Unmanned Aerial Vehicle - Assisted Mobile Edge Network for Disaster eHealth Communications and Resource Allocation Services

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Background

During and after disasters, rescue operations face a number of difficulties as the obstacles for effective and efficient operation. This research concentrates on resource allocation in regard to casualty.

- Most resource deployment strategies are generated manually by professional people associated with their experience (Muaafa, Concho and Ramirez-Marquez, 2014) that may not always be optimal in every case.
- Disasters are unpredictable therefore resource allocation can be complicated due to difficulties in obtaining accurate situation analysis and rapid changes in conditions.
- Information from affected areas may be inaccurate so that accomplishing tasks can be hindered by unforeseen or unexpected issues.
- The requirements and the situations of disaster victims may also change . For example, healthcare requirements may change for both those injured by the disaster and those with pre-existing conditions..

Objective

Disasters can cause mass casualties but resources and time can be in short supply. In this research the following objectives are set:

- Optimizing the response time and emergency resource allocation (by considering the cost factor).
- Identifying the optimal number and the locations of temporary emergency units.
- Calculating the optimal number of emergency vehicles dispatched from each emergency medical centre.

Modelling

This research uses a Multiple-Objective (MO) optimization model to solve the resource allocation problems after disasters. Moreover, this model can enhance the efficiency of emergency response strategies .

An algorithm named Probabilistic Solution Discovery Algorithm (PSDA) is used to solve the multi-objective optimization problem.

In order to describe disaster rescue issues, any region can be divided into multi-sections marked with numbers. In this research we have selected Auckland as our case study (Figure 1). The necessary resources are located in particular sections, such as emergency vehicles, food and water.

TEU : Temporary Emergency Units.
EMS: Emergency Medical Service.

