

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
 - ...



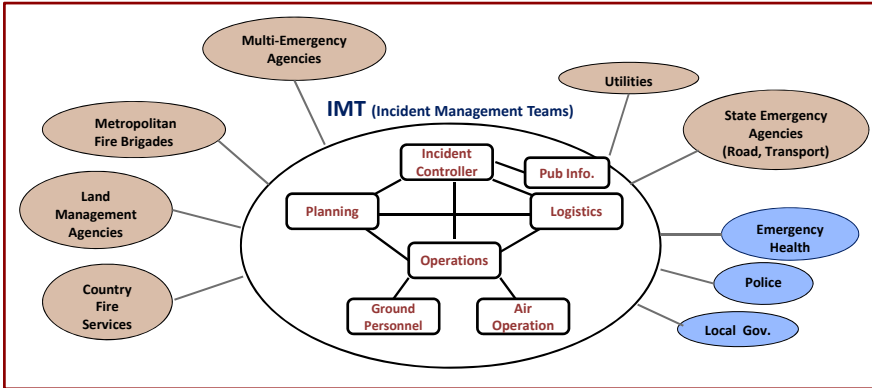


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Motivation


❑ **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 bushfires response teams & agencies

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Motivation

- 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**.

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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.

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Research Objective

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

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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?

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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

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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 Veelen, 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.

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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.

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SNA Approach

- **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 *persons'* training or education, ...
 - **but social network analysis** perspective focus on a person *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.

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Network (individual) Structure

- **Structures**

- *Star* and *Y* structure shows better performance (Bavelas & Leavitt, 1950)

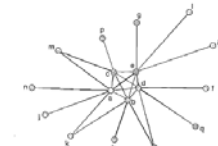


Figure 1 Core-Periphery Structure



Figure 2 Bow-Tie Structure

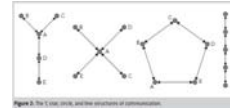
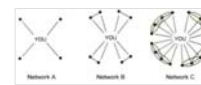


Figure 3 The Y-Shape, which is a modification of communication.

- **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



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Fundamentals of SNA

- **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).

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SNA: Individual Measures

□ 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**)

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

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

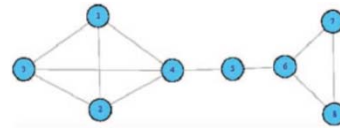
- **Betweenness:** the extent to which an individual lies between others' (shortest) path to reach each others in the network. (**control, power and influence**)

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 .

$$C_B(p_k) = \sum_{i < j} \frac{g_{ij}(p_k)}{g_{ij}}, \quad i \neq j \neq k$$

| Nodes | C_D | C_B |
|-------|-------|-------|
| 1 | 3 | 0 |
| 2 | 3 | 0 |
| 3 | 3 | 0 |
| 4 | 4 | 4 |
| 5 | 2 | 4 |
| 6 | 3 | 3 |
| 7 | 2 | 0 |
| 8 | 2 | 0 |

| Rank | C_D | C_C | C_B |
|------|---------|-------|-----------|
| 1 | 4 | 4,5 | 4 |
| 2 | 1,2,3,6 | 6 | 5,6 |
| 3 | 5,7,8 | 1,2,3 | 1,2,3,7,8 |
| 4 | | 7,8 | |



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SNA: Network Measures

- The concept of density and centralization refer to differing aspects of 'compactness' of a network.
- **Density** describes the general level of cohesion in a graph; **centralization** describes the extent to which this cohesion is organized around particular focal points" (Scott, 1991).

□ 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_B is the network *Betweenness Centrality*, C_C is the network *Closeness Centrality*.

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

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THE UNIVERSITY OF SYDNEY **Content Analysis (1)**

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

Attachment 2 – Operational response, to the Kilmore East, Humevale , Strathewen- St Andrews and Yarra Valley fires

Operational response to the Kilmore East and Wandong fires

2. In relation to operational response to the Kilmore East and Wandong Fires the State refers to the following:

- 2.1 Evidence led before the Commission demonstrates that all CFA Regions, Groups and Brigades were on high alert for the conditions expected on Saturday 7 February 2009, along with other emergency services organisations including the DSE and MFB.
- 2.2 The Region 12, Northern Highway and Seymour Groups were no exception. Prior to and for 7 February, Level 2 Pre-planned Incident Management Teams were in place for those groups.⁴⁸ The brigades and groups also had in place identified and pre-planned personnel to fill the roles of divisional and sector commanders.

⁴⁸ Murphy Ex 505, WIT.3004.021.0001, [26].
⁴⁹ Murphy Ex 41, WIT.3004.001.0001, [15].
⁵⁰ Creek Ex 504, WIT.3004.021.0148, [5].

