Evaluating Emergency Response Network Emergence: The case of the Kilmore East Fire

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Bushfire CRC

Motivation

- Extreme events (e.g., Fire, Tsunami, Flood) are big threats for human life and the environment
  - E.g., Black Saturday bushfires
    - 173 people died
    - 414 people were injured
    - 7,562 people displaced
    - Over 3,500 structures destroyed
    - 450,000 ha (1,100,000 acres) burnt
    - ...
Motivation

- **Emerging Networks**
  - not only different organizations (agencies) need to cooperate properly internally *(intra-team & inter-team)*
  - but they also have to cooperate with other organizations *(inter-organizational)*

  ![Example of bushfire response teams & agencies](image)

- Actors need to use and **exchange** their experience, knowledge and skills and also **share** resources and equipment.

- Thus, to have a **better outcome**, there is a need to coordinate **actors** (i.e., individuals, teams and organizations).

- Investigating **coordination** is needed to find the **drawbacks** and facilitate cooperation.
Introduction

- Each cooperation network structure represents flow of resources (e.g., information).
  - Which needs an specific way to control (facilitate, avoid breakdowns) the flow.

- To understand what the breakdowns are (from a network analysis perspective, there is a need to
  - Evaluate which types of node failures have high level of impact on coordination performance
  - which will lead to develop a better predicting model for understanding the rate of node failure and attack.

Research Objective

To enhance emergency response coordination through
investigating node failure to
better facilitate information flow
among the actors involved in the response network
Research Questions

• Can emerging response network structure during extreme event be identified and evaluated?

• What can be learnt about how do actors’ position change over the emergence of inter-personal response networks during an extreme event?

• How can we identify certain actors who play the coordinating role (through SNA) in inter-organizational response network during an extreme event?

Methodology

 Review of literature on organization, coordination and network theories

 Collect appropriate interaction network data (Content Analysis)
Transcripts and individual statements from the Victorian Bushfires Royal Commission repository analysed to extract individual names, role and the agency they belong to, communication between them, their location during the communication and the devices and technologies they used.

 Investigating network structure dynamics (using Social Network Analysis)
  • Measuring network and individual position and structure
  • Visual presentation
Literature Review - Coordination

• Coordination is an essential activity in distributed systems which permit participants to perform complex composite tasks and achieve (common) goals by interaction (Corkill and Lander 1998; Van Veenen, Storms et al. 2006).

• “good coordination is nearly invisible, and we sometimes notice coordination most clearly when it is lacking” (Malone and Crowston 1990; 1994).

• Different types of coordination in organizations (Dynes and Aguirre,1976)
  — by plan: “based on pre-established schedules and programs directing and standardizing the functioning of organizations”
  — by feedback: “is centred in the transmission of new information so as to facilitate the mutual adjustment of parts”
  — mixture of both types: in real life complex organizations.

Networks, Social Networks, (Social) Network Analysis

1. Networks (graphs) consists of
   – Nodes: individuals, organizations, computers, cells,…
   – Links (ties): friendship, trade, financial exchange, cooperation,…

2. Social Networks
   – A social network is a social structure made up of nodes and ties
     • Social network systems (e.g., Facebook, LinkedIn, …)

3. Social network analysis (SNA)
   – views social relationships in terms of network (graph) theory and examines the structure of relationships between social entities. Thus, it is a methodology to analyse networks from:
     • whole to part (egocentric);
     • structure to relation to individual;
     • behavior to attitude.
• **Social Networks Analysis** focus on the structure (pattern) of relations among a set of actors as a core building block of group and individual behaviour (Krackhardt, 2010)

  − While traditional studies of organizations success often focus on a person’s training or education, …
  − but social network analysis perspective focus on a person’s connections to others (inside or outside the organization).

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**Network Analysis & Disaster Management**

- An extreme response operates as a network of actors (from diverse organizations) who share a common goal: reduce the risk and continuity of operation for the threatened community (Comfort et al., 2010)

- Network structure may affect the risk recognition capacity of the actors involved in the network (Comfort et al., 2010)

- Network Connectedness or fragmentation
  - Isolated actors of a network (disconnected from other actors in the network), may lose influence in the operation of the whole network.
Network (individual) Structure

- Structures
  - Start and Y structure shows better performance (Bavelas & Leavitt, 1950)

- Efficiency (Structural Holes): (Burt, 1992)
  - “Individuals with connections to social clusters or groups who are themselves not well connected perform better”.
  - If an actor performs a bridging (brokering) function between two unrelated actors in the network, the actor will gain more influence in the operation of the whole network.

Units of Analysis: the aggregation of people into units of interest as primary actors in a system (e.g., people, organizations, industries, nations)

Levels of Analysis: different aggregations of the structural (relational) features of interest.

- Level 0: Network Structure
  - What is the overall shape of the network?
  - What effect does this shape have on the performance and behaviour of the group?

- Level 1: Individual Position
  - What is the consequence to the individual who occupies a certain position in the network?

- Level 2: Dyadic Relations
  - How do dyadic network ties form?
  - Why do individuals choose particular others to connect?