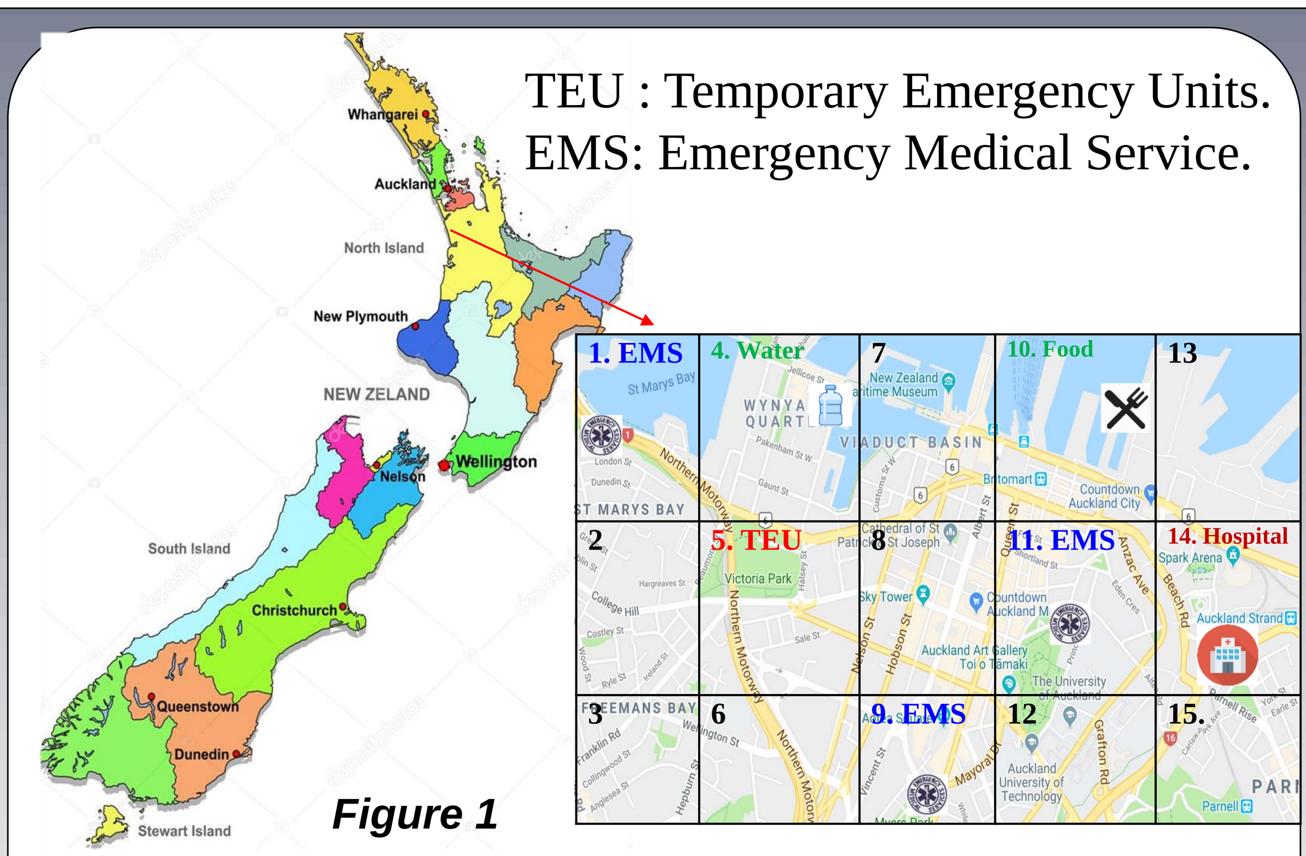

Figure 1

Formulations

1- Response Time

MC_i: Medical Center. It includes both EMS_i and Hospital.
H_{ij}: number of vehicles dispatched from MC_i to TEU_j.
t_{ij}: travel time from section i to section j.
V_{jk}: number of victims to be evacuated from section *k* to TEU_j.
Z_j: the total number of emergency vehicles dispatched to a TEU_j.

$$\min RT = \frac{\sum_i \sum_j H_{ij} * t_{ij}}{\sum_i \sum_j H_{ij}} + \max_{1 \le j \le N} \left(\frac{\sum_k 2 * V_{jk} * t_{jk}}{Z_j} \right)$$

RT gives the average time of dispatching vehicles from TEU to MC and the maximum average time needed to evacuate victims from section k to TEU_j.

2- Total Cost

TEU in section j is indicated as TEU_j. Each TEU_j has two statuses,1 or 0.
$TEU_j = 1$ means that a TEU is deployed at section j.
$TEU_j = 0$ means that no TEU is allocated at section j.
d_{ij}: distance between section i and j.
d_{jk}: distance between section j and k.
A^C: operation cost of each emergency vehicle.
C_j^F : the initial cost of allocating a TEU in a given section j.
A^P: the procurement cost of each emergency vehicle
W^T: total cost of consumed water.
F^T: total cost of consumed food.

$$\min TC = \sum_i \sum_j H_{ij} * d_{ij} * A^C + \sum_j \sum_k V_{jk} * d_{jk} * A^C + \sum_j C_j^F * TEU_j + \sum_i \sum_j H_{ij} * A^P + W^T + F^T$$

TC accounts for the total cost of vehicles dispatched from MC_i to TEU_j, evacuating victims between section j and k, deploying TEUs, procurement of each emergency vehicle, food and water. Based on the MO model and the mentioned equations, an evolutionary algorithm is used.

- Each generation of the algorithm generates an optimal solution.
- Each solution represents an emergency medical response strategy.
- Each response strategy has different locations, different dispatching configurations for emergency vehicles, and different evacuation plans for transporting victims.
- This algorithm can help decision-makers to estimate the trade-offs using strategies with different response time and cost values.

UAVs Mission Planning and Data Sensing

In order to facilitate information gathering from each section of the map (Figure 1), an Unmanned Aerial Vehicle (UAV) are used such that its path is simulated by MATLAB based on a path searching algorithm (Figure 2). In Figure 2 circles are obstacles (generated randomly by MATLAB), and the green curved lines are UAV's path. As it is illustrated, the UAV will bypass all the obstacles on its path.