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

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

- WIT.004.002.0001_Russel-Ree.pdf
- WIT.004.002.0004_Russel-Ree.pdf
- WIT.3004.001.0001_Greg-Murphy_IC1-Kilmore.pdf
- WIT.3004.001.0032_Stewart-Kreitzheim_IC2-Kilmore.pdf
- WIT.3004.008.0309_PeterCreek-June15_Kilmore.PDF
- WIT.3004.021.0209_Rodnev-Holland_GroupOfficer-Whittlesea-Kilmore.pdf

2009 VICTORIAN BUSHFIRES ROYAL COMMISSION Letters Patent issued 16 February 2009 WIT.3004.001.0001

STATEMENT OF GREGORY PETER MURPHY

Date of Document: 20 May 2009 Solicitor's Code: 7977
 Filed on behalf of: The State of Victoria Telephone: +61 3 8684 0444
 Prepared by: Facsimile: +61 3 8684 0449
 Victorian Government Solicitor's Office DX 30077 Melbourne
 Level 25 Ref: PAC 944894
 121 Exhibition Street Attention: John Cain
 Melbourne VIC 3000

I, Gregory Peter Murphy, National Manager, Safety Health and Environment of Patrick Terminals, can say as follows:

PART 1: INTRODUCTION

- 1. My name is Gregory Peter MURPHY and my date of birth is the 7th September 1970. I have been a volunteer fire fighter for Country Fire Authority (CFA) since 1986 and have undertaken roles of Secretary (administrative and planning) and Lieutenant (operational,

THE UNIVERSITY OF SYDNEY **Content Analysis (2)**

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

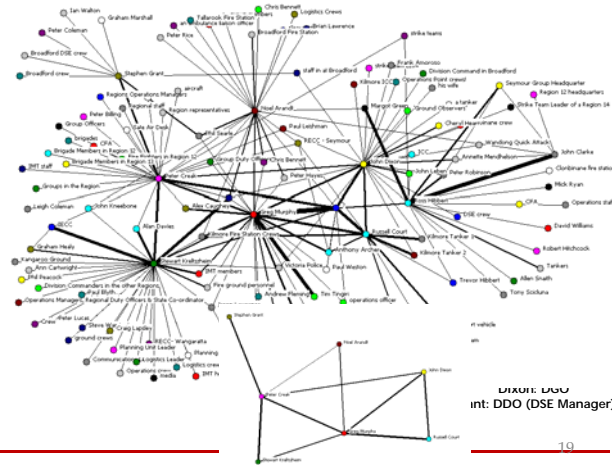
| Who | Role | Who_Org | Where | When | Communication (Action) | Whom | Whom Role | Whom_Org | Who | Whom | Link |
|---------------------|---------------------------------|-------------|-------------|----------------|----------------------------|---|-------------|---------------------|--------------------------|------|------|
| Greg Murphy | Region 12 Pager Holder | Kilmore_JCC | Region 12 | 5-Feb | Receive Forecast for 7th | Meteorology | Meteorology | Greg Murphy | Meteorology | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | weekend before | briefing about impoatone | Fire Station Crews | Kilmore_JCC | Greg Murphy | Kilmore Fire Station Cre | | 1 |
| Peter Creek | Regional Duty Officer of Region | RECC | RECC | 5-Feb | he advised that I would | Greg Murphy | Kilmore_JCC | Greg Murphy | | | 1 |
| Group Duty Officers | | RECC | | | Submitting Level 2 IMT | Greg Murphy | Kilmore_JCC | Peter Creek | Greg Murphy | | 1 |
| Peter Creek | Regional Duty Officer of Region | RECC | RECC | 6-Feb | Request to prepare the | Greg Murphy | Kilmore_JCC | Group Duty Officers | Greg Murphy | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 6-Feb | performed the set-up f | Tim Tingiri Pumper Crew | Kilmore_JCC | Peter Creek | Greg Murphy | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 6-Feb | performed the set-up f | Anthony Archer | Kilmore_JCC | Greg Murphy | Tim Tingiri | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 6-Feb | sent out a page the pre | Brigade members | Kilmore_JCC | Greg Murphy | Anthony Archer | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 7-Feb (11:00) | briefing discussing the | ore Fire Station Crews | Kilmore_JCC | Greg Murphy | Brigade members | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 7-Feb | reviewed the set-up of | Tim Tingiri Pumper Crew | Kilmore_JCC | Greg Murphy | Stewart Kreitzheim | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 7-Feb | reviewed the set-up of | Anthony Archer | Kilmore_JCC | Alan Davies | Stewart Kreitzheim | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | " | tasked to ensure all apone | Fire Station Crews | Kilmore_JCC | CFA | Operations Crews | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | " | was nominated in a rol- | RECC - Seymour | RECC | Peter Creek | Stewart Kreitzheim | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 7 Feb (11:00) | called and gave them a | Brigade members | Kilmore_JCC | Alan Davies | Stewart Kreitzheim | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | Mount Hicke | 11:50 | Receive an alert about | Phil Seabro Mt Hickery tower Mt Hickery tow | Kilmore_JCC | State Coordinator | Stewart Kreitzheim | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | | responded by two Kilim | Brigade members | Kilmore_JCC | Peter Creek | Regional Coordinator | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 11:50 | Assign Noel Arandt as C | Noel ArandR Deputy K | Kilmore_JCC | Peter Creek | Regional Coordinator | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | 11:51 | Receive a pager call ask | ? | Kilmore_JCC | Peter Creek | Regional Coordinator | | 1 |
| Greg Murphy | Captain of Kilmore Fire Station | Kilmore_JCC | | | dispatched the pumpe | Brigade members | Kilmore_JCC | Peter Creek | Group Duty Officers | | 1 |
| | | | | | | | | Peter Creek | CFA | | 1 |
| | | | | | | | | Peter Creek | Regions Operations Mar | | 1 |
| | | | | | | | | Peter Creek | IECC | | 1 |



