hypothesis 1a	Degree centrality	Formal	Before	0.262	No
Hypothesis 1a	Degree centrality	Formal	During	0.0891	No
Hypothesis 1b	Tie Strength	Formal	Before	0.621	No
Hypothesis 1b	Tie Strength	Formal	During	0.036	Yes
Hypothesis 1c	Tier connectedness	Formal	Before	0.372	No
Hypothesis 1c	Tier connectedness	Formal	During	0.01	Yes
Hypothesis 2a	Degree centrality	Informal	During	0.006	Yes
Hypothesis 2b	Tie Strength	Informal	During	0.019	Yes
Hypothesis 2c	Tier connectedness	Informal	During	0.07	Yes

Table 4-36: Summary of Hypotheses statistical results in chapter 4

This chapter has shown the empirical results and calculations related to the hypotheses and has shown systematically that Hypothesis 1 is invalid for all the discussed network measures before the outbreak. Interestingly informal coordination has shown positive correlation for the three measures. Discussion and conclusions concerning these results will be discussed in the following chapter along with qualitative explanation that was communicated by the respondents.

Chapter 5

5. Synthesis and discussion

This chapter discusses and explores the results of the data analysis based on the theoretical perspectives that were introduced in Chapter 2. Hence, this chapter investigates the results of each hypothesis critically and explains the meaning of the empirical results by relating them to the hypotheses proposed in Chapter 2.

This chapter uses the existing theory of coordination in the context of disease outbreak rather than the general and abstract context. First, the initiation and cessation points of the outbreak coordination are discussed using qualitative – and statistical – feedback. The effects of different social network characteristics before the outbreak, namely tie strength, centrality and connectedness, on the formal outbreak coordination are considered, attempting also to deduce conclusions from the statistical results. Then the chapter follows the same discussion framework but this time during the outbreak. Since this is an emerging coordination, the network characteristics of each phase are briefly stated. Lastly, the discussion moves to the other facet of coordination, informal coordination during the outbreak, using the same methodology. To ensure consistency with the hypothesis and framework, tie strength, centrality and connectedness are also used in the informal coordination network, to investigate the influence of each on coordination.

5.1. Pandemic coordination process

Emerging coordination is not expected to have a set starting or finishing point. This might be due to the fact that each organisation is semi-autonomous, with different objectives and goals, as discussed in Chapter 2. Hence, the priorities of one organisation might not be the same as those of another. These different priorities will be reflected in the organisation's timeline and resource commitment. To capture such information in the context of a disease outbreak four

questions were embedded in the survey, namely questions 7 to 10 as described in section 3.5.2.3.

Organisations use different communication methods during a pandemic. Figure 5-1: Method of outbreak notification to initiate coordination shows the percentage of these methods at the particular time “when the outbreak is announced”. Electronic communication (email) followed by phone calls had the highest representation among those communication methods.

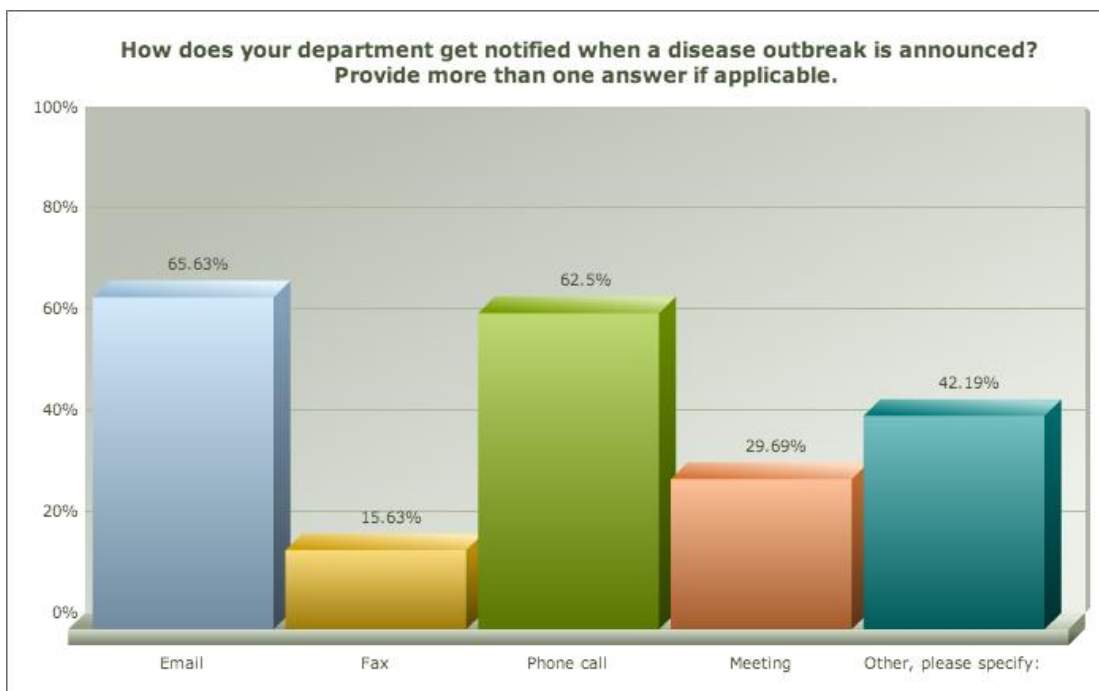


Figure 5-1: Method of outbreak notification to initiate coordination

Fax and face-to-face meetings were the least used methods. Even in the “others” category, 17 respondents defined it as teleconferencing (25.75%). This reveals the importance of modern electronic media and communication in signalling the initiation of the process. But what about when an outbreak has finished? Figure 5-2 shows the notification methods and their percentage when the outbreak is finished.

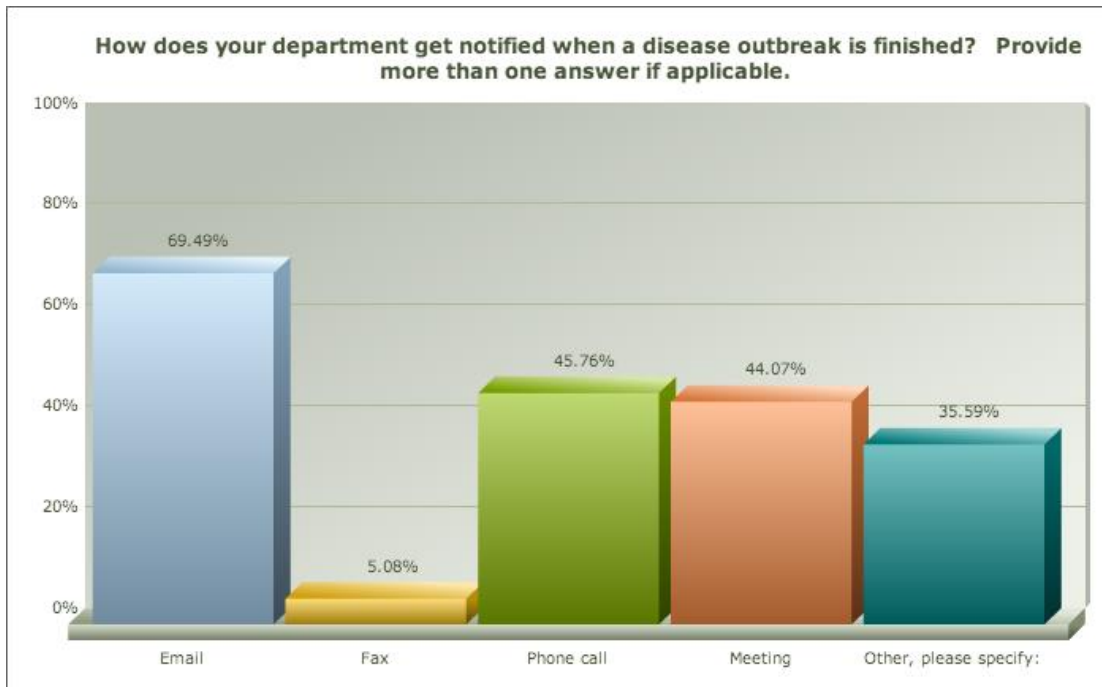


Figure 5-2: Method of outbreak notification to finish the coordination

Here also electronic communication takes precedence with emails being the most frequently used, followed by phone calls. Teleconferencing (part of the “others” category) was a communication method used to notify that the outbreak was over 21% of the time. This again reveals the importance of electronic and technological communication in such an environment.

Some respondents; however, stated, “The outbreak doesn’t need notification to stop working on it. It just tails off”. This means that case thresholds just continue to decrease until that number falls “under the radar” of the health monitoring system.

Figure 5-3 and Figure 5-4 shows consecutively the organisations that take the lead role in the notification process as to “when outbreak is declared and finished”.

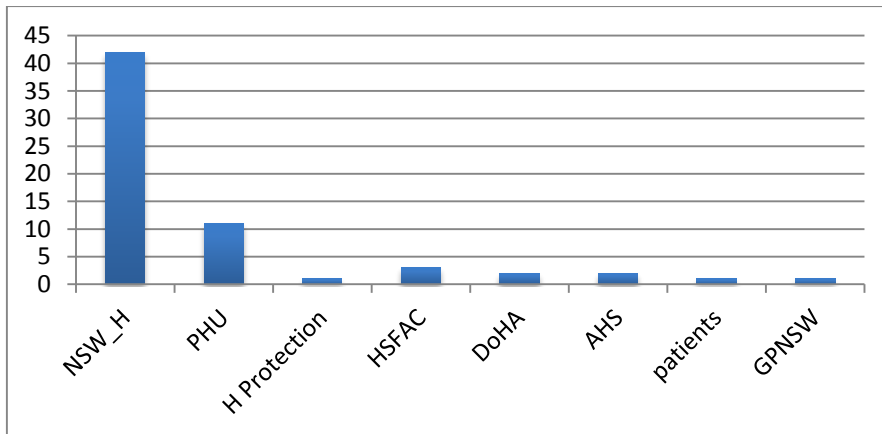


Figure 5-3: Notifying organisations when outbreak is declared

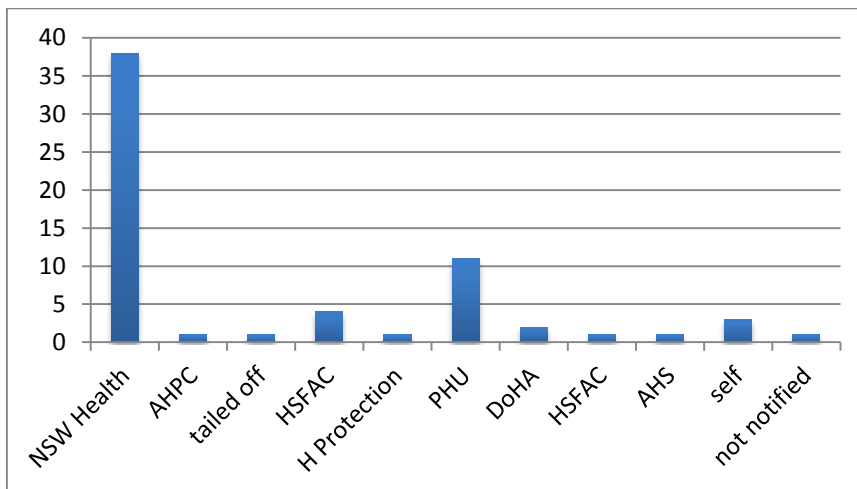


Figure 5-4: Notifying organisations when outbreak is finished.

Table Table 5-1 below lists the organisations in Figure 5-3 and Figure 5-4 along with their abbreviations

Table 5-1: List of organisations in Figure 5-3 and 5-4

Abbreviation	Organisation name
NSW_H	New South Wales ministry of health
PHU	Public Health Unit
H Protection	Health Protection
HSFAC	Health Services Functional Area Coordinator
DoHA	Department of Health and Aging (Federal)

AHS	Area Health Service
GPNSW	General Practitioners of NSW
AHPC	Australian Health Protection Committee

From the two figures 5-3 and 5-4, it is clear that NSW Health (now the Ministry of health) is the main notifier for initiation and termination of outbreak management. Yet on further examination, it seems that the closure phase is more decentralised than the initiation, with 11 notifiers compared to 8. In addition, it is evident that some organisations actually were never notified and others made the decision by themselves, including those that considered the outbreak to have just tailed off. One can conclude that even if emerging or open system coordination – as detailed in Chapter 2 – might be more controlled in its initiation, it tends to become more decentralised as the time passes and each agency needs to make its own decisions. This also might be linked to resource acquisition and need. That is, when the outbreak starts, the agencies involved will need resources, which are provided by the central agency. As the need for these resources decreases due to decline in the number of cases, then decisions tend to be more localised within the agency, hence enabling decentralisation.

5.2. Formal coordination before and during the outbreak and network theory

This section discusses and analyses the results presented in Chapter 4 regarding the formal coordination through which agencies interact and exchange information during the phases of *before* and *during* the pandemic. These two phases encompass most of the outbreak tasks, which were in turn discussed in section 2.6.2. These tasks usually start with horizon scanning, surveillance and detection, followed by diagnostic services as part of routine checks or in anticipation of detected cases. The following sections discuss the three network measures, centrality, tier connectedness and tie strength, and their influence on coordination performance.

5.2.1. Degree centrality and coordination

Prior to any disaster or incident, coordination usually occurs in accordance to the standard operating procedures or their organisational “alignment” as putting it in ambidexterity terms. Organisations rely on their strong ties to provide needed resources (Lin, 2002). This statement has proven to be true for disease outbreak coordination, as becomes evident in this and the next sections.