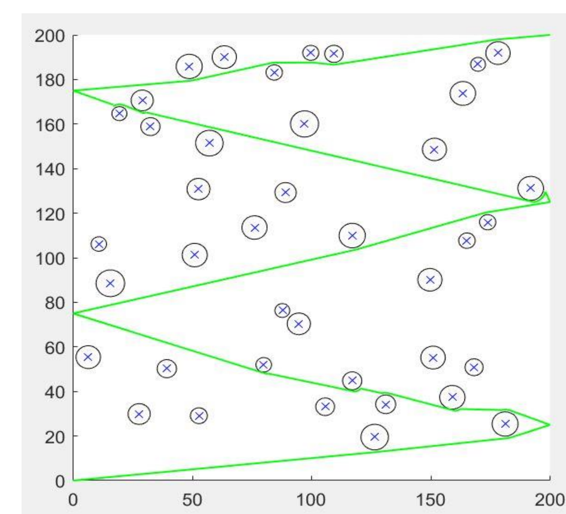

Figure 2

Figure 3

As UAVs can bypass obstacles while they are navigating, they can be utilized in disaster affected areas for searching and collecting information of either victims or available/required resources.
By mapping UAV path to our case study map (Figure 3), we can collect information such as the location, number and situations of victims and rescue resources, and the locations and amount of hospitals, EMSs, food, water, emergency vehicles
The UAVs can broadcast the information to EMSs, hospitals and medical assistance centers to operate rescue actions after the processing is done.
Based on the captured information, the emergency response strategy can be generated through the implementation of PSDA.

Results

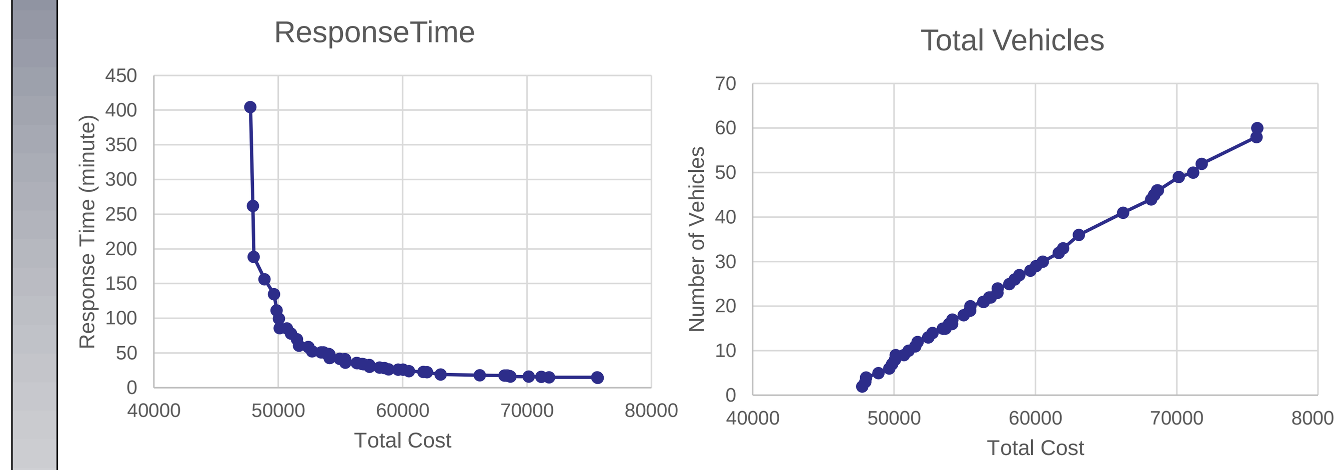

Figure 4

Figure 4 illustrates the relations of response time and total cost, vehicles and total cost respectively. Total cost consists of the summation of the cost of emergency vehicles, water and food. The diagrams show that the total cost increases as the number of the emergency vehicles increasing but the response time decreases. When all the vehicles are dispatched (65 vehicles), the total cost is the maximum, but the response time is a minimum. If the vehicles used are the minimum, for example, one vehicle, the cost is the minimum, but the response time is the maximised.

Conclusion & Future Work

The goal of the research is to find a trade-off point which makes the optimal balance between the cost and the response time. This research presented an MO optimization method which can help decision-makers to decide and make the optimization of the combination of the response time, cost and emergency vehicles and to design an effective response tactics to a disaster. We also discuss, the use of data collected by UAV as the input to the algorithm.
Future research is to find shortest paths from distinct medical centers to victims in various sections.

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