Chapter 21
Modeling Uncertain and Dynamic Casualty Health in Optimization-Based Decision Support for Mass Casualty Incident Response

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ABSTRACT

When designing a decision support program for use in coordinating the response to Mass Casualty Incidents, the modelling of the health of casualties presents a significant challenge. In this paper we propose one such health model, capable of acknowledging both the uncertain and dynamic nature of casualty health. Incorporating this into a larger optimisation model capable of use in real-time and in an online manner, computational experiments examining the effect of errors in health assessment, regular updates of health and delays in communication are reported. Results demonstrate the often significant impact of these factors.

INTRODUCTION

Mass Casualty Incidents (MCIs) can arise in a number of disaster scenarios including, for example, terrorist attacks. They are predominantly characterised by the presence of a large number, relative to the level of available resources, of injured people who must be processed (that is, triaged, rescued, treated and transported to hospital) in as efficient a manner as possible. Deciding how such a processing operation should be carried out is a complex task, in that many inter-dependant

DOI: 10.4018/978-1-4666-6339-8.ch021

decisions must be made in a coordinated manner and under challenging temporal constraints. One potential route to improved decision making is through the design and implementation of a decision support program.

When designing a decision support program for use in MCI response, we aim to produce a tool which will supply the decision makers with advice to assist in the formation of a high quality response operation. In an optimization based program, two components are of fundamental importance – the mathematical model and the optimization algorithm used to find solutions in the model. When considering our aim of delivering high quality advice, development on both components can contribute. The contribution of the optimization algorithm is particularly clear, where increasingly sophisticated algorithms can find higher quality solutions in a shorter time. However, the potential for focused model development to increase performance should not be overlooked. Poorly designed models which have neglected to include pertinent details or rely on invalid assumptions will, regardless of the optimization algorithm employed, lead to unrealistic and/or irrelevant advice being passed to the decision maker which, if followed, will result in poor performance. The potential benefit arising from the inclusion of a particular detail or feature into the model can be quantified through computational experiments, and therefore is directly comparable with any benefit afforded through increasingly sophisticated algorithms.

In the immediate response to an MCI two objectives of clear importance are the protection of human life and the minimisation of suffering (Cabinet Office, 2010). It follows that any model of MCI response should incorporate these objectives in some manner, possibly implicitly. In order to do so, careful consideration must be given to the nature of casualty health in MCIs, considering its representation, dynamic behaviour and the stochastic nature of its measurement.

Casualty Health in MCIs

In MCI response in the UK a triage system is employed when measuring the health of casualties. The purpose of triage (derived from the French *trier*, to sort) is to partition casualties into a number of categories which reflect the urgency with which they require treatment. The resulting information can then be used when deciding how to allocate scarce resources to a large number of casualties, prioritising those who are likely to benefit most.

Two triage systems are used in UK MCI response, each working at a different level of granularity. The first is triage *sieve*, which is carried out immediately following an MCI and must be completed before any treatment can take place. The outcome is the classification of each casualty into one of four categories as described in Table 1 (A. L. S. Group, 2011). A physical label, colour coded according to the triage category, is affixed to the casualty to allow for rapid recognition by other responders during the remainder of the response operation.

These categories are used in the first stage of the MCI response, where casualties must be extracted from the incident site and taken to a designated

Table 1. The four health states used in triage operations.

Category	Description	Explanation
T1	Immediate	Require immediate life-saving procedure
T2	Urgent	Require surgical or medical intervention within 2-4 hours
T3	Delayed	Less serious cases where treatment can be safely delayed beyond 4 hours
T4	Deceased	-