Coordination and Communication among Multiple Agencies in Response to Natural Disasters: An Illustrative Study

Xiaobo Qu [1], Oz Sahin [2] and Sherif Mohamed [3]

Abstract

A number of geographical areas within Australia are subject to frequent and significant natural disasters such as cyclones and flooding. Such events impact individuals and businesses directly and indirectly through the disruption of the routine movement of goods, services and people. The importance of identifying core challenges in the management of transport networks has been highly recognized by state and local governments. In Queensland, the responses to natural disasters involve the efforts from a number of agencies, including local city councils, local disaster management group, emergency services, police services, health/ambulance, and transport authorities, under the coordination of local disaster coordination centre. In this research, we look at the coordination and communication (C&C) among multiple agencies in response to natural disasters. Two organizational C&C mechanisms are evaluated based on the functional resonance analysis method by assuming several representative hypothetical scenarios. The applicability of the two mechanisms is also discussed accordingly.

Keywords: Functional Resonance Analysis Method, Natural Disaster, Southeast Queensland

Introduction

Climate change has been a major and globally significant issue in the world which has huge influences in Australia that higher temperature lead to heatwaves, bush fires, droughts and floods (Apan et al., 2010). The common natural disasters in South East Queensland are cyclones and flooding. These natural disasters have significant impacts on individual and safety. Hobbs and Lawson (1982) presented that Gold Coast suffered a series of serious tropical cyclones, damages estimating at AU$360 million in 1967. According to Bureau of Meteorology, Cyclone Larry was first tracked on 16 March 2006 which was classified as Category 5 with winds over 260 km/h on the northern coast of Queensland (BOM, 2006). Oloruntoba (2010) described that the cyclone Larry caused more than 25,000 Queenslanders lost their homes or farms and personal properties, and over 140,000 people lost their electricity while 30,000 lost their telephone services for days and approximately 280,000 people were affected. Honert and McAneney (2011) described that Brisbane experienced the second largest floods since the 20th Century and 23 people died in Lockyer Valley and approximately 18,000 properties were inundated in metropolitan of the greater Brisbane area, Ipswich and Brisbane River Valley. Many stakeholders, including transport authorities, local city councils, emergency services, health services, etc., have to collaborate in the event of these natural disasters.

[1] Senior Lecturer, Griffith School of Engineering, Griffith University, Gold Coast, 4222
[2] Research Fellow, Griffith School of Engineering, Griffith University, Gold Coast, 4222
[3] Professor, Griffith School of Engineering, Griffith University, Gold Coast, 4222

In Queensland, the responses to these natural disasters involve the efforts from multiple agencies, including city councils, local disaster management group, local disaster coordination centre, transport authorities (e.g. Queensland Department of Transport and Main Roads), emergency/police services, and health/ambulance. In many local governmental areas, local disaster coordination centre is a dedicated centre that leads and coordinates all other agencies in disaster management and response. The main duty of local disaster management group is to issue community information/advice via media release, and to priority and request resources assistance. The health/ambulance looks after the medical treatment of casualties. Emergency/police services are to guide the effective evacuation and rescue, and lead the traffic and crowd control. The communication and coordination (C&C) mechanisms vary from one local governmental area to another. It is much believed that the performance of disaster management and response is largely determined by the efficiency of C&C among different agencies. In this regard, we develop a methodology to quantitatively assess the performances of different C&C performance based on the functional resonance analysis method (FRAM). FRAM model is a method to generate expression and explain the relationships among agencies/functions (Frost and Mo, 2014). It consists of six functions which include Input, Output, Time, Control, Resource and Precondition, where Output is usually considered a function of the other five factors. It should be noted that the Output is usually used to represent the overall performance of the system.

The objective of this research is to analyse the performance of two different C&C mechanisms under different levels of natural disasters. Based on the proposed performance assessment, the applicability of the two mechanisms is also discussed. It is suggested that 1) the one-hub scheme is superior under less disastrous events as the probability of miscommunication is lower; and 2) the two-hub scheme is superior under more disastrous events as the overall performance of the system is better. The remainder of this paper is organized as follows. Section 2 presents the methodology. Section 3 discusses the performance of the two mechanisms under different scenarios. The applicability of the two mechanisms is discussed in Section 4. Section 5 concludes this research and points out the future work.