Content Analysis (3)

5. Building the Network (using SNA tools: e.g. UCINET package)
 & also visualizing the interaction (cooperation) network

| | Degree | Closeness | Betweenness |
|-----------------------------|--------|-----------|-------------|
| Peter Creak | 24 | 52.743 | 36.378 |
| Stewart Kreitzheim | 26.4 | 46.125 | 33.067 |
| John Dixon | 23.2 | 48.077 | 32.803 |
| Greg Murphy | 20 | 51.653 | 23.253 |
| Noel Arandt | 18.4 | 43.253 | 19.285 |
| Ross Hibbert | 15.6 | 39.557 | 16.116 |
| Stephen Grant | 6.4 | 36.023 | 8.203 |
| Russell Court | 9.6 | 39.809 | 6.855 |
| John Clarke | 4 | 37.092 | 3.391 |
| Jason Lawrence | 2.4 | 36.982 | 1.6 |
| CFA | 1.6 | 28.539 | 1.6 |
| Killmore Fire Station Crews | 3.2 | 39.432 | 1.376 |
| Victoria Police | 1.6 | 37.764 | 1.185 |
| Phil Searle | 2.4 | 37.202 | 1.184 |
| strike teams | 1.6 | 37.651 | 1.135 |
| staff in at Broadford | 1.6 | 33.693 | 1.123 |
| RECC - Seymour | 3.2 | 38.226 | 0.706 |

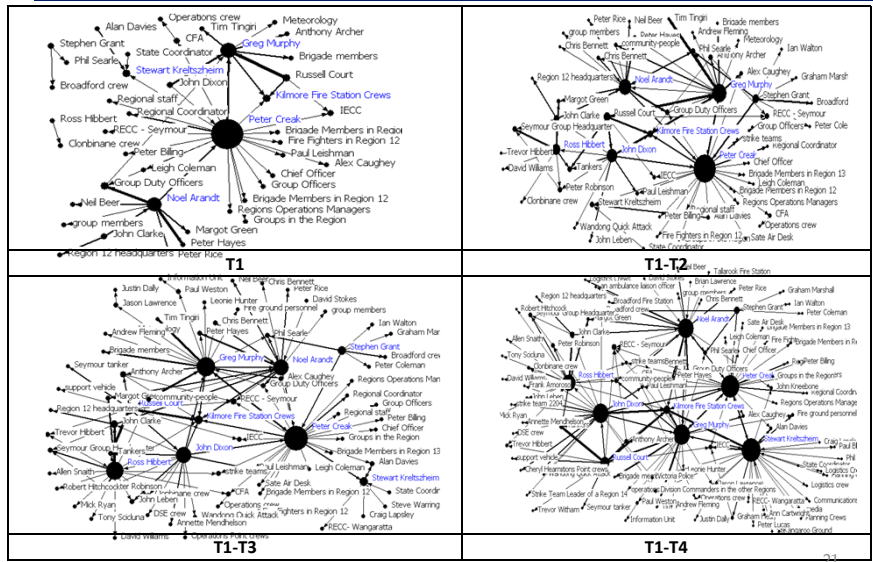


The Killmore Cooperation Network Dynamic Analysis

--- T1 --- **t(1)** --- T2 --- **t(2)** --- T3 --- **t(3)** --- T4 --- **t(4)**
 7 Feb (11:50) (13:05) (16:00) mid-night
 Fire starts Killmore as ICC IC change