Previous research has claimed that the ego-network measure – centrality – is associated with performance (Burt, 1976, Rosenthal, 1997). Centrality depicts the degree to which an individual obtains information and controls benefits from non-redundant ties, and it is theorised to positively influence performance. Such assertions also were supported by the controlled experiment conducted by Bavelas (1950) in which individuals were given certain information to assemble in order to reach a decision, with the purpose of issuing orders to solve a puzzle. Bavelas found that centralised structures (e.g. star) performed better than decentralised ones (e.g. circle). It was suggested that the reason was that decentralised information floats better than centralised information. Numerous follow-ups were conducted to the Bavelas experiment to study the impact of different structures on communication and problem-solving performance. Unfortunately, the empirical studies did not produce consistent and cumulative results. In fact, some results were contradictory with each other and with the original Bavelas findings. For example, several researchers confirmed that the *star* structure performed better than the *all-channel* one (Leavitt, 1951, Mulder, 1959, Mohanna and Argyle, 1960, Cohen, 1962). On the other hand, other empirical research also determined that the *all-channel* structure was better than the star for simple task design (Guetzkow and Dill, 1957), while still others found no significant differences between the *star* and *all-channel* structures with regard to their performance (Shaw, 1954, Mulder, 1960).

Similar inconsistent evidence can also be found for “complex” task design. Heise and Miller (1951) found that the star structure showed better performance than the all-channel one in “complex” task design. However, other controlled experimental research showed that the all-channel structure was more conducive to performance than the star or wheel structure for “complex” task design (Shaw 1956; Shaw and Rothschild 1956; Shaw, Rothschild et al. 1957; Shaw 1958). Later, Mulder (1960), in another experimental set up for “complex” task design,

found no significant difference between the star and all-channel communication structures with regard to their perceived level of task-completion. In conclusion, there are empirical and experimental results that suggest that centrality can have positive, negative, or no effect at all on performance.

The results in the present study indicate that degree centrality did not influence performance. The correlation coefficients presented in Table 4-25 confirm that there was no significant correlation between degree centrality and performance.

5.2.1.1. Before the outbreak

The lack of correlation can be attributed to the fact that communication guidelines and procedures are adhered to before the outbreak actually starts. Organisations tend to communicate mostly with people and organisations that they usually communicate with, *according to what are in the books*. For example, respondent 5038216 reported:

“Well, we’re coordinating all of the time with ambulance and we’re coordinating all of the time with GPs. We’re coordinating all of the time certainly internally with specialists departments such as Respiratory and obviously Public Health.”

The same respondent then said:

“So before disease outbreak happens, we’re certainly communicating constantly with all of those departments which is ongoing – an ongoing sort of management. We would be with all of our own facilities.”

It also seems that before the outbreak, health workers tend to focus on increasing their communication frequency rather than widening the spectrum of their communication. Referring back to section 2.4.4.1, network efficiency, it is not the number of direct links from one node that increase efficiency, it is rather the number of total links as compared to the number of alters. For example, if four links connect to four alters who in turn connect to another four each, this will be more efficient than having a total of 16 links to 16 alters, as per Figure 2-7.

Thus, if the links were well established and operated according to the standard operating procedures or organisational alignment, then it would be sufficient. Creating more links does not tend to increase the coordination performance in the disease outbreak context. For example, respondent 4821701 reported:

“We were communicating with – probably more through the HASFAC that communication was coordinated and then the HASFAC would be responsible for disseminating that information to the other agencies and the same for the other agencies with getting that information.”

Also respondent 4181107:

“Talk to your own administration firstly, and I hope the Department of Health. Usually you coordinate with your institution and administration and by that time you hope that someone from the Department of Health would contact you and ask what you need.”

5.2.1.2. During the outbreak

During the disease outbreak, nodes definitely tend to increase their centrality by extending and initiating new links to new alters. There may be different reasons for this, such as providing or seeking information, resources, decisions, or to adapt to the new environment – being the second characteristic of ambidexterity. However, will this actually increase the efficiency of the coordination as a whole?

According to the correlation result, increasing centrality does not correlate with better performance during this stage either. The reason might be that many of these links are actually redundant, as respondent 3593163 reported:

“Duplication of information happened because PHU were also getting information from hospitals and sending it to the state. It was a mess. Infection control people used to give us information and we sent it to the bunker. They collated info from ICU – Intensive Care Unit - ... And sent to us, we aggregated them and sent them to the bunker. We sent copy to (PHU)...It wasn't a disaster so the communication was bad; the chain of command was not followed. It wasn't a disaster as such.”

Also respondent 3910135:

“We get information from multiple channels; I will get the same email six times per day. From PUH, NSW Health, etc...There were lots of emails flowing around.”

This finding contradicts the findings of Bavelas findings in the controlled laboratory experiment, but conforms to the findings of Guetzkow and Simon (1955) that decentralised structures work better than centralised structures when tasks become more complex. Unlike the laboratory setup of those experiments, this study explores complex dynamic networks that evolved within a disease outbreak response. In such extreme and dynamic events, standard operating procedures cannot always be followed. These events require a dynamic coordinated system that can adapt to unanticipated and evolving conditions. In such situations, an individual alone cannot effectively handle tasks that are complex in nature. The same holds true when the central actors of any network structure are overwhelmed with many communications from the other actors in that structure.

This result suggests that decentralised structures (in terms of degree centrality) might perform better than centralised ones. A decentralised network structure can minimise the problems associated with a centralised structure of having a single point of vulnerability by modularising a centralised network into smaller stars connected with additional links. A decentralised structure provides a better opportunity for organisations to maintain self-reliance because emergency management personnel are adapted to working independently. A decentralised network can also make decisions more quickly, allowing the structure to react quickly to emergencies. An emergency manager can usually make a decision without having to wait for it to go up a chain of command, a feature that allows emergency agencies to react quickly to situations where fast action can mean saving lives. As well, networks in which a few actors have a high degree of centrality may induce increasingly centralised decision making, which in turn may have a negative influence on coordination performance. A decentralised network relieves some of the load of emergency managers when others are allowed to perform some tasks. Emergency managers can then spend more time on big-picture items and concentrate on the most important decisions. For example, respondent 4284390 reported:

“AHS: daily by email and weekly by teleconference, there was about 80-90 people in the teleconference which was awkward but we would manage. It was important because they

had direct access and needed someone authoritative like [Senior Health Director name omitted] which was valuable and gave recognition of what they were doing.”

These results suggest that before as well as during the outbreak, plans should not focus on increasing the centralisation of the personnel, as this does not necessarily lead to better pandemic management. Interestingly, some health workers were practising the same concept; respondent 4284390 reported:

“The communication lines existed but we escalated them when the pandemic was declared. In terms to forge new communication with groups, there was normal business communication and can’t see new communication being brought in.”

Also respondent 4045418:

“The organisations that we coordinated with are basically that I have said at the beginning, I didn’t feel any additional that we needed to speak to... but I didn’t find that there was new or unusual I didn’t talk to. There were pretty extensive networks across the whole of government so there wasn’t anyone new that I can recall. So it was all those that you had on the front page.”

5.2.2. Organisational tier connectedness and coordination

Zhiang (2002) was one of the few researchers who studied the concept of tiered connectedness as discussed in section 2.3.1.3 . He looked at the dynamics of how such connectedness worked in crisis and how organisations tried to extend their reach by initiating new links to different tiers based on their resource requirements and dependence (Blau, 1986). Such links are directional because they originate from one node and extend to another. Zhiang concluded that local nodes rely on their strong ties to provide resources to local communities in crisis. However, when they realise that their resources are insufficient, they will activate their ties to the upper tier level – state level in this case – so they can coordinate and acquire more resources. If the need persists, then both state and local governments will activate or strengthen their weak ties to the federal level so to coordinate more resources. Kutu and Hossain (2010) correlated connectedness with increased coordination, as that will increase the quality of information and accessibility to it during emergency.

The empirical results presented in section 4.4.3 show that “*before the outbreak*” tier connectedness is not correlated to coordination performance. This is consistent with Zhiang’s results, in that the organisations rely on their own resources first and hence do not need to coordinate to obtain additional resources. An explanation for this behaviour is that extra communication needs resources by itself; hence, at times of less need they tend to commit their current resources internally and preserve them to deal with tasks on hand, rather than utilising their resources to service communication channels. Also before the outbreak, much coordination will be about exchanging potential case information, informing the public, surveillance, etc. ... These are usually standard communication protocols.

Yet when “*outbreak starts*”; tier connectedness is correlated positively with coordination performance. In other words, the more organisations connect to “*one tier up*” nodes, the better they will coordinate. This might be obvious due to many reasons; the main one is that usually those “*one-tier-up*” organisations are expected to have more resources. Local level organisations need to connect to state level ones that in turn connect to federal level organisations to provision these needs.

There may be some cases in which a local agency is connected to many other local ones; this means that if it requires more resources it will need to arrange them from local agencies that in turn connect to the state level organisations.

Tier connectedness can also be designed so as to increase network efficiency, as discussed in the previous section. Hence, one authoritative node might step in to aggregate many links in order to save communication resources between lower level ones, as in this example from respondent 4821701:

“LABS: That was more done directly through Health Protection. We were really encouraged as Public Health units not to have each of the Public Health units ringing and harassing the LABS because they were so overwhelmed. So if there was anything specifically that we wanted we did it by Health Protection and they just had one person who liaised with laboratory.”

Due to some previous relationships, different tier connectedness might also help organisations solve issues that are outside their jurisdiction, as respondent 3662303 explained:

“Our relationship with 3M and other private bodies has helped a lot because org_x [name changed] didn’t pay their bills so the private companies wanted to stop their supply.”

Health professionals were aware of the concept of connectedness and they used it when they needed it, as per respondent’s 4284390 comment:

“The communication channels were there but haven’t been really used. The communication lines existed but we escalated them when the pandemic was declared.”

As expected, connectedness can also be used for cross-jurisdiction coordination, as explained by respondent 4821701:

“...even asking for assistance from their agencies [Food Authority] if it’s something outside our jurisdiction like inspections of premises”

The result is that Hypothesis H1c is not valid before the outbreak but is valid during the outbreak. A practical implication would be that during the outbreak, coordination could be enhanced by incorporating formal one-tier-up connectedness.

5.2.3. Tie strength and coordination performance

Tie strength was defined as the frequency of communication between the nodes during the coordination process. Tie strength is indicative of the quality of the relationship between two nodes. Several studies have focused on the strength of network ties as a source of different kinds of information exchange (Hossain and Kuti, 2010). This was first elaborated by Granovetter (1973a), who argued that strong ties connect individuals who have frequent encounters with each other and provide greater motivation for assistance . Strong ties strengthen trust relationships, which further enable divulging useful knowledge and information (Reagans and McEvily, 2003, Levin and Cross, 2004). The issue of the strength of ties has two angles, the first advocated by Granovetter (1983) when he argued that weak ties are a source of novel information; Burt (1992) added the second view, that weak ties are a source of competitive advantage due to controlling information flow. On the other hand, Krackhardt (1992) debated and provided empirical evidence that strong ties have a positive influence on performance.

In the disease outbreak context, as in any disaster situation, it is expected that high frequency of communication is needed and desired as an enabler of better communication and hence coordination.

Consistent with the previous network results, “*before the outbreak*” shows that tie strength does not influence coordination. The practical implication is that in the phase before an outbreak is announced, communicating every day or every week does not necessarily lead to better performance. This can be attributed to the fact that the communication patterns and context are still standardised in that phase. During that phase, messages are expected to be routine and informational only, and as such might not entail novel information requiring further collaboration.

However, “*during the outbreak*”, empirical results indicate that coordination performance is correlated with tie strength. Thus, communication frequency becomes an enhancer of collaboration. Frequent communication provides an ideal atmosphere for effective communication exchange. This also means improved access to information of better quality, which in turn enables health staff to perform their role better due to the information sharing that needs to be turned into performable actions in this phase. Actions need resources that must also be mobilised distributed and utilised as quickly as possible, because of the expected impact on human life and welfare if delayed. Hence, the results of this study indicate that more frequent communication means that organisations perform their role better, leading to improved access to and distribution of resources. It should also be noted that the frequency of communication was not rigid all the time. When the impact of the pandemic decreased, health workers reduced their communication frequency, as some examples from the respondents’ answers show. Respondent 4045418 stated:

“During the pandemic, to start with we met daily, every business day so we didn’t meet on the weekend, every two or three weeks then we dropped to three times per week after two months and then we dropped back to once per week. And then probably from September on we dropped to once per month to finalise the transitioning back to normal.”

Respondent 4259129 said:

“During the contain phase the information were passed quickly and communication intensified.”

Such communication also helped organisations to build and maintain situational awareness and to build a better understanding of the big picture, which is vital when dealing with large outbreaks such as H1N1. An important example of the importance of quick and frequent communication is the dissemination of case definitions. Case definition is the set of criteria under which patients with ILI (influenza like illness) are considered as patients – also called cases – and admitted to the case management system. This has consequences for resource allocation (hospital or ICU beds, nurses, medication, ventilators, etc.), and also for the pandemic reporting and statistics. It is essential, therefore, that case definition be unified across the whole geographically dispersed and multi-specialised health management system (hospitals, border quarantine, emergency departments, GPs, and any place where patients might present themselves). This case definition continued to evolve and change during the outbreak, even sometimes on daily basis. This matter was resolved, for example, within the HNEAHS (Hunter New England Area Health Service) by increasing the frequency of communication from the HSFAC EOC (emergency operation centre) to the front line (being EDs, GPs, and medical centres). The case definition ended up being fully disseminated and deployed into medical management systems within 30 minutes, down from 2 days in the early phases of the outbreak. This was done by increasing the communication frequency and also entailed receiving confirmation that the end organisation was using the newly distributed case definitions. Respondent 5038216 said:

“But we are using case definitions as an example because that could change couple of times a day at one stage.”