- Level 3: Cognitive Social Structure
  - Do actors perception of the network affect on their behavior?

“Perceptions can lead to ties, strategic ties lead to central network positions, and stratification of these positions can lead to systematic behavior” (Krackhardt, 2010)
Individual Position: Centrality

- **Degree**: number of adjacent nodes (active, popular, informal leaders)
  
  \[ C_D(p_k) = \sum_{i=1}^{n} a(p_i, p_k) \]

- **Closeness**: the sum of (shortest) distances for an individual to reach every one else in the network. (disseminator, independent)

  \[ C_C(p_k) = \sum_{i=1}^{n} d(p_i, p_k)^{-1} \]

Where \( d(p_i, p_j) \) is the number of edges (links) in the geodesic (shortest path) linking \( p_i \) and \( p_j \).

- **Betweenness**: the extent to which an individual lies between others’ (shortest) path to reach each others in the network. (control, power and influence)

  \[ C_B(p_k) = \sum_{i=1}^{n} \sum_{j \neq i \neq k} \frac{g_{ij}(p_k)}{g_{ij}} \]

Where \( g_{ij} \) is the number of geodesic (shortest paths) linking \( p_i \) and \( p_j \) and \( g_{ij}(p_k) \) is the number of geodesic linking \( p_i \) and \( p_j \) that contains \( p_k \).

Network Centralization

- **Degree**: 
- **Closeness**: 
- **Betweenness**: 

Where \( n \) is number of points (nodes) in network, \( p^* \) is the point with maximum centrality and \( p_i \) denotes point \( i \) in the network, \( C_D \) is the network Degree Centrality, \( C_C \) is the network Closeness Centrality, \( C_B \) is the network Betweenness Centrality.

- **Density**: proportion of ties in a network (whole / ego) relative to the total number of possible ties.
Content Analysis (1)

1. Finding the File related to a special fire (e.g., Kilmore)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilmore 04/05/2009.pdf</td>
<td>Kilmore fire Incident Controller statement</td>
</tr>
<tr>
<td>Kilmore 04/06/2009.pdf</td>
<td>Kilmore fire Incident Controller statement</td>
</tr>
<tr>
<td>Kilmore 05/06/2009.pdf</td>
<td>Kilmore fire Incident Controller statement</td>
</tr>
<tr>
<td>Kilmore 06/06/2009.pdf</td>
<td>Kilmore fire Incident Controller statement</td>
</tr>
</tbody>
</table>

2. Finding key players of the fire (e.g., Incident Controller) in that file

- Greg Murphy
- John Doe
- Jane Smith

3. Extracting the “Statement of the person name” (starts with WIT)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIT.004.008.0000_Release-Rev.pdf</td>
<td>WIT statement of incident controller</td>
</tr>
<tr>
<td>WIT.004.008.0001_Release-Rev.pdf</td>
<td>WIT statement of incident controller</td>
</tr>
<tr>
<td>WIT.004.008.0002_Release-Rev.pdf</td>
<td>WIT statement of incident controller</td>
</tr>
<tr>
<td>WIT.004.008.0003_Release-Rev.pdf</td>
<td>WIT statement of incident controller</td>
</tr>
</tbody>
</table>

Content Analysis (2)

4. Reading the statements files (of main key players) to extract their interactions

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Person 1</th>
<th>Person 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greg Murphy</td>
<td>John Doe</td>
<td>Jane Smith</td>
</tr>
<tr>
<td>Greg Murphy</td>
<td>John Doe</td>
<td>Jane Smith</td>
</tr>
<tr>
<td>Greg Murphy</td>
<td>John Doe</td>
<td>Jane Smith</td>
</tr>
<tr>
<td>Greg Murphy</td>
<td>John Doe</td>
<td>Jane Smith</td>
</tr>
</tbody>
</table>

PART 1: INTRODUCTION

My name is Gregory Murphy, and my date of birth is the 15th September 1970. I have been a volunteer fire-fighter for Country Fire Authority (CFA) since 1989 and have undertaken roles of Secretary (administrative and planning) and Lieutenant (operations).
5. Building the Network (using SNA tools: e.g. UCINET package)
& also visualizing the interaction (cooperation) network

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### The Kilmore Cooperation Network
Dynamic Analysis

<table>
<thead>
<tr>
<th>Time</th>
<th># of Actors</th>
<th># of Interactions (Links)</th>
<th>Density</th>
<th>Diameter (Average Path)</th>
<th>Clustering Coefficient</th>
<th># of Components</th>
<th>The Giant Component Size</th>
<th>Network Centralization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>43</td>
<td>73</td>
<td>0.04</td>
<td>1.921</td>
<td>0.342</td>
<td>3</td>
<td>38</td>
<td>49.59</td>
</tr>
<tr>
<td>T2</td>
<td>59</td>
<td>153</td>
<td>0.045</td>
<td>2.559</td>
<td>0.469</td>
<td>1</td>
<td>59</td>
<td>41.2</td>
</tr>
<tr>
<td>T3</td>
<td>78</td>
<td>213</td>
<td>0.036</td>
<td>2.58</td>
<td>0.6</td>
<td>1</td>
<td>78</td>
<td>30.72</td>
</tr>
<tr>
<td>T4</td>
<td>104</td>
<td>286</td>
<td>0.027</td>
<td>2.776</td>
<td>0.69</td>
<td>1</td>
<td>104</td>
<td>23.82</td>
</tr>
</tbody>
</table>