Methodology

Functional Resonance Analysis Method (FRAM)

Functional resonance analysis method (FRAM) provides a way to describe outcomes using the idea of resonance arising from the variability of everyday performance (Frost and Mo, 2014). A typical FRAM model consists of four steps:

1) Identify and describe the essential functions, and characterise each function using six basic characteristics;
2) Check the completeness / consistency of the model;
3) Characterise the potential variability of the functions in the FRAM model, a well as the possible actual variability of the functions in one or more instances of the model;
4) Analyse the overall performance based on scenario analysis.

The six basic characteristics include input, output, preconditions, resources, time, and control, which are detailed as follows.

1) Input (I) - which the function processes or transforms or that which starts the function;
2) Output (O) - which is the result of the function, either a specific output or product, or a state change;
3) Preconditions (P) - conditions that must be exist before a function can be executed;
4) Resources (R) - that which the function needs or consumes to produce the output;
5) Time (T) - temporal constraints affecting the function (with regard to starting time, finishing time, or duration);
6) Control (C) - how the function is monitored or controlled.

Coordination and Communication Mechanism

As mentioned in the introductory section, we will analyse the coordination and communication among local disaster coordination centre, local disaster management group, Queensland department of transport and main roads, Queensland police/emergency services, Queensland health/ambulance, and local city councils. Two C&C mechanisms are proposed and evaluated. The first C&C mechanism is currently used by many local city councils (e.g. Logan city council). Under this mechanism, there is only one local disaster coordination centre. All communications among different agencies have to go through local disaster coordination centre. In other words, local disaster coordination centre receive and disseminate all information. Evidently, if local disaster management group or local disaster coordination centre does not perform well, the whole system would be not functioning normally. This system is very similar with the hub and spoke system that has been widely used in the transport network design (Wang et al. 2013&2015; Liu et al., 2014).

Figure 1 depicts the FRAM diagram for this mechanism, representing the interactions among different agencies. In this research, this mechanism is hereafter referred to as one-hub scheme. During the discussions with local disaster managers, we have found that there is a potential to separate the one local disaster coordination centre as two sub-local disaster coordinator centres. City councils and transport authorities usually cooperate to provide the functionality of the infrastructure. Other agencies work together for rescue, evacuation, and medical treatment. In this regard, we split one local disaster coordination centre as two sub centres in the proposed mechanism. The interactions among different agencies are illustrated in Figure 2. There are two sub coordination centres: one for city council and transport authorities, another for emergency/police and health/ambulance. Under this scheme, these agencies are categorized as two groups. The communications among groups are through two sub local disaster coordination centres. Different from the one-hub scheme, there are communications between different agencies in the same group. In this research, this mechanism is hereafter referred to as one-hub scheme.