Also respondent 5047657 stated:

“Pheromone communication worked well, where we contacted people after sending them the case definition which made them familiar with us and built trust relationship. This two-way communication was great.”

5.3. Informal and formal coordination during the outbreak and social network measures

This section discusses the results of Hypothesis H2 that investigates informal coordination during the outbreak through analysing the correlation results presented in Chapter 4. These results are linked to the formal coordination results discussed in the previous section. The aim is to highlight the dynamics of both types of social network that were formed during the outbreak. Informal communication “can be an invaluable tool for systematically assessing and then intervening at critical points within the informal network” (Cross et al., 2002). Formal and informal networks are distinct in theory, but heavily intertwined in organisational real-life. To understand the organisational culture, it is necessary to understand how both formal and informal structures interact. If the formal organisation is the circles and lines in the organisation chart, the informal networks are the lines that are not drawn (Uhr, 2009).

5.3.1. Informal communication before the outbreak

During the pilot study, we have interviewed some of the executives in the outbreak coordination bureaucracy and intervention planning and management. In addition, I was invited to participate in train disaster simulation exercise based on the “Emergo Train System “. The exercise spanned multiple health systems and providers in the Hunter New England AHS such as John Hunter Hospital, Public Health Unit, Emergency Department in John Hunter hospital, X-Ray department, and Ambulance service. Hot debriefing for all the participants followed this exercise. The pilot study clearly showed that there was a strong web of informal communication between that AHS personnel based on many factors, some of which are:

- Personnel working in remote areas remain in their geographical areas for long time, hence even formal relationships turn to informal ones after many years of working within the same locality albeit different positions.
- Many of these personnel have grown up in these remote areas and went to schools with the same people they are working with. Hence, these informal relationships are developed based on long history of trust makes them prevail over even the formal ones.

- The training exercises that takes place multiple times per year works as an introducer platform for any workers that yet doesn't know each other so that the informal relationships gets established them by open colleague introducing the new worker to another hence establishing the trust relationship.

5.3.2. Centrality and coordination performance

The informal communication network is a mapping of personnel that exchange work-related information or services outside the standard formal structures. These are surely expected to increase during crises as the need for collaboration surges. It is important to highlight the fact that there is no current theory in general that points to an optimal structure of the informal relations in an organisation (Krackhardt and Stern, 1988), let alone in a crisis situation and especially in the disease outbreak context.

The correlation results for the degree centrality of the informal network show that it is positively correlated with performance, as in section 4.4.4. That means that ego's performance is related to the number of links he or she establishes informally – outside the standard operating structure – during the outbreak as trying to adapt the organisational structure to the new situations.

This result is somehow expected, based on the understanding that informal networks are purposefully formed ones rather than being dictated by operating manuals and procedures. These links are built based on need and mutuality. The ego assess her or his requirements and needs, then outreaches intentionally to the alter that is capable of satisfying that need. Hence, the more links that egos create, the more it is expected they will be able to coordinate and acquire their needs. Using Krackhardt and Hanson's (1993) analogy "If the formal organisation is the skeleton of the company, the informal is the central nervous system driving the collective thought process, actions and reactions of the business units". Hence those nerves are activated whenever one part of the body wants to communicate a change (pain, pleasure), which again underlines the purposeful awareness of building such links and networks. Respondent 3333690 explained some of the needs that invoked informal communication:

"Informal coordination in pandemic? There is lots of information to process so if you get a

knowledgeable person that will save you going through going five different documents. There is time cost for informal communication – you can't talk to everyone. Informal helped the formal communication with groups that we already have links to."

"The informal network was heads-up that something formal is coming through. So it's used to get things done more quickly. So yes, it was efficient."

This explains the main difference between centrality in formal and informal coordination. In the formal coordination, centrality is pre-designed and assigned based on the wider organisational structure, which in many cases may be sub-optimal, and carries the burden of assigning resources to communicate that might not even necessarily affect coordination. On the other hand, informal coordination is a pre-mediated and conscious decision by the ego to increase the centrality stemming from the awareness of needs. Therefore, the ego will direct these links directly to the target (alter) that can help. Also egos will be willing to commit resources to this communication cost since they will assess that the reward is greater than the effort or cost.

Respondent 4288732 elaborated on this, saying:

"During the contain phase, the number of cases was increasing in isolation, people were not receiving their packages within couple of days so we used the informal channels to get this done. Informal used local knowledge."

"Basically it was when we needed more information or more resources. That's when we went off talking to people."

For example, the complaint about repetitive messages received in formal communication was discussed. When establishing an informal link, the ego does not build a link to an alter that will be source of information already received. If that occurs, then it is expected that the ego will later sever that link and move to another one, as there is no organisational commitment and obligation to maintain that inefficient and ineffective link.

5.3.3. Informal tier connectedness and coordination performance

Tier connectedness in informal coordination has the same role as in formal coordination, namely to communicate to other jurisdictional levels and acquire resources from higher-level

authorities. Informal tier connections might follow the same pattern as formal ones, as discussed by Zhiang (2002), where egos will look for their local resources and then try to connect to higher-level tiers as they need resources, information, and decisions. However, the difference between the two types of links is that informal ones are consciously built and maintained based on the health worker's prior knowledge of the alter, and that it is through this particular altar, objectives can be achieved. Usually this requires that both nodes know each other beforehand and that a mutual trust relationship exists between them.

The result for informal tier connectedness during the outbreak shows that it was correlated with coordination performance, similar to the formal coordination result. This is a logical result, especially for informal coordination, as informal networks are quick to grow and transmute according to changing circumstances (Groat, 1997). Connecting to other tiers means that the health workers are diversifying their links due to their own needs and requirements while trying to communicate more quickly at the same time. This is reflected in the words of respondent 3333690:

"We set up email list communication with the ID physicians, respiratory and ICU physicians. It was circumventing the hospitals so it was informal communication. We got some feedback that it was appreciated."

Also respondent 3662303 stated:

"Cut off 20 people you don't need to talk to."

One important note is that in a hierarchical world, such connectedness is not desired nor allowed. Yet in the networked organisational domain, informal tier connectedness is usually an accepted and tolerated practice to the extent that some contended that 70% of communication occurs at the informal level (De Mare, 1989). One important feature that stimulates informal tier connectedness is that informal networks transmit messages faster than formal ones (Davis, 1979). This means that information reaches its destination before formal communication does. Respondent 4366750 stated:

"Informal coordination is the way you solve problems quickly, in the formal hierarchy, you have to go up the hierarchy then across the hierarchy and then down, the military model. Simple things can take ages and mistakes ... happen in the communication in that sense, so for

example, if you want to know what is the capacity of the laboratory to do certain test, the PHU people are the ones that need to make sure that the test was done, so they need to talk to the ED on how the swabs need to be taken and if the issue's in the capacity, the PHU will talk to the labs as well. There was formal communication with the labs as they were part of the teleconference... Good informal coordination when you have a formal system and people know each other. In health systems people work in more networked arrangements, they used to work in informal professional hierarchy. The quality of the staff was very good."

Some respondents mentioned cross-jurisdictional informal communication. Respondent 4821701 stated:

"I think that would be all – or Victorian schools, but we've got schools along the border. We found that because the Melbourne Health Protection is centralised in Melbourne, they are quite often unaware of border issues. Albury is in Victoria, but it's one community. We did have some informal communication with the Victorian local governments or Victorian schools."

Also respondent 4045418 stated:

"Use telephone calls, if you get through to people. Also in the federal – Commonwealth- Department of Health and Aging DoHA I've got some contacts, also my counterparts in other jurisdictions, they weren't the CHOs , Chief Health Officer, – that's [names omitted] list – they were health emergency coordinators who were equivalent to the state HSFACs."

Respondent 4284390 stated:

"Informal: I instigated this process, constant communication with cross-jurisdiction, Queensland and Victoria, to compare what we are doing. We were much [more] prepared than any other state so we shared the information with them. So we did a weekly meeting and daily email of sending the summary of NSW critical care units."

Interestingly, informal connectedness worked jurisdictionally from the top- down because high-level management would want to obtain realistic information from the lower tiers, as respondent 5038216 elaborated:

“Usually the managers try to give you a rosy picture about what’s happening there. So in this case, I might need an independent, an informal channel that will gather information and report them directly about the actual, actual reports.”

5.3.4. Informal tie strength and coordination performance

Tie strength has been defined as the frequency of communication between two nodes, be it daily, weekly or monthly, as a representation of the quality of relationship between those nodes. Informal tie strength is also different in its dynamics from formal tie strength. It is based on needs and mutual agreement between both ends of the link. A health worker who initiates a link does so only for the sake of coordinating more resources or to communicate information – either outward or inward. The other party on the other side of the link is willing and accepting of this form of communication, due to mutual trust and benefit. Yet both of them know that this channel is activated in need and hence there is no requirement for it to be active on frequent basis, weekly or daily. This link will be used only when there is need to communicate or coordinate. Hence increasing or decreasing the frequency of communication should be directly related to the sense of necessity for coordination, and hence should reflect back to enhance coordination performance.

This explanation is further supported by the correlation result where the empirical values showed a direct correlation between tie strength and coordination performance. This result is congruent with the formal coordination result during the outbreak, in that the empirical results presented earlier show that formal coordination during the outbreak was also correlated to tie strength. Hence, both forms of coordination play a complementary role in achieving higher performance.

The following response provides an overview of how informal tie strength varied in accordance with requirements. This is reiterated by respondent 4284390:

“Informal: I instigated this process, constant communication with cross-jurisdiction, Queensland and Victoria to compare what we are doing. We were much [more] prepared than any other state so we shared the information with them. So we did a weekly meeting and daily email of sending the summary of NSW critical care units. Then I would include the other jurisdictions with that. Weekly meetings by teleconference. We rang the intensive care initially

once per day to get their status for the first two weeks because we hadn't the Flu Web setup, and made a summary that [was] sent out every day for two weeks including weekends until the Flu Web was set up."

Another response about intensifying of the informal channels when the outbreak started came from respondent 4284390:

"The communication channels were there but haven't been really used. The communication lines existed but we escalated them when the pandemic was declared."

On last note about the intra organisational communication during the outbreak. Meaning the communication that takes place within the same department. Most of the workers that I've interviewed were working in small departments. Therefore, it was expected, and actually they explicitly stated many times during the interviews, that all the workers within the same department or organisational unit talks with each other informally before, during or after the outbreak.

5.4. Moderating variable effect

After establishing the correlation relationships between the independent and dependent variables, the regression calculations for the moderating variable discusses whether the tier level of the organisation had an effect on the coordination performance. The results showed that this was the case. For formal coordination, the moderating variable effect was significant for both tie strength ($\rho=0.015$), and connectedness ($\rho=0.047$). This further supports Zhiang's finding (2006) that during crisis, communication with tier levels becomes important as organisations utilise their resources and try to acquire more from different tiers, hence the pre-established ties are strengthened.

As for the informal coordination, the regression results indicated that tier level conspired with tie strength ($\rho=0.042$) and degree centrality ($\rho=0$) to influence coordination. This also indicates that tier level played a role in strengthening and increasing the number of links that an organisation could utilise during the outbreak.

5.5. Conclusion and introduction to next chapter

This chapter looked into different relationships between network measures and coordination performance during the pandemic. The results showed that some network measures, namely connectedness and tie strength, played an important role both formally and informally to enhance coordination. Also degree centrality of the informal network positively affected coordination.

The next chapter concludes this dissertation by providing an overall summary of key findings and the implications of these findings for research and practice, future research directions, and limitations of this study.

Chapter 6

6. Conclusions, recommendations and future directions

This chapter summarises the results of the research in terms of theory, method and domain, along with the assumptions. Then I reflect on the research process and experience before providing some practical recommendations. The chapter concludes with suggestions for future directions.

6.1. Key findings

This dissertation contributes to the growing body of literature on social network theory and its use as a tool for analysing complex coordination relationships. By combining social network theory, coordination theory and complex systems theory, this thesis provides an interdisciplinary study in the context of a disease outbreak.

The results of the proposed hypotheses are presented in Table 6-1.

Table 6-1: Summary of the results of hypotheses

Hypothesis	Phase	Details	Result
H1a: Formal coordination	Before the outbreak	Degree centrality	No correlation with performance
H1b: Formal coordination		Tie strength	No correlation with performance
H1c: Formal coordination		Tier connectedness	No correlation with performance
H1a: Formal coordination	During the outbreak	Degree centrality	No correlation with performance
H1b: Formal coordination		Tie strength	Correlation with performance
H1c: Formal coordination		Tier connectedness	Correlation with performance

H2a: Informal coordination	During the outbreak	Degree centrality	Correlation with performance
H2b: Informal coordination		Tie strength	Correlation with performance
H2c: Informal coordination		Tier connectedness	Correlation with performance

6.1.1. Theory

Being multidisciplinary, this research taps into different theories, namely the theory of coordination, theory of social networks, and theory of complex adaptive systems. Those theories are combined to provide answers to the key motivating questions about inter-organisational coordination for pandemics.

Theoretically, the results presented in Table 6-1 clearly indicate that coordination is not only multidisciplinary but also dynamic. The first three rows in Table 6-1 demonstrate that network measures were not correlated with performance before the pandemic began. However, once the outbreak began, the network measures became relevant and usable to determine coordination performance, except for the case of centrality in formal coordination. These findings have implications for coordination, some of which are explained below through the lenses of this study.

