POST-DISASTER EMERGENCY LOGISTICS MODEL FOR FLOOD CRISIS EVENT

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ABSTRACT: Emergency teams' efficiency in responding to disasters is critical in saving lives, reducing suffering, and for damage control. Quality standards for emergency response systems are based on government policies, resources, training, and team readiness and flexibility. This paper investigates these matters regarding Saudi emergency responses to floods in Jeddah in 2009 and again in 2011. The study is relevant to countries who are building emergency response capacity for their populations: analysing the effects of the disaster, communications and data flows for stakeholders, achieving and securing access, finding and rescuing victims, setting up field triage sites, evacuation, and refuges. The research problem in this case was to develop a dynamic system model capable of managing real time data to allow a team or a decision-maker to optimise their particular response within a rapidly changing situation. The Emergency Logistics Centre capability model responds to this problem by providing a set of nodes relevant to each responsibility centre (Civil Defence, regional/local authority including rescue teams, police and clean-up teams, Red Crescent). The dynamic systems approach builds model capacity and transparency, allowing emergency response decision-makers access to updated instructions and decisions that may affect their capacities. After the event, coordinators and researchers can review data and actions for policy change, resource control, training and communications. In this way, knowledge from the experiences of members of the network is not lost for future position occupants in the emergency response network. The conclusion for this research is that the Saudi emergency response framework is now sufficiently robust to respond to a large scale crisis, such as may occur during the hajj with its three million pilgrims. Researchers are recommended to test their emergency response systems using the Emergency Logistics Centre model, if only to encourage rethinking and flexibility of perhaps stale or formulaic responses from staff. This may lead to benefits in identification of policy change, training, or more appropriate pathways for response teams.

INTRODUCTIONRD

Catastrophes occur frequently, with earthquakes in China, New Zealand, and Haiti; tsunami in Japan and Indonesia; fires in Australia, Europe and the United States; and devastating floods around the world. Some 500 natural disasters each year kill approximately 70,000 people and affect more than 200 million people worldwide and the cost of response and rehabilitation is incalculable (Duran, Gutierrez, & Keskinocak, 2011). Researchers and media reports show that in the majority of occurrences, emergencies on a large scale expose flaws in institutional response and collective behaviour, highlighting the social processes that characterise such events.

The scale of such disasters now prompts a global response, and governments and international organisations such as Red Cross, Red Crescent and Oxfam respond quickly to a catastrophe, bringing in emergency supplies and human resources. Researchers have also responded to the humanitarian crises, examining the preparation and execution of relief efforts. However, the new field of 'humanitarian logistics' is in its infancy, described by Overstreet, Hall, Hanna, and Rainer (2011) as emerging from logistics research, theory of constraint, and management information systems.

Systems planning precedes a response to a humanitarian crisis, and several researchers have offered logistics, management, communications and complex modelling systems to overcome the issues of resources, chaos, and aid (Beamon & Balcik, 2008; Aslanzadeh, Rostami, & Kardar, 2009). However, Beresford and Pettit (2009) use the Thai tsunami response to question the traditional approach of preparedness, response and recovery, noting that the Thai government was under-prepared and the scale of the disaster quickly overwhelmed supply routes and communications. The Thai government now uses a less rigorous model, based on local communication networks, early warning systems, and danger mitigation rather than placement of large scale emergency resource stocks.

The need for logistic network models leads to the development of dynamic network flow in this paper, where time is included to accommodate travel through each arc. This is the case in the emergency logistics problem, where the objective is to minimise delay of services. Ford and Fulkerson (1958) introduced time to the maximum flow problem, using binary search. Burkard, Dlaska, and Klinz (1993) showed that the quickest flow problem is related to the maximum dynamic flow problem and to linear fractional programming problems. The generalisation of the quickest flow problem as the quickest transhipment flow was proposed by Hoppe and Tardos (2000) as a dynamic network with several sources and sinks; each source with a certain supply and each sink with a specified demand. A polynomial algorithm for this problem was posited to solve the problem in the minimum overall time.

The literature on general dynamic flow problems includes a survey to 1985 by Aronson (1989) that concentrated on the maximum flow and transhipment problems in discrete time. Powell, Jaillet, and Odoni (1995) focused on dynamic modelling issues with discrete time settings and stochastic parameters, whilst Kotnyek (2003) gave an overview of dynamic flow problems and solution techniques. To study evacuation plans, Hamacher, Heller, and Rupp (2013) used location analysis and dynamic network flows, using exact algorithms to solve the single facility version. They described their model as nodes which were rooms or cross-streets in a building or a region to be evacuated, and edges as doors or street, proposing a heuristic for q-FlowLoc and a mixed integer program. Location analysis was introduced as a new technique in evacuation modelling, as it is important to identify the optimum site for vehicles or facilities for efficiency and time minimizing (Hamacher et al. 2013).