7 Feb (11:50) (13:05) (16:00) mid-night

Fire starts Kilmore as ICC IC change

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Kilmore Coordination Network Evolution

Active Actors (Agents)

Table 2. Top 10 (Out-Degree) Centralized personnel in Kilmore inter-personal coordination network (Seekers)

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T1-T2</th>
<th>T1-T3</th>
<th>T1-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Peter Creak</td>
<td>0.110</td>
<td>Peter Creak</td>
<td>0.080</td>
</tr>
<tr>
<td>2</td>
<td>Noel Arandt</td>
<td>0.081</td>
<td>Greg Murphy</td>
<td>0.078</td>
</tr>
<tr>
<td>3</td>
<td>Greg Murphy</td>
<td>0.043</td>
<td>Noel Arandt</td>
<td>0.060</td>
</tr>
<tr>
<td>4</td>
<td>Russell Court</td>
<td>0.038</td>
<td>John Dixon</td>
<td>0.052</td>
</tr>
<tr>
<td>5</td>
<td>John Dixon</td>
<td>0.019</td>
<td>Russell Court</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Greg Murphy: IC1 -- Kreltszheim: IC2
Peter Creek: RDO (RECC) -- Noel Arandt: DIC1
Russell Court: Tanker1 Crew -- John Dixon: DG0

Table 2. Top 5 (In-Degree) Centralized personnel in Kilmore inter-personal coordination network (Providers)

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T1-T2</th>
<th>T1-T3</th>
<th>T1-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greg Murphy</td>
<td>0.06</td>
<td>Greg Murphy</td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td>Group Duty Officers</td>
<td>0.02</td>
<td>Kilmore Fire St. Crews</td>
<td>0.03</td>
</tr>
<tr>
<td>3</td>
<td>Kilmore Fire St. Crews</td>
<td>0.02</td>
<td>Peter Creak</td>
<td>0.03</td>
</tr>
<tr>
<td>4</td>
<td>Greg Kreltszheim</td>
<td>0.02</td>
<td>Peter Creak</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>Peter Hayes</td>
<td>0.02</td>
<td>Noel Arandt</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Identifying Influential Actors (important for information flow)

Top 5 intermediating actors (brokering between actors): Betweenness Centrality

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T1-T2</th>
<th>T1-T3</th>
<th>T1-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Peter Creek</td>
<td>1.62</td>
<td>Peter Creek</td>
<td>7.90</td>
</tr>
<tr>
<td>2</td>
<td>Noel Arandt</td>
<td>1.80</td>
<td>Noel Arandt</td>
<td>6.70</td>
</tr>
<tr>
<td>3</td>
<td>Greg Murphy</td>
<td>1.48</td>
<td>Greg Murphy</td>
<td>4.00</td>
</tr>
<tr>
<td>4</td>
<td>Group Duty Offi</td>
<td>0.29</td>
<td>John Clarke</td>
<td>2.58</td>
</tr>
<tr>
<td>5</td>
<td>CRA</td>
<td>0.23</td>
<td>Ross Hibbert</td>
<td>1.61</td>
</tr>
</tbody>
</table>

- Brokering role gives the power and control of the information flow
- Brokering role well express the coordinating role of the RDO (Regional Duty Officer)
- Deputy Incident Controller (DIC) has a better brokering role that the Incident Controller (IC)
- Almost the same actors are listed among top 5 brokering roles

Conclusion

- We used social network analysis measures in order to quantify and distinguish the response networks structure and each actors' position and structure in the response networks.

  - More samples of data for analysis are needed in order to find
    - the threshold for the optimal network structure metrics (e.g., density, centralization)
    - the correlation between the network structural changes and network measures and performance
The actors who play the *brokering* (*intermediating*) role, not only receive requests from some organizations but also respond to them or forwarding their request to proper actors.

- **Points of strengths and weaknesses within and among networks** (considering information flow congestion, resources requested, ...)

- **Failure of these nodes (actors) lead to the break down of the overall network** (as may lead to fragmentation of the network)

- **Brokering role identifies formal and informal coordination roles, thus is useful to for comparison of network structures: what is prescribed (in procedures) with what really happens.**

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We found that the increasing rate of communication leads to the conditions where organizational structures need to move in the direction to exchange new information which is usually away from their preparedness plans.

- **This verifies the need for coordination by feedback in addition to plan** (*Dynes and Aguirre*, 1976).

- **This study is a first step forward in investigating the emerging structure of inter-personal response dynamics during emerging disasters and its effect on improving coordination output.**

- **This study contributes to emergency management literature by evaluating dynamic changes of actors and organizational roles and positions as inter-organizational response networks emerge during the extreme event.**
Q & A - Comments

THANK YOU