Firstly, the theory of coordination has been further extended and inspected in different perspectives. It is no longer mechanistic but an open system of interacting agents embedded in a social system. Studying coordination in its two facets, formal and informal, further supports considering coordination to be dynamic. Formal coordination is based mostly on the standard operating procedures, and informal coordination grows organically within and between the nodes.

Secondly, the theory of social networks is used to analyse the coordination structure, first by mapping the nodes and their respective links, then by analysing the structure to determine its performance empirically. Three main measurements have been used: node centrality, tier

connectedness and tie strength. Combining coordination and social networks theories creates a complex adaptive system, such as that employed by Kapucu (2005) and Comfort (2001) for similar scenarios. This research did not try to simulate the coordination system using a controlled laboratory experiment so as to determine the relationship between network structure and performance, as Bavelas (1950) and Leavitt (1951) did. Instead, data was gathered from personnel who worked in the intervention of disease outbreaks, and the analysis provides an important contribution to the literature of both inter-organisational coordination and disease outbreak management.

It should be noted that there was no theoretical performance measure for the study of such coordination. Going back to Bavelas (1950) and Leavitt (1951), both of them used predefined performance measure such as solving a simple task in controlled environment. Considering coordination as interdisciplinary by nature enables the development of a new performance measure for each discipline. Hence this research developed a new performance measure for pandemic coordination, being the speed of response to the pandemic, represented by the start of the networked coordination structure. Then the abovementioned social network measures were calculated to determine if they influenced performance.

The empirical correlation results with the proposed performance measure speed of response to the pandemic shows that the results are consistent, providing further validity to the use of social networks theory to study coordination within complex inter-organisational scenarios.

6.1.2. Method

Since this research uses social network theory as a methodology for understanding and then analysing the coordination structure, it utilises relational data that employs node relations to explain group outcomes. The social network field is an emerging one, which is gathering momentum in different research disciplines, with inter-organisational relationships being just one of these. As discussed in Chapter 3, there are two methods for gathering network relational data, egocentric and sociocentric, with the latter being dominant.

In this research, the sociocentric method was used, based on a snowballing technique used to select the candidates for interview. It was decided to produce the data collection instrument in

two phases so as to ensure that it was reliable and valid. An exploratory questionnaire was first designed, which was used to further design the main instrument. This instrument collected both qualitative and quantitative data. Quantitative data was used to provide empirical validation or rejection of the proposed hypotheses, and the qualitative data provided in-depth views of causes, reasons, and context for the empirical results.

Surveys were conducted with about 70 respondents representing a wide range of professional and bureaucratic backgrounds and positions within the network that managed pandemic intervention. This combination of the sociocentric relational network, the qualitative and quantitative instruments, and the respondents interviewed, created a wealth of domain-related information about coordination related to the pandemic, as well as statistical data for validation.

Reflection on the methodology used to collect the data leads to the conclusion that this approach could also be applied in other coordination research that uses network theory as its analysis tool. Assuming that the researcher has little specific domain knowledge, he or she will need to gain familiarity with the domain by using an introductory questionnaire and interviewing a group of domain experts. Then, after these qualitative interviews, the researcher will be ready to construct the survey instrument and then to further verify it by some preliminary interviews with subject matter experts before beginning the main data collection phase. It is also preferable that the interviews be approached from both quantitative and qualitative perspectives if possible. This will further strengthen the researcher's domain knowledge and support the empirical results with reasons and causes.

A key contribution of this dissertation is that the triangulation methodology provided a theoretically motivated and practically verified survey, which met validity and reliability requirements and would be replicable in other domains in which coordination needs to be investigated. The analysis method used in this research also provided a replicable framework that can be used to validate data in other domain contexts.

6.1.3. Domain

This study began with a generic review of coordination and then progressed to investigating it in the disease outbreak domain. Theoretically, this study looked at how pandemics propagate, with the main focus on influenza in the recent H1N1 2009 outbreak. Then the research proposed two main theories about how to measure the performance of both facets of coordination, formal and informal. The domain of the research highlighted that pandemic coordination is an ongoing task that must be addressed both before and during the pandemic itself. Hence, the formal coordination was investigated before and during the pandemic. The results showed that network measures were not associated with performance before the outbreak. During the outbreak, however, network measures (centrality, connectedness and tie strength) correlated with pandemic performance. Another network measure, the tier level of the organisation, was found to moderate the relation between the independent variables (tie strength, connectedness and centrality) and the dependent one being the initiation speed of outbreak coordination.

This whole structure provides a complete framework that can be used in any outbreak context.

6.2. Implications of this study

This section discusses the practical implications and contributions of this thesis for identifying important properties of the proposed social network based modelling framework and the two coordination models (for both formal and informal networks) in the context of coordination during a disease outbreak. The implications of the research include building on the foundations of the new definitions of network theory and proposing an extension called “open systems coordination”. The implications also include the development of a social network based modelling framework as an analytical tool for “open system coordination”, thereby extending the applicability of current network theories. Contributions also include enhancement of the research methodology and demonstration of the modelling of coordination in the context of pandemic coordination. Practical contributions include guidelines for developing an efficient pandemic management network, acknowledgment of the importance of both formal and informal networks, and delineation of the patterns of usage of informal networks.

6.2.1. Research implications

The first research implication is that this dissertation has contributed to coordination theory by offering a generalised social network based modelling framework with domain-based performance measures. Coordination theory has developed to the stage where it is acknowledged as being interdisciplinary. However, most of the studies in the literature relating to coordination and coordination theory are based on a specific domain or environment, or else consider specific and limited types of interdisciplinary coordination, such as product and functional hierarchies or centralised and decentralised markets, as discussed in Chapter 2. Hence, modelling coordination based on a social networks framework that is applicable in diverse domains enriches coordination theory itself and provides more examples of interdependencies that exist between coordinating units. This in itself is one-step in the path of proposing new coordination models for “open system coordination” which reflect the complexities and probabilistic nature of present-day tasks.

Similar to the first contribution above, the second research contribution is the approach followed to model coordination. The tradition understanding of coordination has been one of “*command and control*” and “*top-to-bottom*”, even in the discipline of disaster management, which inherited this approach from the military context. By investigating in the context of a disease outbreak in a complex environment and a large geographical area, this investigation has provided a new perspective for understanding how the structure of a collaborative network of actors affects the performance of the overall network. This new approach for modelling coordination enriches the present literature of coordination theory.

Another contribution is extension of the applicability of present structural network theories of centrality, tie strength and connectedness (Bavelas, 1950, Granovetter, 1973c) to a new research domain, namely disease outbreak management as part of disaster management. This dissertation applies the concepts of these three network theories to analysis of the whole organisational network. The outcomes for centrality observed in this research are different from those reported by Bavelas (1950), who tested his theory in the controlled laboratory environment, whereas this research takes the approach of addressing a real-life problem in an open, complex environment. The results of this research also confirm that tie strength theory

has an influence on network performance (Granovetter, 1973c). Therefore, this research reveals a path for demonstrating the applicability of network theories.

Another contribution lies in the combination of both formal and informal networks within the coordination model. Most coordination studies have investigated one or the other of these networks at one time. This may well be the first time that both networks have been studied together, hand in hand, in any context, and more specifically in the context of management of a disease outbreak. Also this research shown that an important value of the ambidextrous organisational behaviour , being *adaptability*, is actually applied during the course of coordination by adopting the informal coordination techniques.

This study was made more interesting by virtue of its methods of data analysis. Both quantitative and qualitative methods were used, in both formal and informal networks providing empirical validation and in-depth reasoning. Moreover, deciding on a performance measure for informal networks in this research context was an innovation of itself. Again, to the author's knowledge, no such performance measure for informal networks had previously been developed; hence, this study used a comparative perception between formal and informal performance as a dependent variable. It will certainly be of interest to combine formal and informal coordination in further studies in different contexts and domains.

One more contribution lies in the data collection method. Data collection followed a middle path between the social sciences and the postpositive view. Hence, the data collection instrument was designed based on the domain context but using the network relational data collection methodology. That instrument also collected both formal and informal coordination information at the same time from the same respondents, providing a complete view of both networks and enabling comparison of the performance results of both networks.

6.2.2. Practical implications

The findings of this research can be practically applied to disease outbreak coordination within the following settings.

First and foremost, informal coordination should be considered as a normal and acceptable practice. A small number of respondents focused on following the hierarchical structure, but

the great majority used informal coordination as a normal fact of life. Such behaviour cannot and must not be challenged; rather it should be accepted and even encouraged within the total structure. Informal coordination can provide benefit in the following ways, as reported by many respondents:

- 1- Informal coordination gets results. It is a direct way to get something done.
- 2- It reduces bureaucracy.
- 3- It is a way of sharing knowledge.
- 4- Since it is a trusted network, it alleviates concerns for non-clinical people.
- 5- It produces more accurate information than formal coordination in many instances, such as about laboratory capacity.
- 6- It helps in following matters up; people know who to go to, to make sure necessary follow-up occurs.

This research also underlines the importance of networks for emergency staff working in complex environments. From the data collected and correlated, the importance of social networks cannot be discounted when it comes to coordination. It is clear that there was general awareness and consensus about social networks in the health system, as elucidated by the respondents.

The results emphasise the importance of quick communication (tie strength). However, the result for degree centrality is that it was not correlated with performance. Reading both results together, it is recommended that organisations should not increase their links to numerous other organisations, rather should increase the frequency of communication with key organisations and, in the event of an emergency such as a pandemic, increase communication frequency from monthly to daily or weekly if possible .

Further, diversifying the formal links between different tiers of organisations would help to ensure the communication of novel data between different tiers of organisations (local, state, federal, others).

Before any outbreak has occurred, when organisational plans are being designed for communication during outbreaks, these plans need not focus on increasing the number,

frequency or diversity of links. Nowadays, all information is shared online, and most of it does not require special communication channels.

On the informal side, all the social network measures (centrality, tie strength and tier connectedness) are important and have the potential to enhance performance. It is only necessary for authorities to facilitate the use of communication media and technology and health professionals will use it willingly and dynamically according to their needs. However, some activities that can build informal links should be planned, such as trans-unit training and inter-organisational social activities. These will foster informal networks, which can be utilised later during situations requiring coordination.

The findings from all the proposed hypotheses and regression models in this research make it possible for healthcare policy managers and professionals to validate the implementation of the organisational policies that have been suggested in regard to communication and coordination matrices. If a policy development authority follows the findings of H1, for example, then he or she can investigate the success of the implementation of the H1 findings by applying the correlation model that was used for H1. However, H2, the informal coordination hypothesis, might be trickier since there is no pre-set plan for this. Hence, it might be advised that the policy development or training authority go through the process of surveying the health organisations and professionals that are part of the disease outbreak management network, and then use the correlation method for H2 to test whether these links are associated with improved performance.

The survey itself can be considered a general contribution, since it was designed with no specific health organisation in mind. It can be applied in any health system that coordinates pandemic management in any geographical location (country, state) and also within any organisational format (more hierarchical, more networked, more decentralised).

A note of caution is needed in interpreting the implications and outcomes of this research for general health management systems. The implications stated are not necessarily reflective of the whole population of health personnel in Australia or around the world, but they are at least worthy of consideration within the context of a disease outbreak. The level to which these

implications may be generalised is considered in the discussion of limitations at the end of this chapter.

6.3. Future directions

An aim of this research was to develop a framework for modelling coordination in the disease outbreak domain and then to understand how the collaboration networks, links and structure affect the performance of the overall system. The research was built bottom-up to create a complex theory, implementation, methodology, data collection instrument, and measurement and performance package. Like any other research initiative, this research presents many opportunities for future development and study.

Firstly, the NSW Health system on which this dissertation is based is networked and decentralised by design. It would be interesting to perform a comparative study using the same model and constructs with a more centralised health system such as that in the state of Victoria in Australia. Comparison of the network measures and performance of both states would be illuminating.

Secondly, future research could consider each local area health service within NSW and compare it to other local area health services within the same state from the perspective of network structure and performance.

Thirdly, this research used as its performance measure (dependent variable) the speed with which a node joined the coordination network after the outbreak was announced within the state. To the author's knowledge, no global performance measure has yet been developed. For example, mortality and morbidity rates are used to count cases or deaths. Yet this cannot be used when modelling performance, since there are many demographic differences between different countries and states for the same disease. Therefore, any such rate will be biased and not applicable in comparative studies. It would be interesting to work with clinical and health management authorities to develop compounded non-biased, preferably universal criteria to measure performance in the coordination of disease outbreaks.

Fourthly, this research studied pandemic coordination during two major phases, before and during. Yet the "*during the pandemic*" phase can be further subdivided into more phases. In

Australia these are “*delay, contain and protect*” sub-phases. It would also be interesting to study the network patterns of each of those sub-phases and to investigate whether each phase has its individual performance measure or networking pattern, and how the positions of different nodes change across sub-phases. This would surely help practical coordination by informed changes of policy and designed plans appropriate to each sub-phase.

6.4. Limitations of the study

This research is still embryonic in its domain and, as with all such research, it has limitations that need to be recognised and identified. The first limitation is the degree of generalizability of the results. Data was collected from about 70 health professionals and a model was developed and verified based on these results. However it cannot be claimed that these results are universally applicable and acceptable. Reiterating what was stated in the previous section about future directions, more research using the same methodology needs to be conducted in similar and different demographics and environments so as to further verify or maybe modify some of the outcomes of this study before taking them into the world of practice. This study can be used as a starting point in the domain of large-scale pandemic coordination, study that to the author’s knowledge has not been previously attempted. Furthermore, the domain of this study is complex, unique and ever changing. Emergency management personnel work in dynamic complex environments, which also mean that every disease outbreak coordination is different from the others. Many new factors join the theatre; pathogen change is only one of them.