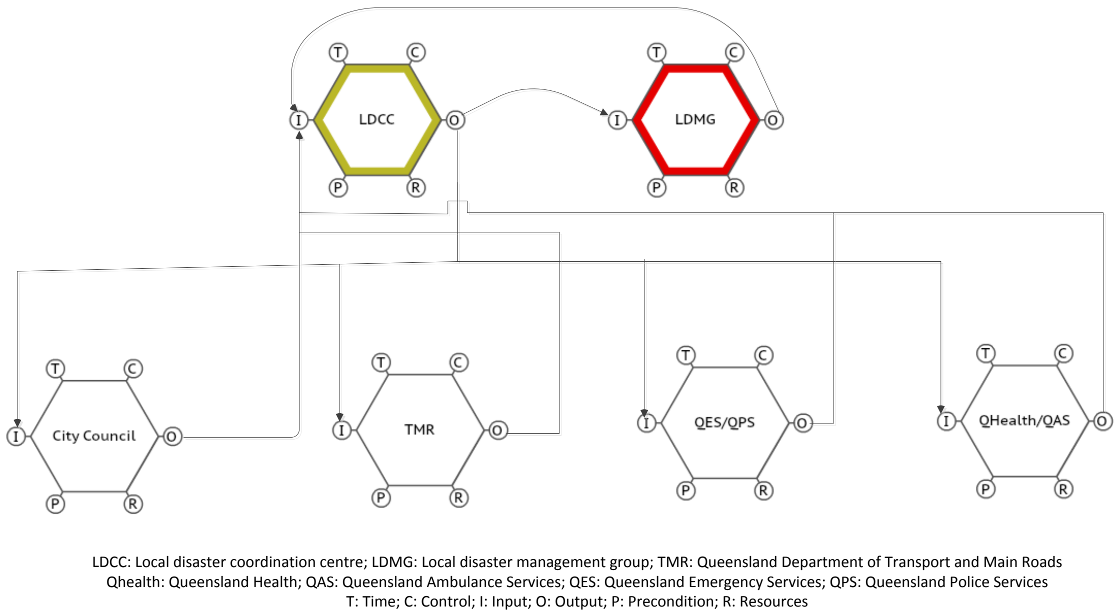

Figure 1. One-hub scheme

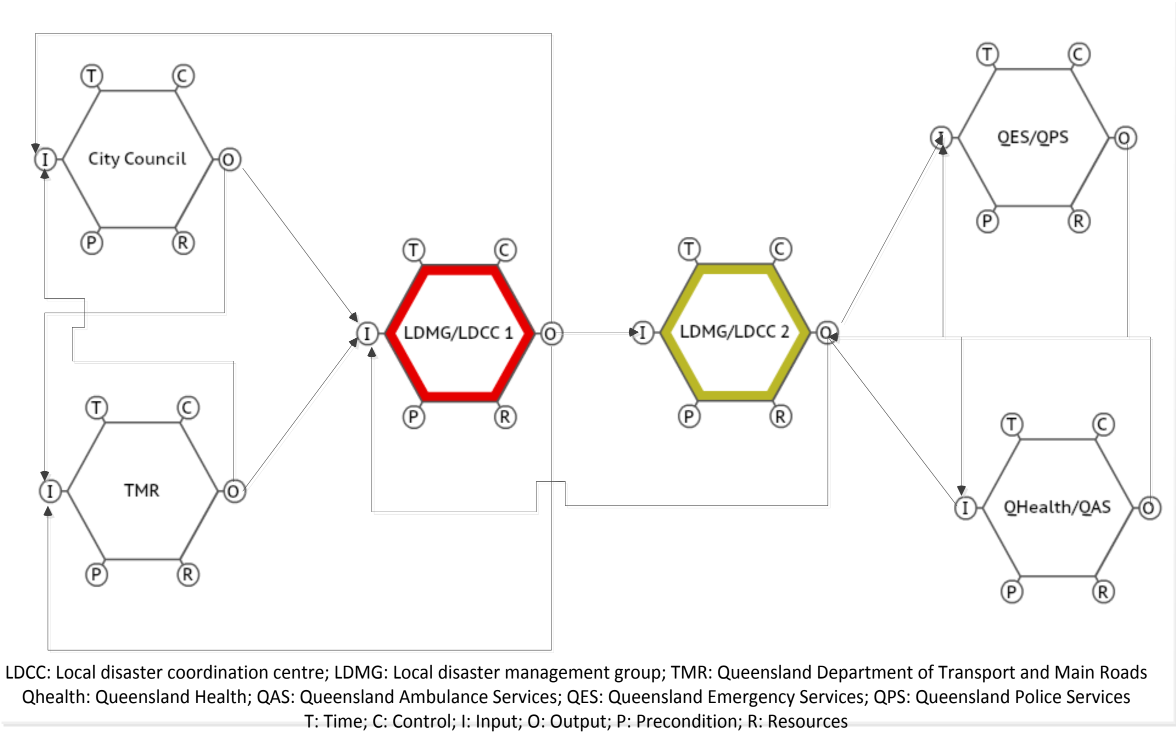

Figure 2. Two-hub scheme

Scenario Analyses

In this section, we analyse two basic scenarios to compare the differences among the two systems. Under scenario 1, we assume the LDCC and LDMG are rated as 4 in the scale of 5. We further assume one or more of the other four agencies are rated as 1 in the scale of 5. As such, we can establish a relationship between number of non-functioning agencies and the overall performance. Under scenario 2, we assume all agencies except LDCC are rated as 4 in the scale of 5. We change of the performance of LDCC and a relationship between the performance of LDCC and overall performance can be established. In this sensitivity analyses, the following equation is used to represent the relationship between output and other factors.

$$O_i = \frac{P_i\left(I_i + R_i + C_i + T_i\right)}{25} \qquad (1)$$

where O_i, P_i, I_i, R_i, C_i, and T_i refer to the output, precondition, input, resources, control, and time with respect to the agency *i*, respectively. As can be seen in the figure, the two-hub scheme is more robust and the one-hub scheme is heavily affected by the performance of the hub – LDCC. If the LDCC performs well, the overall performances of these two schemes are the same. In view of less links among stakeholders for one-hub scheme, it is considered superior as it is more reliable.