| | T1 | T1-T2 | T1-T3 | T1-T4 |
|----------------------------|-------|-------|-------|-------|
| # of Actors | 43 | 59 | 78 | 104 |
| # of Interactions (Links) | 73 | 153 | 213 | 286 |
| Density | 0.04 | 0.045 | 0.036 | 0.027 |
| Diameter (Average Path) | 1.921 | 2.559 | 2.58 | 2.776 |
| Clustering Coefficient | 0.342 | 0.469 | 0.6 | 0.69 |
| # of Components | 3 | 1 | 1 | 1 |
| The Giant Component Size | 38 | 59 | 78 | 104 |
| Network Centralization (%) | | | | |
| Degree (undirected) | 49.59 | 41.2 | 30.72 | 23.82 |
| In-Degree | 5.02 | 3.04 | 2.46 | 3.34 |
| Out-Degree | 10.39 | 7.43 | 5.18 | 4.81 |
| Betweenness (undirected) | 3.54 | 7.61 | 4.69 | 6.19 |

Kilmore Coordination Network Evolution



Active Actors (Agents)

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

| | T1 | | T1-T2 | | T1-T3 | | T1-T4 | |
|---|---------------|------|---------------|------|---------------|------|----------------------|------|
| | Actors | Deg | Actors | Deg | Actors | Deg | Actors | Deg |
| 1 | Peter Creak | .110 | Peter Creak | .080 | Greg Murphy | .055 | Stewart Kretzschheim | .051 |
| 2 | Noel Arandt | .081 | Greg Murphy | .078 | Ross Hibbert | .051 | Greg Murphy | .050 |
| 3 | Greg Murphy | .043 | Noel Arandt | .060 | Peter Creak | .047 | John Dixon | .044 |
| 4 | Russell Court | .038 | John Dixon | .052 | Russell Court | .047 | Noel Arandt | .040 |
| 5 | John Dixon | .019 | Russell Court | .052 | Noel Arandt | .040 | Russell Court | .040 |

Greg Murphy: IC1 -- Kretzschheim: IC2
 Peter Creak: RDO (RECC) -- Noel Arandt: DIC1
 Russell Court: Tanker1 Crew -- John Dixon: DGO

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

| | T1 | | T1-T2 | | T1-T3 | | T1-T4 | |
|---|------------------------|------|------------------------|------|------------------------|------|------------------------|------|
| | Actors | Deg | Actors | Deg | Actors | Deg | Actors | Deg |
| 1 | Greg Murphy | 0.06 | Greg Murphy | 0.04 | Kilmore Fire St. Crews | 0.03 | Kilmore Fire St. Crews | 0.04 |
| 2 | Group Duty Officers | 0.02 | Kilmore Fire St. Crews | 0.03 | Greg Murphy | 0.02 | Greg Murphy | 0.02 |
| 3 | Kilmore Fire St. Crews | 0.02 | Peter Creak | 0.03 | Tankers | 0.02 | Tankers | 0.02 |
| 4 | Stewart Kretzschheim | 0.02 | Tankers | 0.02 | Peter Creak | 0.02 | Peter Creak | 0.01 |
| 5 | Peter Hayes | 0.02 | Noel Arandt | 0.02 | Noel Arandt | 0.01 | Stewart Kretzschheim | 0.01 |



Identifying Influential Actors (important for information flow)

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

| | T1 | | T1-T2 | | T1-T3 | | T1-T4 | |
|---|-----------------|------|--------------|------|--------------|------|----------------|------|
| | Actors | nBet | Actors | nBet | Actors | nBet | Actors | nBet |
| 1 | Peter Creak | 3.63 | Peter Creak | 7.90 | Peter Creak | 4.85 | Peter Creak | 6.37 |
| 2 | Noel Arandt | 1.80 | Noel Arandt | 6.70 | Noel Arandt | 4.76 | Noel Arandt | 5.41 |
| 3 | Greg Murphy | 1.48 | Greg Murphy | 4.00 | Greg Murphy | 3.29 | Stewart Krelts | 5.03 |
| 4 | Group Duty Offi | 0.29 | John Clarke | 2.58 | John Clarke | 1.45 | Greg Murphy | 4.13 |
| 5 | CFA | 0.23 | Ross Hibbert | 1.61 | Ross Hibbert | 1.23 | John Clarke | 1.25 |

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

- 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

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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

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Conclusion (Cont.)

- 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 for comparison of network structures: what is prescribed (in procedures) with what really happens.

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Conclusion (Cont.)

- 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 by 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.

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Q & A - Comments