Another limitation of this study is that survey respondents were asked to remember events that in some instances had occurred one to two years earlier. This might cause some “*memory prejudice*” or motivational change through certain political considerations within organisations. Even though attempts were made through the survey design and interviews to alleviate such expected biases, it nevertheless remains important to evaluate the outcomes carefully and to reflect on the directions they might indicate for extra research validation.

One interesting note is that many of respondents asked if we wanted the links that emerged from their department or from themselves. We needed to emphasise that the formal communication is the departmental one and the informal one is the personal one. However, based on the responses, I assume that many of the respondents dealt with their personal entity and the deterrent one and hence the formal communication is a reflection of their own personal ones to some extent.

Finally, this research gained real value by surveying health professionals in Australia who are extremely busy and always dealing with complex tasks. Some respondents were very generous with their time, information, and remarks. It is hoped that the results presented here create new discussions and produce new, valued questions about the relationship between social networks and inter-organisational relationships in complex adaptive environments. However, it is still essential to state at this point that the model suggested in this research does not claim or have the ambition to explain all the variances that accounted for coordination, but rather to explore the theoretical proposition that social network factors are significant social constructs, which contribute to enhanced performance. This study used social network theory to study complex coordination, but it is acknowledged that other theories might be able to do the same from other perspectives. I am confident that as human knowledge and tools develop, better theories and research methodologies will also be developed to investigate these environments.

7. References

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Appendix A

Qualitative questionnaire

A- *Situation:*

- Outbreak: How is the outbreak detected?
- What is the information route from the time an infection is detected until containment is successful?
- What are the criteria to categorise a disease spread as being DO? (Cases threshold/ Are there different thresholds for different disease types?)
- What are the criteria for when a certain disease has been contained and a “back to normal” situation is declared?

B- *Coordination of actors:*

- **Inter-organisational:**
 - Organisations that coordinate together whenever a DO is declared
 - name/ role(intervention, communication)
 - Jurisdiction (community/local/state/Federal/private/WHO)
 - contact details
 - phase of mobilisation (is it called to join)
 - area of work
 - Where: Area/jurisdiction/service covered by each organisation. (some organisations might cover geographical area; some might cover professional service; others might cover information or communication services)
 - Workflow: how does involvement start, progress and finish for each organisation.
- **Intra-organisational:** In order to research informal networks: What are specific departments within these orgs that get involved? Same questions as above.
- **Individuals:** Individuals playing pivotal role in intervention and outbreak management and coordination. Name/contact/position/role before DO/role during DO/communication procedures or protocols.
- **Action:** An overview of how the coordination process (communication and intervention) takes place.
- **Is there a communication plan/protocol/standards?**
 - Is it predefined?
 - Does it change and how?
 - Are historical data available?
 - How does involvement start, progress and finish for each organisation?

C- *Processes for real-time decision support*

- How does the Decision Support Systems work, inputs /feeds /real-time data/ situational information?
- How is information added, processed and distributed to relevant parties (who, where, when and how)?

D- *Determinants for success coordination/intervention:*

- How do you measure coordination gaps?(e.g., are there WHO standards)
- What are the criteria to determine a successful intervention? (e.g. Do you use epidemiological measures, comparing against historical data, etc.)
- Any performance indicators?
- How do you measure intervention efficiency? (if it is different from success)
- Has any reflective analysis been done to check past and present efficiency of response?

E- Resource management: Resource optimisation is the direct outcome of the coordination process.

- Generally, what are the resources needed or exchanged during a disease outbreak?
- How are resources ordered?
- How are they received?
- Do you consider information exchange as a resource?
- Resource deployment: is it centralised or decentralised?
- How do you measure resource efficiency?
- How do you measure resource gaps?

Appendix B

The Survey

The University Of Sydney

Project Management Research Group.

Disease Outbreak Coordination Survey

This page is the Key for the survey. It contains explanations for the symbols that will be used in the survey tables. Please **tear this page off the survey**, and keep it near you as you are filling up the survey.

- 1- **Type of agency** : (I=International, F=Federal, S=State, L=Local, P=Private, O=Other)
- 2- **Training carried:** (M=Monthly, Q=Quarterly, S=semi-annually, A=annually)
- 3- **Frequency of communication:** (W=weekly, M=monthly, S=semi-annually, A=annually)
- 4- **Communication type:** (IP=Providing info, IR=Receiving info, RR=Resource Request, RS=Resource Supply, M=meeting, FW=Field Work, O=other please specify)
- 5- **Phase:** (D=Delay, C=Contain, P=Protect)

To return the survey please contact *Fadl Bdeir*

Tel: 0414 968 401

Fax: 2 9351 8642

Email: fadl.bdeir@sydney.edu.au

Thanks and appreciate your contribution and support.

The University Of Sydney

Project Management Research Group.

Disease Outbreak Coordination Survey

Name: _____

Tel: _____

Email: _____

Section 1: About your organisation

This section asks general questions about your organisation which participates in disease outbreak coordination

*1)

Name of your organisation?

(Organisation might be like NSW public health, Western Sydney Public Health Unit...)

*2)

Which department or unit - within the organisation mentioned above- do you work?

*3)

What is your position within the department?

4
)

Which of the following activities describe the duties of your department / unit in dealing with disease outbreaks?

Choose more than one answer if applicable.

- Leadership and guidance
- Collecting information
- Information analysis and dissemination
- Training other organisations
- Epidemiology
- Detection (including Surveillance)
- Community education
- Emergency care (Emergency Department and Intensive care unit).
- Other, please specify:

5) **Does your department provide resources to others, please specify type of resource and other departments/organisations name:**

(resources like PPE ,Personal Protective Equipment; Vaccine, ...)

	Type of agency	Name of agency	Type of resource
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

6) **Do you employ external agencies during transport of any disease outbreak related equipment or material?**

(equipment transported like ventilators; material transported like samples, vaccines)

	Type of agency	Name of agency	What are the transported materials?
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

- 7) **How does your department get notified when a disease outbreak is announced? – Provide more than one answer if applicable.**

- Email
- Fax
- Phone call
- Meeting
- Other, please specify:

- 8) **Which organisation / department notify you that disease outbreak is declared?**

- 9) **How does your department get notified when a disease outbreak is finished? – Provide more than one answer if applicable.**

- Email
- Fax
- Phone call

Meeting

Other, please specify:

10)

Which organisation /department notify your department when outbreak is finished?

Section 2: Planning and developing policies

This section is about planning coordination before the Disease Outbreaks.

11) In your opinion, how important is it to have a prepared coordination plan to deal with disease outbreaks

Not important

Somewhat important

Good to Have

important

Very important

12) In case your department collaborated with other organisations / departments /units to develop the disease outbreak operating procedures; can you please list those organisations / departments /units?

Type of agency

Name of agency

1		
2		
3		
4		

7		
8		
9		
10		

14
)

In case you provide input to policy development for other departments/units/organisations. Can you please indicate which level you provide input to? - Provide more than one answer if applicable.

- Federal.
- State.
- Local.
- Your organisation only.
- Other, please specify:

Section 3: Internal Training:

This section is about internal training that might take place prior to Outbreaks

15) **Does your organisation conduct periodical internal training exercises on Disease outbreak management? (Internal means: not in conjunction with any other organisations)**

Yes No

16)

How often are these exercise scenarios conducted?

- Monthly
- Quarterly
- Semi-annually
- Annually
- Other, please specify:

17)

How many employees participated in the internal training exercises?

Section 4: Trans-unit Training

The section is about trans-unit disease outbreak training exercises that are conducted with other organisations/departments/units.

18) **Have your department / unit participated in joint training or exercises with other organisations / departments/ units:**

Yes

No

19) **Please list these organisations / departments and the period in which these training exercises were conducted?**

	Type of agency	Name of Agency	Training carried
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

20) Which organisation / department was leading the training or exercises?

--

21) How did you measure your preparedness after the training compared to what it was before the training?

- No difference
- Somewhat better
- Better
- Excellent

Section 5: Formal Coordination:

This section - and the one follows - are the main parts of the survey. This one discusses formal coordination with other organisations. Formal being coordination carried according to the formal reporting and communication lines.

22) Prior to any disease outbreaks Does your department communicate with other organisations/ departments about outbreaks?

Such communication might be exchanging information, sending or receiving updates about cases.

	Name	Organisation type	Frequency of communication	Communication
1				
2				

3				
4				
5				
6				
7				
8				
9				
10				

23 Which Organisations/departments / units do you coordinate with during any of the three phases of the disease outbreak?

Note: Use the last column to indicate the phase; if the coordination happened in more than one phase then use combination of the first letters of each phase like "DC" for delay/contain phases.

	Name	Type of agency	Communication frequency	Communication type	Phase - use more than one letter if needed (D=Delay,C=Contain,P=Protect)
1					
2					

3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

1 6					
1 7					
1 8					
1 9					
2 0					

24 Which organisations/ departments/units that you ***don't normally coordinate with*** (they are not) part of the coordination and communication plan), but needed to do that during the ***any of the three*** phases of the outbreak management?

Note: Use the last column to indicate the phase; if the coordination happened in more than one phase then use combination of the first letters of each phase like "DC" for delay/contain phases.

	Name	Type of agency	Communication frequency:	Communication type	Phase - use more than one letter if needed (D=Delay,C=Contain,P=Protect)
1					
2					
3					
4					

5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Section 6: Inter-organisational Informal communication and coordination:

Informal communication can be defined as the communication that takes place outside the standard hierarchy or channels in order to "get the job done" like when someone knows a person in another organisation or department, then he/she contacts that person directly rather than going through the normal channels . It is important to study this type of communication since it helps to understand how the real coordination really takes place besides the "blue print" one. This section deals with "Inter-organisational informal communication" i.e. with other organisations (outside your organisational boundaries)

2) Which other organisations/departments/units do you informally coordinate with during the any of the three phases of the outbreak management?

Reminder: This question applies for Inter-organisational boundaries.

Note: Use the last column to indicate the phase; if the coordination happened in more than one phase then use combination of the first letters of each phase like "DC" for delay/contain phases.

	Name	Type of agency	Communication frequency	Communication type	Phase - use more than one letter if needed (D=Delay,C=Contain,P=Protect)
1					
2					
3					
4					
5					

6				
7				
8				
9				
0				
1				
2				
3				
4				
5				
6				
7				
8				

2
6)

Which organisations that you ***don't normally coordinate with*** (they are not part of the coordination and communication plan), but ***needed to create informal*** communication channels during ***any of the three*** phases of the outbreak management?

Note: Use the last column to indicate the phase; if the coordination happened in more than one phase then use combination of the first letters of each phase like "DC" for delay/contain phases.

Department name	Type of agency	Communicati on frequency:	Communicati on type:	How many days the coordination started after outbreak.	Phase - use more than one letter if needed (D=Delay,C=Contain ,P=Protect)
--------------------	-------------------	---------------------------------	-------------------------	--	---

--	--	--	--	--	--

- 27) **How efficient was informal coordination in “getting things done” compared to formal one?**

Not efficient at all
 Sometimes efficient
 Efficient
 Efficient Most of the times
 Very Efficient

- 28) **At which stage of the coordination you realised the need for informal coordination?**

- 29) **How do you rate the importance of informal coordination in bridging coordination gaps?**

- It is not needed at all.
 Can be used sometimes.
 Useful.
 Needed most of the times.
 It is essential!

Section 7: Intra-organisational informal coordination

This page is about informal coordination that takes place within the same organisation (it might be another department or unit in your organisation) and is called Intra-organisational informal communication.

30
)

Which departments, within your organisation, do you informally coordinate with during any of the three phases of disease outbreak?

Note: Use the last column to indicate the phase; if the coordination happened in more than one phase then use combination of the first letters of each phase like "DC" for delay/contain phases.

	Department name	Type of agency	Communication frequency:	Communication type:	Phase - use more than one letter if needed (D=Delay,C=Contain,P=Protect)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Section 8: Coordination measures:

31) **How updated was the formal outbreak coordination plan that you had?**

Non Existent

- Old and obsolete
- Partially relevant
- Mostly relevant
- Up to date

32)

Please rate which communication methods were most effective:

(1 = least effective, 7 = most effective)

Land line phone	<input style="width: 60px; height: 40px;" type="text"/>
Mobile phone	<input style="width: 60px; height: 40px;" type="text"/>
Fax	<input style="width: 60px; height: 40px;" type="text"/>
Mobile Text message	<input style="width: 60px; height: 40px;" type="text"/>
Email.	<input style="width: 60px; height: 40px;" type="text"/>
Web portal	<input style="width: 60px; height: 40px;" type="text"/>
Others, please specify:	<input style="width: 60px; height: 40px;" type="text"/>

Comments:

33)

How long did it take the coordination to start after the outbreak is declared

- 34) **How long did you perceive for the implementation of the plan to be optimal after its initiation?**

- 35) **What are the additional resources did you use during the outbreak?**

- 36) **What are the main three errors/mistakes that were done (or usually happen) during the outbreak intervention please list from the most important to the least important?**

37)

Please list the three most important factors that informal coordination facilitated your work, from most to least important:

To return the survey please contact *Fadl Bdeir*

Tel: 0414 968 401

Fax: 2 9351 8642

Email: fadl.bdeir@sydney.edu.au

Thanks and appreciate your contribution and support.

Appendix C

Ethics approval documents

Below is the ethics application that was submitted to ethics committee:

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

Application Form for Ethical and Scientific Review of Low and Negligible Risk Research – New South Wales

Purpose of this form

The purpose of this form is to enable applicants to provide sufficient detail about the research project to allow the Human Research Ethics Committee (HREC) to make an informed decision about the ethical and scientific acceptability of the proposal.