Scenario 1

In order to evaluate the impact of number of non-functioning agencies on overall system, we conduct a sensitivity analysis with respect to one-hub and two-hub schemes. The results were presented by Table 1 and Figure 3. As can be seen in the figure, the performances of these two schemes are almost identical.

Table 2: Sensitivity analysis for Scenario 1

One-hub scheme		Two-hub scheme	
LDCC	Overall performance	LDCC	Overall performance
0	2.91	0	2.91
1	2.43	1	2.47
2	1.96	2	2.03
3	1.48	3	1.58
4	1.01	4	1.14

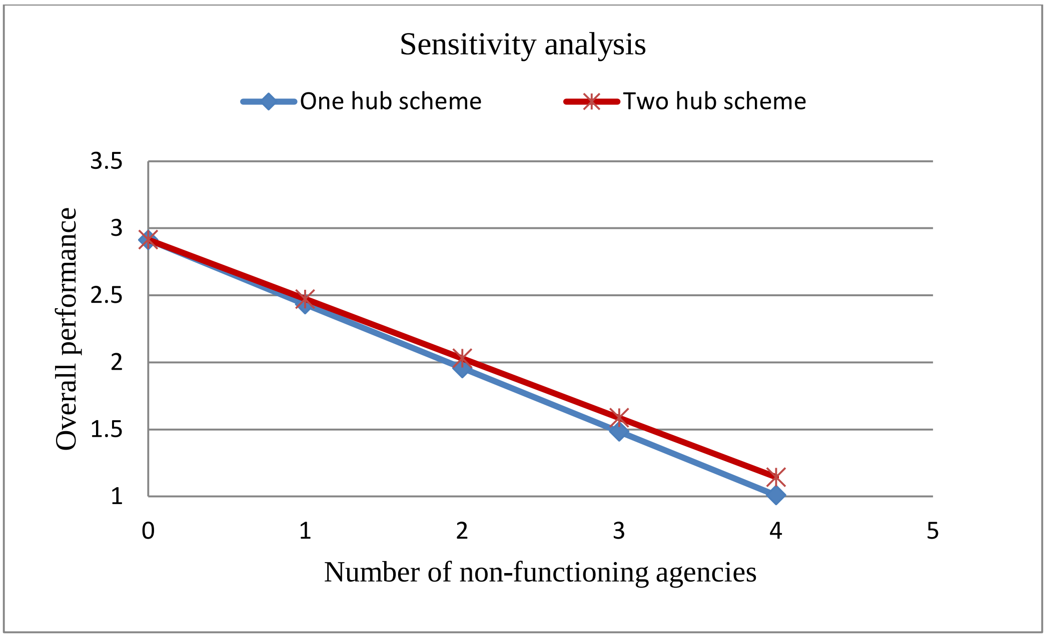

Figure 2: Sensitivity analysis for Scenario 1

Scenario 2

In order to evaluate the impact of the performance of LDCC on the overall system, we conduct a sensitivity analysis for LDCC (1, 2, 3, and 4 for all factors) with respect to one-hub and two-hub schemes. The results are presented by Table 2 and Figure 4.

Table 2: Sensitivity analysis

One-hub scheme		Two-hub scheme	
LDCC	Overall performance	LDCC	Overall performance
1	2.12	1	2.41
2	2.32	2	2.54
3	2.56	3	2.73
4	2.97	4	2.97