COMPARISON OF DISCRETE AND CONTINUOUS MODELLING

Time modelling in dynamic network flow research considers discrete time steps and continuously monitored time. Discrete research typically uses the time-expanded network, either explicitly in algorithms or implicitly in proofs to produce theoretically or practically efficient algorithms (Ford & Fulkerson, 1962). Research on the continuous approach considers networks with time-varying capacities and costs for optimal solutions whilst generalising the model (Fleischer & Tardos, 1998; Hall, Hippler & Skutella, 2003). Whilst there are practical solutions for discrete time problems, theoretical results occur for continuous time problems which are reduce to discrete time (Kotnyek 2003). Hence, this research focuses on the discrete time model for dynamic emergency logistical planning.

SYSTEMS MODELLING POST-DISASTER

There is little research interest in post-disaster modelling, and this has consequences for disaster response organisations who require financial and physical resources and competency training maintained at a high level for an optimum response. Of those who have investigated disaster response from a system modelling approach, Ramezankhani and Najafiyazdi (2008) studied a location-specific earthquake zone in Iran, where the city of Bam was largely destroyed in 2003. Their approach was to build up a dynamic system to simulate the disaster response teams' activities in the zone after a subsequent earthquake within the relevant fault lines. They developed a series of models specific for search and rescue teams, medical teams, food supplies, transport, and building debris removal, which were incorporated into a general systems model. However, this model was specific also to the response teams, not to recovery or maintaining response capacity after a disaster.

In a contemporary paper, Gonçalves (2008) as noted, proposed that disaster relief organisations could use system dynamics modelling to assist planning and maintain response capacity. Because of the nature of disaster responses as complex systems with substantial dynamic inputs, long time delays, multiple feedback effects, and nonlinear responses to decisions; simulation modelling can assist with relationships among variables, time-dependent results from decisions, and allow the exploration of new strategies. Models may be constructed with many variables, such as Ramezankhani and Najafiyazdi (2008) used, but on an organisational level rather than a response level.

Other disaster relief models at a national level were developed by Pettit and Beresford(2005) in regard to military-non-military response, and Helbing (2012). Helbing noted thecascading effects of large-scale disasters, which occur through non-linear and/or networkinteractions. The effects of the disaster spread in many different fields, such as disease, and thecollapse of trust and civil order in the face of overwhelming adversity. Systems modelling can beused to identify sources and drivers of systemic risks post-disaster and these show that linear, intuitive, or experience-based approaches may not capture the functioning of social and economic systems. An inability to react to external factors in decision making can lead to under-control and failure to establish a strong response, leading to unwanted side effects, and sudden paradoxical shifts. Using a dynamic systems approach allows anticipation of events, avoidance, or for decision-makers to mitigate systemic risks and certain disasters resulting from them.

COMMUNICATIONS AND INFORMATION SHARING

In all emergencies, communications are vital to managers and operations. Data flows are critical to rescue operations and telecommunications are among the first systems to fail in an emergency. There are several categories where communications failure may occur, and this section reviews the literature in this regard.

Table 1, below, provides three levels for communications and data sharing, community (government agency or crisis centre), agency, and individual. For the government/community level, collaboration is constrained by the various organisations and their disparate goals in responding to the crisis and possibly the lines of communication that require one responsible person to respond to the crisis centre, rather than lateral responses between the disciplines of each contributing organisation.

Further, each agency is restricted to its protocols and its individual responsibilities, that is, according to various tasks to certain groups or individuals. Finally, communication failures among individuals and an attempt to gain information rather than passing it along constrains communication flows (Bharosa et al. 2016).

Table 1. Overview of information sharing and coordination problems (Bharosa et al. 2016)

Coordination level	*Perspective being adopted*	*Typical problems*
1. Community	Institutionalisation and political power between actors, Interorganisational interdependencies and collaboration procedures	Organisational silos, no incentives for horizontal information sharing, conflicting role structures, mismatch between goals, independent projects, lack of meetings, standardisation/interoperability, heterogeneous systems
2. Agency	Organisational procedures, division of roles, tasks and responsibilities, standards, values and rules	Reliance on protocols, focus on vertical information sharing, allocation of responsibilities, contact persons, privacy, security and authentication
3. Individual	Human cognition/perception of uncertainty and time pressure, Personal propensity to adopt innovations	Information overload, inability to determine what should be shared, misinterpretation of information, bounded rationality, prioritisation of own problems, information quality, system quality, access limit

CONCLUSIONS

In planning for disaster response, the magnitude of each event appears to defeat the efficacy of aid distribution to those who most need it. Despite national foreknowledge of the effects of disasters, maximum preparation, and the prompt response of physical and human resources to a site, seemingly these actions are still inadequate in mitigating the effects of overwhelming and chaotic situations. There are several logistical reasons for this: the country's disaster response framework, the preparedness of the emergency teams, the geophysical conditions and proportions of the disaster, the unpredictability of the course of events, and the vulnerability and numbers of people involved. Grounded in specific places and times, data collection from the disparate and unfolding events could allow predictions of the path of destruction, more effective communications and targeting of aid, including routes open for delivery from distribution centres. System modelling takes this a stage further, allowing robust models to be developed that can respond on a sectional basis and to real time data flows.

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