HREC approval and authorisation by the Public Health Organisation are required for all human research projects prior to commencement.

Use of this form

This form must be completed by the Co-ordinating Investigator responsible for the conduct of the research project within the NSW public health system.

If you believe that the research project involves only low or negligible risk to participants and may be eligible for expedited ethical and scientific review, you must discuss the project with an HREC Executive Officer before completing this form.

If the HREC Executive Officer advises that the project is not eligible for expedited review, you must complete an application for full HREC review using the National Ethics Application Form (NEAF).

The HREC may request a full review using NEAF following assessment of your application for expedited review if it considers the risk to participants to be greater than low risk.

- Completing this form
- Submitting this form

Signing of the declaration by the HREC indicates that it has provided ethical and scientific approval for the project

1. Project reference**1.1. Project type**

- Single-centre Multi-centre
 Low risk Negligible risk

1.2. Project title

State the full title of the project.
 modelling disease outbreak coordination using network analysis

1.3. Name/ID of HREC reviewing the project

Select the name/ID of the HREC that this application will be submitted to.
 Hunter New England Human Research Ethics Committee (EC00403)

1.4. Site/s involved in this project for which ethical and scientific approval is being sought from this HREC

List all sites involved in the project and indicate the site/s requiring ethical and scientific approval from this HREC.

Site name: Hunter New England Area Headquarters Does the site require ethical and scientific approval from this HREC?:
 Yes No

1.5. Previous ethical review

Is this project being submitted to (or has it previously been submitted to) other ethical review bodies?
 Yes No

1.6. Peer review

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

Application Form for Ethical and Scientific Review of Low and Negligible Risk Research – New South Wales

Purpose of this form

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1. Project reference**1.1. Project type**

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Site name: Does the site require ethical and scientific approval from this HREC?:
 Hunter New England Area Headquarters Yes No

1.5. Previous ethical review

Is this project being submitted to (or has it previously been submitted to) other ethical review bodies?
 Yes No

1.6. Peer review

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

Has the project been peer-reviewed?

Yes No

2. Project details

2.1. Project summary

Briefly describe in plain language the aim, background, participant group(s), method and possible outcomes.

The aim of the project is to research and study emerging coordination between different organisations that will intervene during disease outbreak.

The participants are : Fadl Bdeir PhD student. The University of Sydney. Liaquat Hussein , Associate professor, University of Sydney. Dr John Crawford University of Sydney. Chris Kewely , Director, Nursing & Midwifery Services and HSFAC Hunter New England Health . Jenny Carter Manager Patient Flow , Deputy HSFAC HNEH.

Method will start with interviewing managers in different organisations that deal with disease outbreak. Then filling a questionnaire about how organisations coordinated together to model the process.

Outcomes: Better intervention and coordination process reflected in less morbidity and mortality

2.2. Research methodology

Outline the proposed method, including project design, data collection techniques, data to be collected, number of participants, tasks participants will be asked to complete and analysis of results. Provide a justification of the proposed sample size, including details of statistical power of the sample, where appropriate.

The project will start by interviewing about 20 health workers , managers of different divisions for different organisations that deals or dealt with disease outbreak coordination. We will be using the snow ball effect to determine those managers. It will not include any interviews with the community or patients as they are outside the scope of the project.

Data to collected:

- name of organisation/division
- normal role in business days.
- type of work during disease outbreak.
- which organisations do you coordinate with during disease outbreak.
- what phase during the outbreak cycle do you coordinate with these organisations.
- discussing existing communication plans and systems - for outbreak scenarios.
- resources management and distribution.
- Better coordination mechanisms.

Participants will be asked to ask such questions. Then a larger sample of organisations will be taken where participants will be asked to fill a survey that also asks for such information.

sample size is based on that the area has a limited number of agencies (organisations) that can coordinate together during outbreak.

2.3. Likely benefits of the project for the participants, institution and/or community

This project is expected to provide better coordination modelling that will enhance the coordination and resources distribution.

2.4. Actual or potential risk associated with the project

None. there will be collection or any exposure of any personal data.

3. Anticipated start and finish dates

3.1. Anticipated start date

State the date on which any study procedure or any part of the protocol is expected to be implemented.

27/10/2010

3.2. Anticipated finish date

State the date on which data analysis is expected to be completed at all sites involved in the project.

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

11/06/2013

4. Research personnel**4.1. Co-ordinating Investigator**

Title:	Mr
First Name:	Fadl
Surname:	Bdeir
Position:	PhD Student
Department:	Civil Engineering
Organisation:	The University of Sydney
Mailing Address:	The University of Sydney
Suburb/Town:	Darlington
State:	NSW
Postcode:	2006
Phone (business):	0293515229
Phone (mobile):	0414968401
Fax:	0293518642
E-mail:	fadl.bdeir@sydney.edu.au

4.2. Principal Investigator(s)

Do not complete this table if the project involves a single site as the Co-ordinating Investigator and Principal Investigator will be the same person.

Selected Site Not Set

Principal researcher / investigator

Title:	Mr
First Name:	Liaquat
Surname:	Hossain
Position:	Associate professor
Department:	Civil Engineering - Project Management
Organisation:	The University Of Sydney
Mailing Address:	The University of Sydney- Building J05
Suburb/Town:	Darlington
State:	NSW
Postcode:	2006
Phone (business):	0290369110
Phone (mobile):	
Fax:	0293518642
E-mail:	liaquat.hossain@sydney.edu.au

4.3. Investigator(s)**5. Consent****5.1. Will informed consent be obtained from participants?**

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

 Yes No

If 'No', outline why participant consent will not be obtained
Since no personal data is collected.

6. Data and privacy**6.1. Is there a requirement for the project to collect, use, or disclose individually identifiable or re-identifiable data of a personal nature about participants without their consent?** Yes No**6.2. Storage and security of data**

Provide this information for each site which requires ethical and scientific approval from this HREC, listed in response to Question 1.4 of this form.

Site name	
Location of stored data	The University of Sydney
Format of stored data	Computer file
Arrangements for security of stored data	no identifiers , encrypted Hard drive, password protected.
Duration data will be stored	research duration , 3 years.
Method of destruction of data	deleting them and uninstalling the application.

6.3. Will individually identifiable data about participants be disclosed in the dissemination of research results? Yes No**7. Conflicts of interest****7.1. Are any 'conflict of interest' issues likely to arise in relation to this research?** Yes No

Last Printed: 20/10/2010 18:26:20

Reference:

Online Form

Declaration by the Co-ordinating Investigator, Principal Investigators, and Investigators (including students where applicable)

Project Title:	modelling disease outbreak coordination using network analysis
----------------	--

I/we certify that:

1. All information in this form is truthful and as complete as possible.
2. I/we have had access to and read the NHMRC *National Statement on Ethical Conduct in Human Research 2007* (National Statement).
3. The research will be conducted in accordance with the National Statement.
4. The research will be conducted in accordance with the ethical and research arrangements of the organisations involved.
5. I/we have consulted any relevant legislation and regulations, and the project will be conducted in accordance with these.
6. I/we will immediately report to the HREC anything which might warrant review of the ethical and scientific approval of the proposal, including:
 - a. Serious or unexpected adverse effects on participants;
 - b. Proposed changes in the protocol;
 - c. Unforeseen events that might affect continued ethical and scientific acceptability of the project.
7. I/we will inform the HREC and the Public Health Organisation, giving reasons, if the research project is discontinued before the expected date of completion.
8. I/we will not continue the research if ethical approval or site authorisation is withdrawn and will comply with any special conditions required by the HREC and the site.
9. I/we understand and agree that study files and documents and research records and data may be subject to inspection by the HREC, Research Governance Officer, the sponsor or an independent body for audit, inspection and monitoring purposes.
10. I/we will adhere to the conditions of approval stipulated by the HREC and will co-operate with HREC monitoring requirements. At a minimum annual progress reports and a final report will be provided to the HREC and the site.
11. I/we will only commence this research project after obtaining authorisation from the Public Health Organisation and approval from the HREC.

Name	Designation	Signature	Date
Fadl Bdeir	Student		20/10/2010
Liaquat Hossain	Principal investigator		20/10/2010

Ethics approval document is presented on the next page:



Health
Hunter New England
Local Health Network

10 March 2011

Mr F Bdeir
Civil Engineering
The University of Sydney
Darlington NSW 2006

Dear Mr Bdeir,

Re: Modelling disease outbreak coordination using network analysis (11/03/16/5.13)

HNEHREC Reference No: 11/03/16/5.13
NSW HREC Reference No: HREC/11/HNE/78
NSW SSA Reference No: SSA/11/HNE/79

Thank you for submitting the above protocol for single ethical review. This project was considered to be eligible to be reviewed as Low and Negligible risk research and so was reviewed under the by the Hunter New England Human Research Ethics Committee expedited process at an executive meeting held on **10 March 2011**. This Human Research Ethics Committee is constituted and operates in accordance with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research (2007)* (National Statement) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*. Further, this Committee has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review. The Committee's Terms of Reference are available from the Hunter New England Area Health Service website: http://www.hnehealth.nsw.gov.au/Human_Research_Ethics.

I am pleased to advise that following acceptance under delegated authority of the requested clarifications and revised Information Statement [**amend as appropriate**] by Dr Nicole Gerrard Manager, Research Ethics & Governance, the Hunter New England Human Research Ethics Committee has granted ethical approval of the above project.

The following documentation has been reviewed and approved by the Hunter New England Human Research Ethics Committee:

- For the Information Statement and Consent Form (Version 1.0 dated 31 December 2010); and
- For the Questionnaire (Version 2.0 dated 10 March 2011)

For the protocol: **Modelling disease outbreak coordination using network analysis**

Hunter New England Research Ethics & Governance Unit

(Locked Bag No 1)
(New Lambton NSW 2305)
Telephone (02) 49214 950 Facsimile (02) 49214 818
Email: hnehrec@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/research_ethics_and_governance_unit

Approval from the Hunter New England Human Research Ethics Committee for the above protocol is given for a maximum of **3** years from the date of this letter, after which a renewal application will be required if the protocol has not been completed.

The *National Statement on Ethical Conduct in Human Research (2007)*, which the Committee is obliged to adhere to, include the requirement that the committee monitors the research protocols it has approved. In order for the Committee to fulfil this function, it requires:

- A report of the progress of the above protocol be submitted at 12 monthly intervals. Your review date is **March 2012**. A proforma for the annual report will be sent two weeks prior to the due date.
- A final report must be submitted at the completion of the above protocol, that is, after data analysis has been completed and a final report compiled. A proforma for the final report will be sent two weeks prior to the due date.
- All variations or amendments to this protocol, including amendments to the Information Sheet and Consent Form, must be forwarded to and approved by the Hunter New England Human Research Ethics Committee prior to their implementation.
- The Principal Investigator will immediately report anything which might warrant review of ethical approval of the project in the specified format, including:
 - any serious or unexpected adverse events
 - Adverse events, however minor, must be recorded as observed by the Investigator or as volunteered by a participant in this protocol. Full details will be documented, whether or not the Investigator or his deputies considers the event to be related to the trial substance or procedure. These do not need to be reported to the Hunter New England Human Research Ethics Committee
 - Serious adverse events that occur during the study or within six months of completion of the trial at your site should be reported to the Manager, Research Ethics & Governance, of the Hunter New England Human Research Ethics Committee as soon as possible and at the latest within 72 hours.
 - All other safety reporting should be in accordance with the NHMRC's Safety Monitoring Position Statement – May 2009 available at http://www.nhmrc.gov.au/health_ethics/hrecs/reference/files/090609_nhmrc_position_statement.pdf
 - Serious adverse events are defined as:
 - Causing death, life threatening or serious disability.
 - Cause or prolong hospitalisation.
 - Overdoses, cancers, congenital abnormalities whether judged to be caused by the investigational agent or new procedure or not.
 - Unforeseen events that might affect continued ethical acceptability of the project.

Hunter New England Research Ethics & Governance Unit

(Locked Bag No 1)
(New Lambton NSW 2305)
Telephone (02) 49214 950 Facsimile (02) 49214 818
Email: hnehrec@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/research_ethics_and_governance_unit

- If for some reason the above protocol does not commence (for example it does not receive funding); is suspended or discontinued, please inform Dr Nicole Gerrand, as soon as possible.

You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained.

A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

Should you have any concerns or questions about your research, please contact Dr Gerrand as per the details at the bottom of the page. The Hunter New England Human Research Ethics Committee wishes you every success in your research.

Please quote **11/03/16/5.13** in all correspondence.

The Hunter New England Human Research Ethics Committee wishes you every success in your research.

Yours faithfully



For: Associate Professor M Parsons
Chair
Hunter New England Human Research Ethics Committee

Hunter New England Research Ethics & Governance Unit

(Locked Bag No 1)
(New Lambton NSW 2305)
Telephone (02) 49214 950 Facsimile (02) 49214 818
Email: hnehrec@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/research_ethics_and_governance_unit



Health
Hunter New England
Local Health Network

10 March 2011

Mr F Bdeir
Civil Engineering
The University of Sydney
Darlington NSW 2006

Dear Mr Bdeir,

**Re: Modelling disease outbreak coordination using network analysis
(11/03/16/5.13)**

**HNEHREC Reference No: 11/03/16/5.13
NSW HREC Reference No: HREC/11/HNE/78
NSW SSA Reference No: SSA/11/HNE/79**

Thank you for submitting an application for authorisation of this project. I am pleased to inform you that authorisation has been granted for this study to take place at the following sites:

- **Hunter New England Local Health Network**

The following conditions apply to this research project. These are additional to those conditions imposed by the Human Research Ethics Committee that granted ethical approval:

1. Proposed amendments to the research protocol or conduct of the research which may affect the ethical acceptability of the project, and which are submitted to the lead HREC for review, are copied to the research governance officer;
2. Proposed amendments to the research protocol or conduct of the research which may affect the ongoing site acceptability of the project, are to be submitted to the research governance officer.