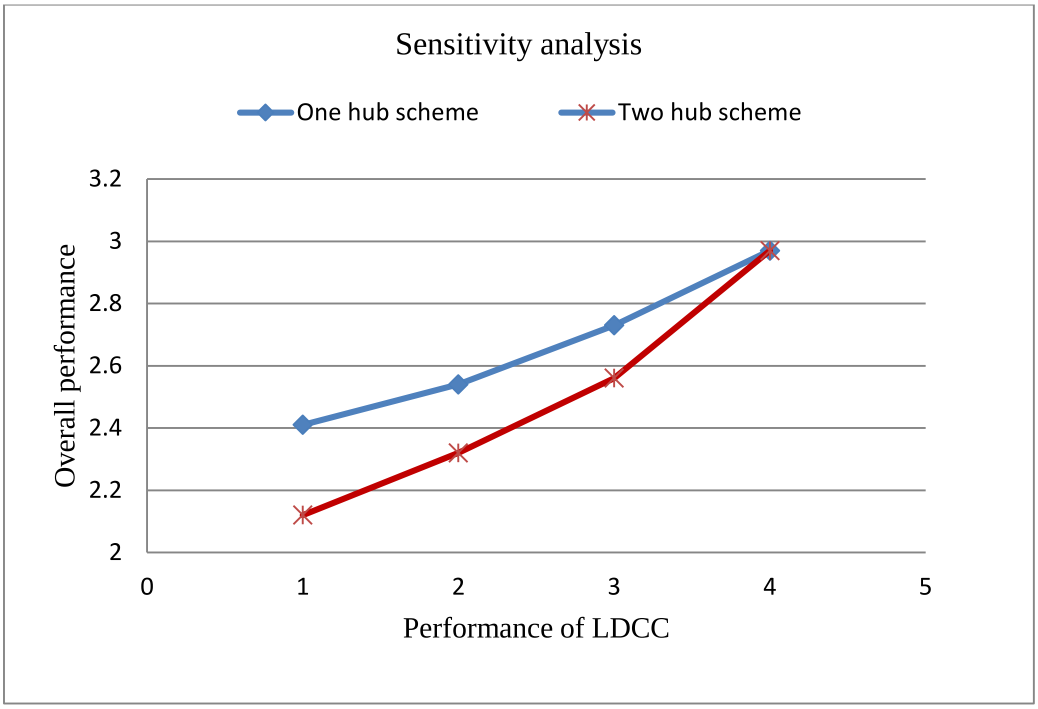

Figure 4: Sensitivity analysis for Scenario 2

Conclusions and Future Works

A number of geographical areas within Australia are subject to frequent and significant natural disasters such as cyclones and flooding. Such events impact individuals and businesses directly and indirectly through the disruption of the routine movement of goods, services and people. The importance of identifying core challenges in the management of transport networks has been highly recognized by state and local governments. In Queensland, the responses to natural disasters involve the efforts from a number of agencies, including local city councils, local disaster management group, emergency services, police services, health/ambulance, and transport authorities, under the coordination of local disaster coordination centre. In this research, we look at the coordination and communication (C&C) among multiple agencies in response to natural disasters. Two organizational C&C mechanisms are evaluated based on the functional resonance analysis method by assuming several representative hypothetical scenarios. The applicability of the two mechanisms is also discussed accordingly.

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Disclaimer

The views expressed in this paper only reflect the opinion of the authors and should not be considered as official opinions from transport authorities.

References

Apan, A., Keogh, D., King, D., Thomas, M., Mushtaq, S., and Braddiley, P., 2010. The 2008 floods in Queensland: A case study of vulnerability, resilience and adaptive capacity. National Climate Change Adaptation Research Facility, Gold Coast, 171pp.

BOM, 2006. Bureau of Meteorology, Available at http://www.bom.gov.au/cyclone/about/eastern.shtml Accessed on 17 July 2015.

Frost, B. and Mo, J. P. T, 2014. System Hazard Analysis of a Complex Socio-Technical System: The Functional Resonance Analysis Method in Hazard Identification. Australian System Safety Conference, Melbourne Australia, 28 — 30 May 2014.

Hobbs, J. E., and Lawson, S. W., 1982. The tropical cyclone threat to the Queensland Gold Coast. *Applied Geography*, 2(3), 207-219.

Honert, V. R. C., and McAneney, J., 2011. The 2011 Brisbane floods: causes, impacts and implications. *Water*, 3(4), 1149-1173.

Liu, Z., Meng, Q., Wang, S., Sun, Z., 2014. Global Intermodal Liner Shipping Network Design, *Transportation Research Part E*, 61, 28-39.

Oloruntoba, R., 2010. An analysis of the Cyclone Larry emergency relief chain: Some key success factors. *International Journal of Production Economics*, 126(1), 85-101.

Wang, S., Liu, Z., Meng, Q., 2015. Segment-based alteration for container liner shipping network design. *Transportation Research Part B*, 72, 128–145.

Wang, S., Meng, Q., Yang, H., 2013. Global optimization methods for the discrete network design problem. *Transportation Research Part B*, 50, 42–60.