Yours faithfully

A handwritten signature in black ink, appearing to read 'Nicole Gerrand'.

Dr Nicole Gerrand
Research Governance Officer
Hunter New England Local Health Network

Hunter New England Research Ethics & Governance Unit

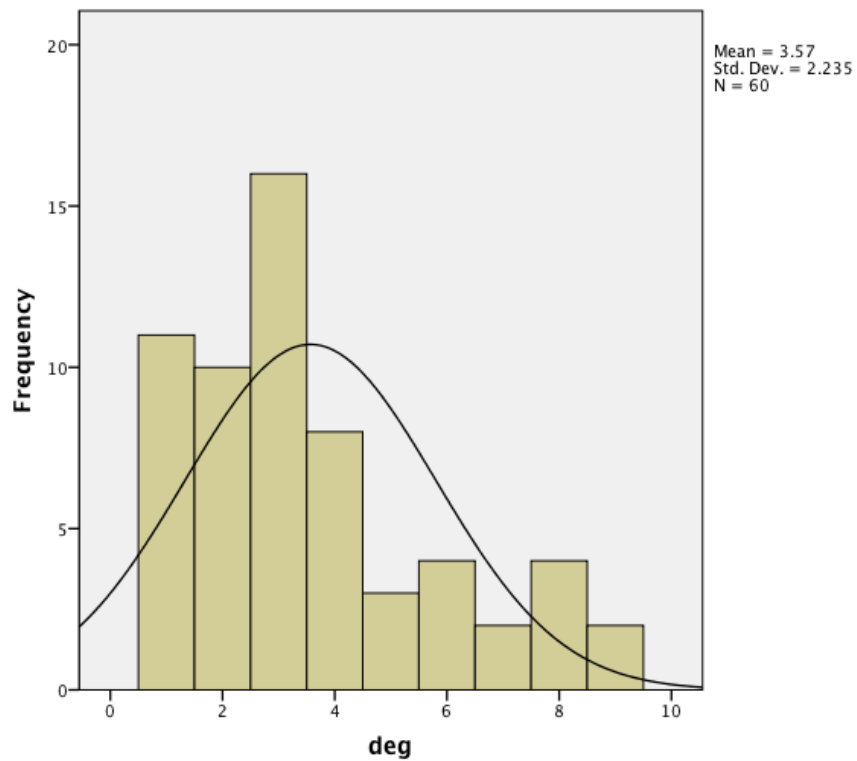
(Locked Bag No 1)
(New Lambton NSW 2305)
Telephone (02) 49214 950 Facsimile (02) 49214 818
Email: hnehrec@hnehealth.nsw.gov.au
http://www.hnehealth.nsw.gov.au/research_ethics_and_governance_unit

Appendix D

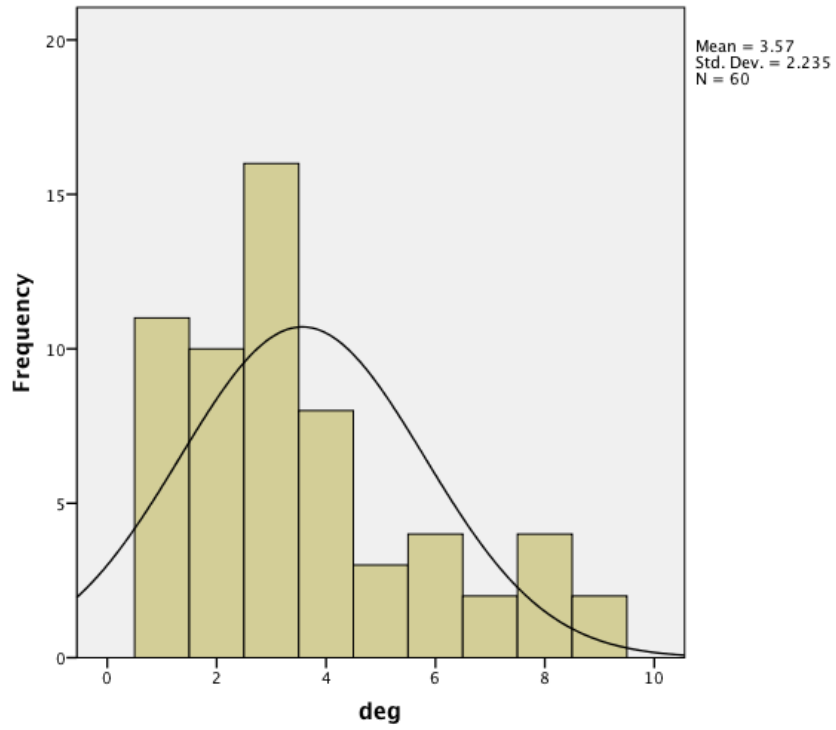
Histograms for independent variables:

Formal coordination before the outbreak:

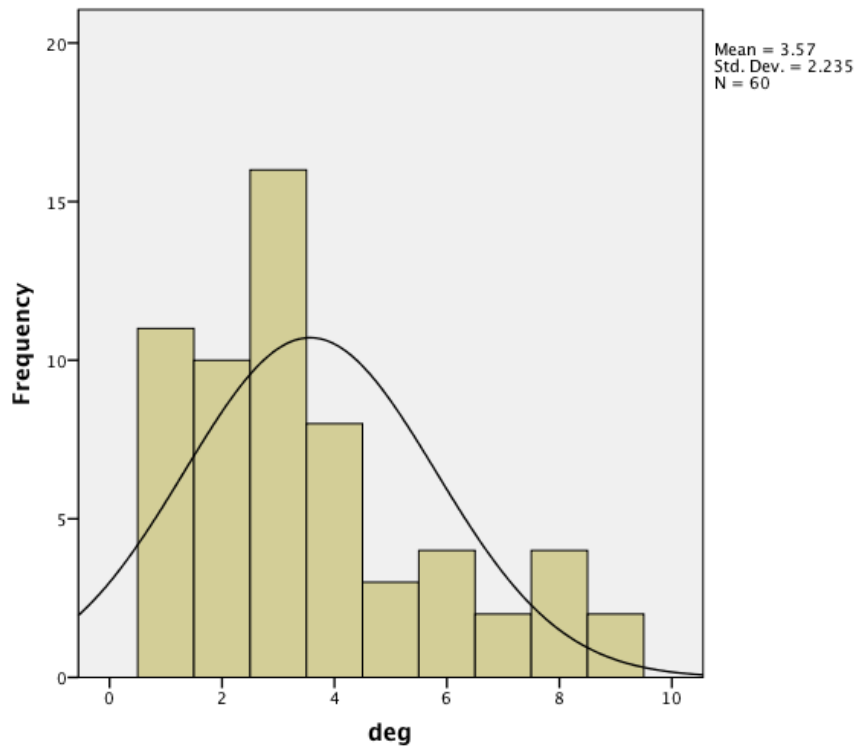
1-Degree centrality histogram:



2- Tie strength histogram:

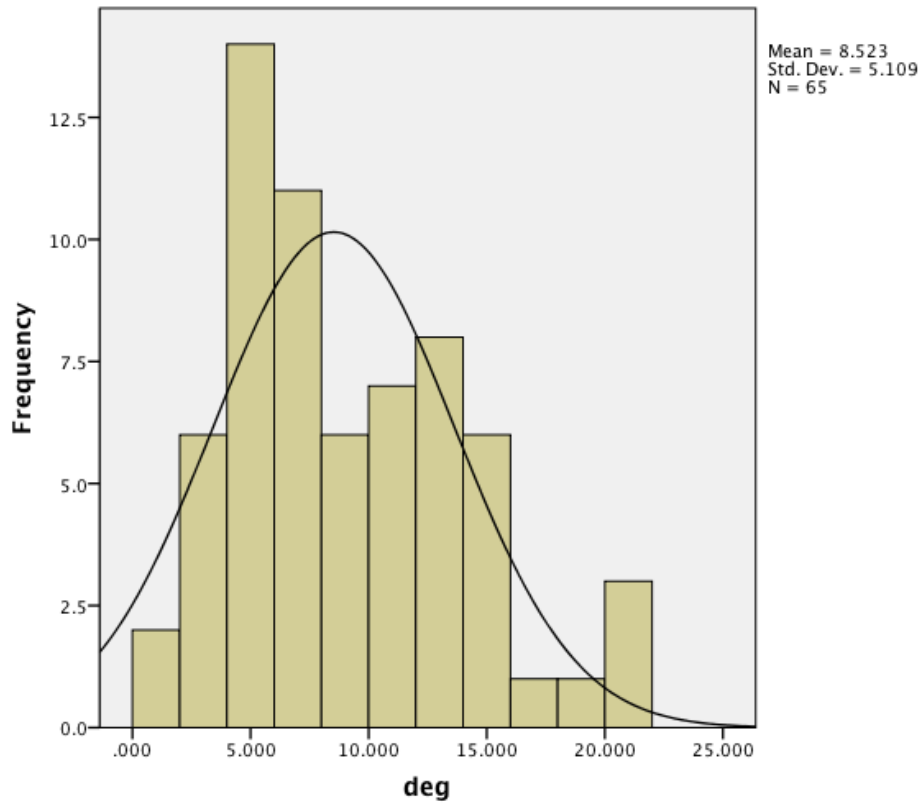


3- Connectivity histogram

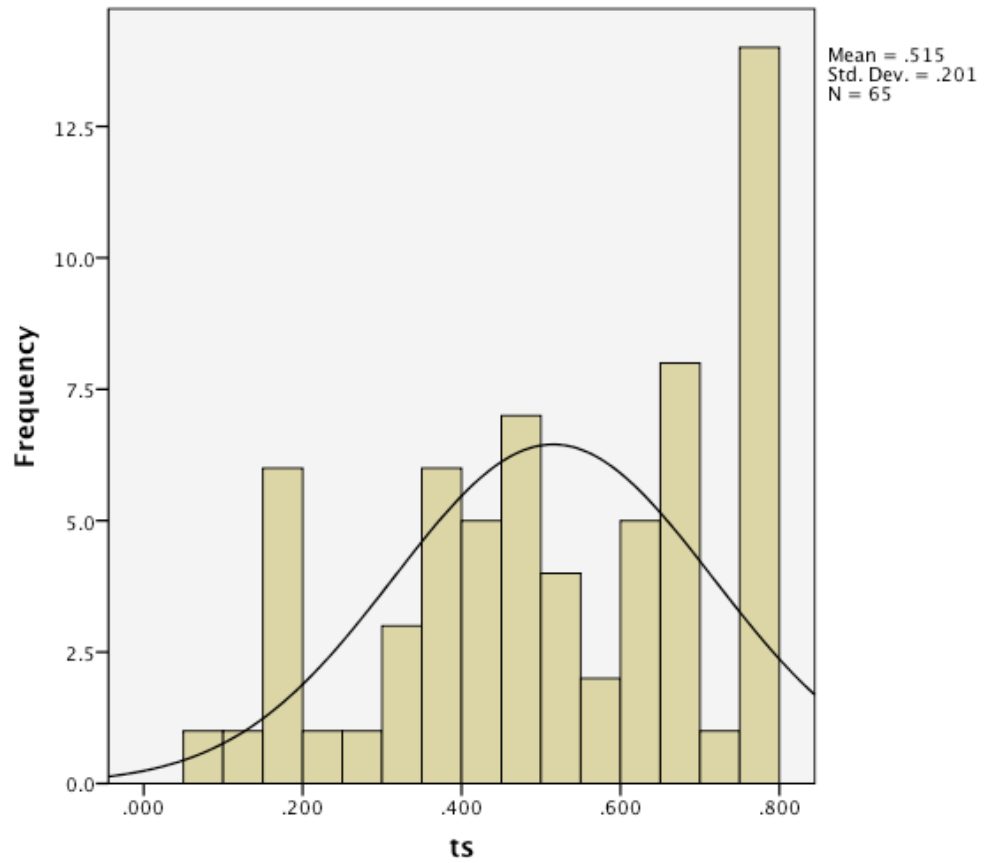


Formal coordination during the outbreak:

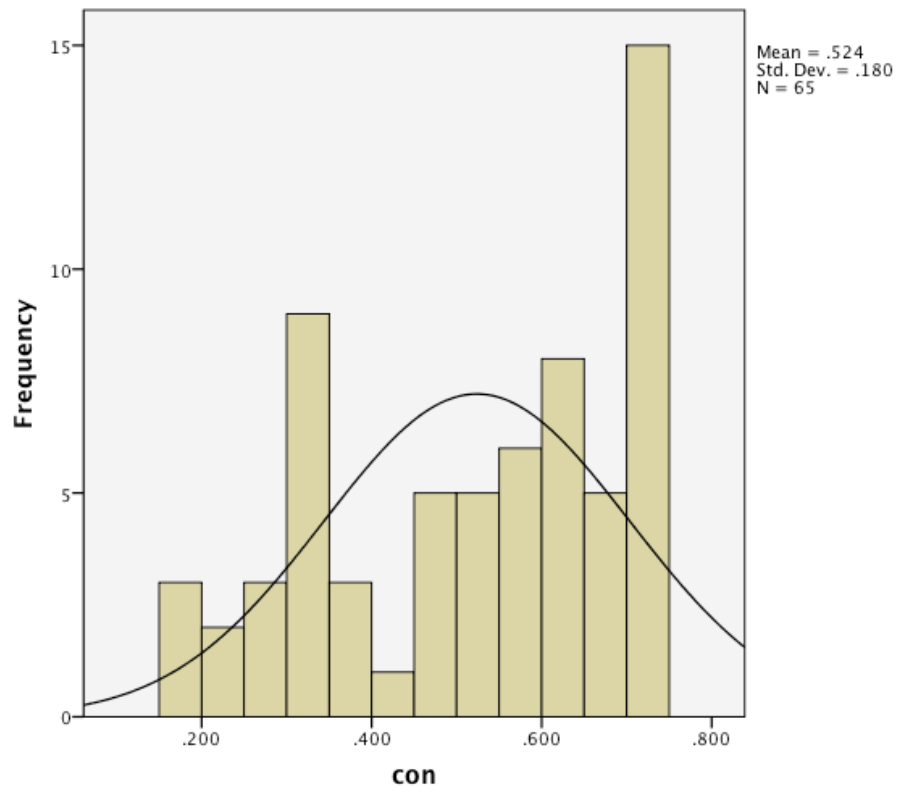
1- Degree centrality histogram:



2- Tie strength histogram:

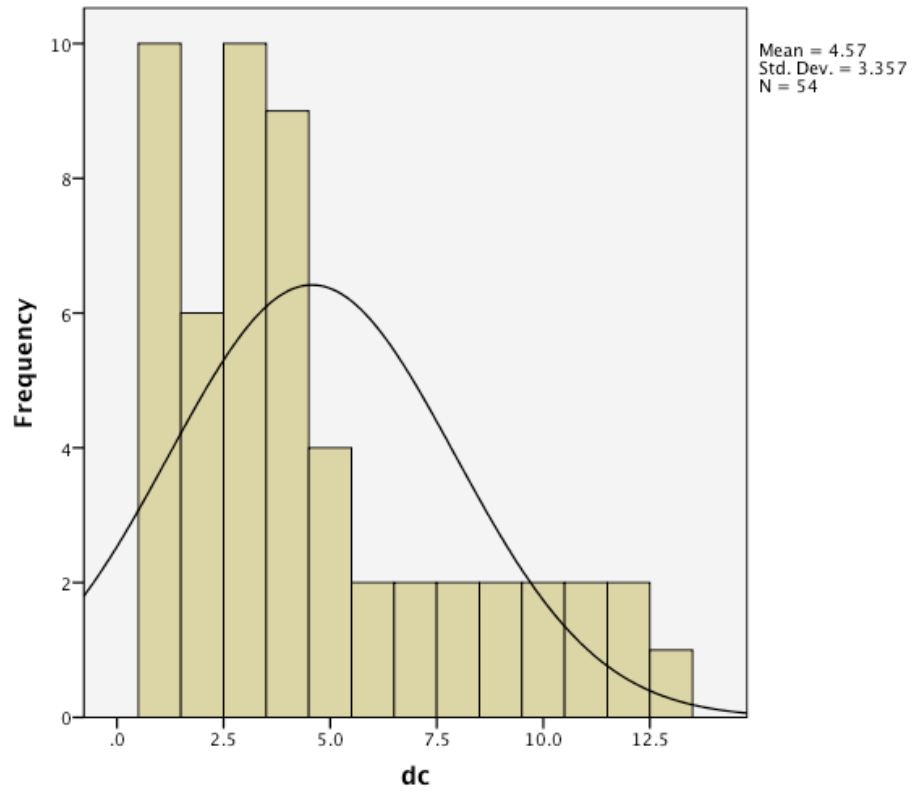


3- Connectedness histogram:

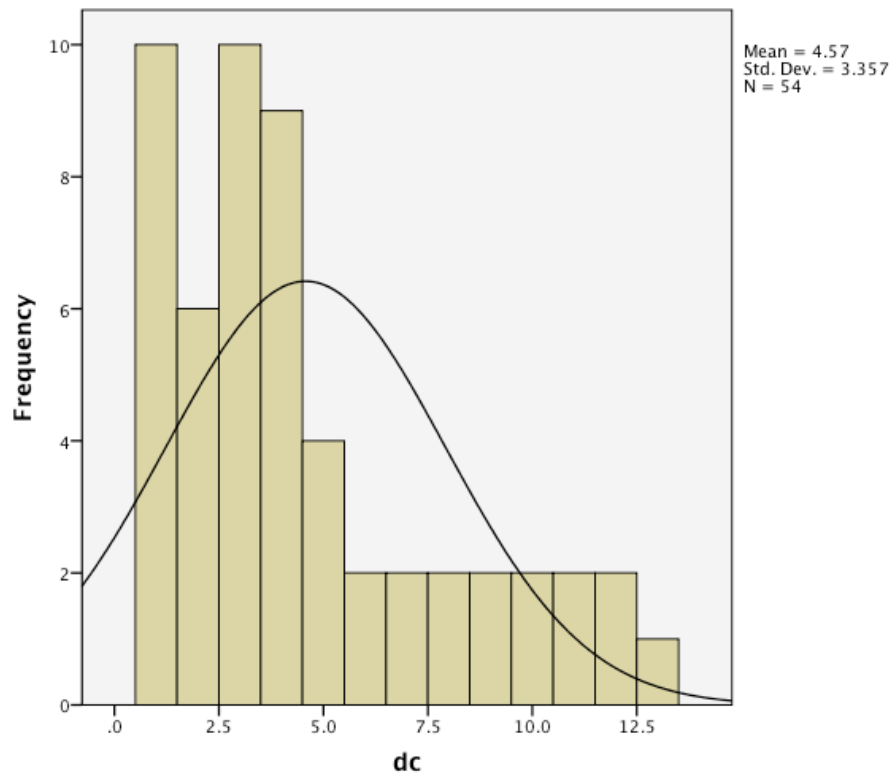


Informal coordination during the outbreak:

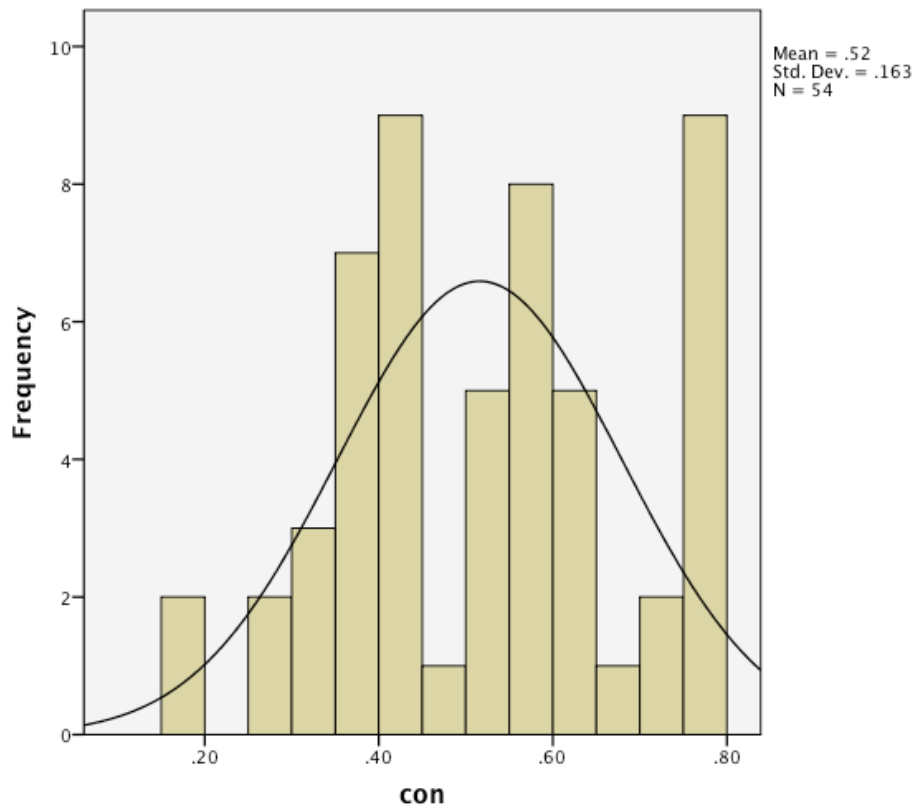
1- degree centrality histogram



2- Tie strength histogram



3-Tier connectedness histogram



Appendix E

List of general positions interviewed along with the general task description

Organisation name	Department	Position
Western Sydney Local Health District	Centre Infectious and Microbiology	Infectious Diseases and Microbiology Specialist
Centre for Infectious Diseases and Medical Laboratory Services	Clinical Virology	Clinical Research
South Eastern Sydney Local Health District	Public Health Unit	Director of Health
NSW ministry of Health	Center for Health Protection/Communicable Disease Branch	Public Health Laboratory Surveillance (PHLS)
NSW Ministry of Health	Centre for Health Protection -/ Communicable Disease Branch (CDB)	Medical Epidemiologist
Western Sydney Area Health Service	ICPMR - CIDMLS (Centre of infectious disease and microbiology laboratory service)	Public Health Liaison

Sydney West Public Health Unit	PHU	Manager
Nepean Blue Mountains Local Health District	PHU / Health protection team	Senior infectious disease surveillance officer
NSW health	Biopreparedness unit	principle project officer and medical advisor
Sydney South West PHU	PHU	Acting director
Sydney South West PHU	PHU Communicable diseases	Team Leader for the Communicable disease team
Sydney West Area Health Service	PHU (Communicable Disease and Immunization)	Public Health Epidemiologist
Ambulance Service NSW	Health Emergency Management Unit (CDU)	Director
Westmead Children's Hospital	Emergency Department	Medical Head
NSW Ministry of Health	Centre for Health Protection, AIDS/Infectious Diseases Branch	Senior Policy Analyst
Royal Price Alfred Hospital	Emergency Department	Medical Director
Napean Blue Mountains Local Health District	Epidemiology	Senior Research and Evaluation
Royal Prince Alfred Hospital	Pharmacy	Director
Sydney West Area Health Service	Public Health Unit	Environmental Health

		Officer
CDU for Napean Blue Mountain and Western Sydney Local Health District	CDU	Director
NSW Ambulance Service	State Wide Service - Aeromedical Retrieval Services	Director
Royal Prince Alfred Hospital	ICU	Director of ICU (also Cochair of NSW IC task force)
Ambulance Service of NSW	Special Operations Unit	Manager of Special Operations Logistics
(Napean / BM AHS)	Population Health Unit	Senior Environmental Health Officer
Australian General Practitioners network	NA	Immunization coordinator
South Eastern Sydney Area Health Service - Pathology	Microbiology Lab	Microbiology Registrar
North Coast Area Health Service	North Coast PHU	Director
NSW Ministry of Health	Health emergency management unit	Alternate State Medical Controller
Napean Hospital	Infection Control - pathology	Clinical Nurse Consultant

Napean Hospital	Executive	Director Nursing and Midwifery
ICPMR (Centre of Infectious disease and microbiology services)025	ICPMR (Centre of Infectious disease and microbiology services)	Director
South East Area Laboratory Services	Microbiology	Assitant Director Microbiology
Westmead Hospital	Infection control department	Co-manager
NSW Ministry of Health	Centre of Health protection	Manager of Surveillance - Epidemiologist
Greater Southern Area Helath Service	Public Helath Unit	Surveillance officer
Royal Prince Alfred Hospital	Infection Control Unit	Clinical Nurse Consultant
NSW Police force	District Emergency Management	District Emergency Management officer
Balmain Hospital	GP Consulting	Director
NSW Ministry of Health	Director of NSW Health CDU within the AHS in the Ambulance	Director
Bankstown Hospital Inetsive Care Unit	Intensive Care Unit (ICU)	ICU Consultant (Senior ICU specialist)

Sydney west area health service	community health in the family health team	Community health nurse
Hunter New England Public Health Unit	Public Health Unit	Epidemiologist
NSW Ministry of Health	Microbiology	Staff microbiologist
Npapean Blue Mountains GP network	Immunization	Project Coordinator
NSW Ministry of Health	Development branch	State wide coordinator for critical care
Centre for population health	Western Sydney and Napean Blue Mountains local health district.	Director
Greater Southern Local Health District	PHU	Clinical Nurse Consultant
Sydney West AHS	centre for population health	office coordinator
Greater Southern AHS	Public Helath Unit	Senior Enviornmental Health officer
GP NSW	Immunization practice	Immunization coordinator
Western Sydney Area Health Service	Epidemiology	Senior evaluation officer
Sydney South West AHS	Health Service Functional Area Coordinator (HSFAC)	HSFAC director and director of population

		health and planning
NSW Ministry of Health	Coordination and policy unit	Manager of emergency response coordination
NSW Ministry of Health	Emergency Management unit	Deputy director
Greater Southern AHS	PHU	Epidemiologist
NSW Ministry of Health	Centre of epidemiology and research	Senior epidemiologist
Greater Southern AHS	Infectious disease surveillance	Infectious disease surveillance officer
Greater Southern AHS	PHU	Director of PHU
NSW Ministry of Health	Centre of Epidemiology and research	Manager for population health information branch
Hunter New England AHS	HSFAC	Bio preparedness officer
GP Access	Operation Management	Pandemic Coordination
Hunter New England AHS	communication unit	Communication officer
Hunter New England AHS	HNE population Health	Bio-preparedness epidemiologist
NSW Ministry of Health	Centre for Health protections	Manager
Hunter New England AHS	HSFAC	Area director of Nursing and HSFAC disaster manager

Dept of Primary Industries	Biosecurity Preparedness	Leader of Biosecurity preparedness
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