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Web Based Tool for Resource Allocation in Multiple Mass Casualty Incidents

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Abstract— **In this paper we introduce a web based real time resource allocation tool that can assist the incident commanders and resource managers in the complex task of resource allocation and transportation for multiple simultaneous incidents that occur in close geographical proximity. The tool takes real time inputs like the location of emergency sites and damaged routes from Google Maps, generates an optimal transportation plan so that emergency sites with highest priorities for a resource are assigned the resources in the least amount of time. The optimal solution is presented graphically using Google Maps. Our solution can be used for emergency resource allocation at both the initial response stage and later stages.**

Index Terms— **Decision Support Systems, Emergency Resource Management, Mass Casualty Incidents, Resource Allocation**

I. Introduction

Optimal deployment of emergency resources in multiple mass casualty incidents is a challenging task due to the competition for the limited available crucial resources (e.g. emergency personnel, vehicles, equipment and supplies) and the damaged transportation infrastructure (congested, blocked or destroyed roads). Timely allocation of resources during an incident plays a crucial role in an effective response system.

The IS-703 course [1] (National Incident Management System-NIMS resource management) offered by the FEMA Emergency Management Institute, mentions that in case of complex incidents, "*It may become necessary to move from a first-come-first-served protocol to an incident and/or resource prioritization system, requiring additional policy and technical assistance*".

To meet these guidelines a decision support system that performs resource allocation needs to meet the following requirements: 1. consider multiple emergency sites in close geographical proximity and multiple resource depots, 2. consider the resource requirements and their priorities at each emergency site, 3. consider real time inputs that can affect the resource allocation like damaged routes, 4. easy to use web based user interface that can be viewed from any location.

A number of research papers propose various decision support systems for disaster management [2-4]. Although they use similar optimization techniques to frame the resource allocation problem, none of these papers meet requirements 1-4 mentioned above.

Our tool can assist incident commanders and resource managers in this complex task of resource allocation and transportation for multiple simultaneous incidents that occur in close geographical proximity. The proposed system is a real time web based tool for resource allocation (RETRA) that takes real time inputs like location of emergency sites and damaged routes from Google Maps, generates an optimal transportation plan so that emergency sites with highest priorities for a resource are assigned resources in the least amount of time. RETRA will inform the incident commander on the arrival times of resources to the emergency sites. RETRA will also provide dispatching information to each resource depot about the deployed resources and the transportation routes. RETRA can be used for emergency resource allocation at both initial response stage and later stages.

The paper is organized as follows. RETRA system architecture is discussed in Section 2 and the RETRA decision support system is presented in Section 3. Section 4 describes a hypothetical disaster scenario and how RETRA handles such a scenario. The conclusions are reported in Section 5.

II. System Architecture

RETRA's architecture is composed of the following components as shown in Figure 1:

a. Real Time Inputs: Inputs to RETRA include disaster location, requested resources and any routes damaged due to the emergency. Requested resources along with the priorities will be given by the Incident Commander.

b. Available Resources Database: A database of the available emergency response resources and their location within a certain radius of the disaster area is available. The emergency response resources include: Emergency medical services (EMS) teams, fire fighters, cops, hazardous material (HAZMAT) teams, etc.

c. Decision Support System Optimization Solvers:

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Optimization solvers like MATLAB optimization toolbox are used to solve these linear integer programming problems. The output of the solver is a transportation plan that includes the number and kind of resources allocated from each resource depot to the disaster site as well as the deployment route.

d. Visualization Unit: It displays the transportation plan obtained by the optimization solver on Google Maps using Google Maps API.

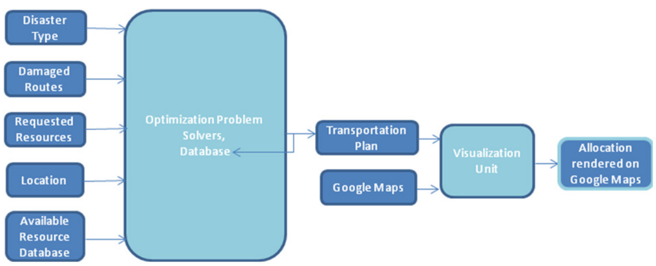

Figure 1. RETRA architecture

A block diagram showing implementation details of the RETRA system is shown in Figure 2. The proposed system is currently under development.

1. User Interface (UI): The UI takes input from the Incident Commanders and renders output on Google Maps. The UI also enables to add and delete resource depots. It is designed using HTML pages with JavaScript.

2. PHP Hypertext Preprocessor (PHP) server: A server implemented in PHP is used to interface with (MySQL) database and MATLAB optimization solver.

3. MySQL database: MySQL databases are used to store details about resource depots, available number of resources at each depot.

4. MATLAB optimization solver: A MATLAB optimization solver to solve the optimization problem in Section 3.

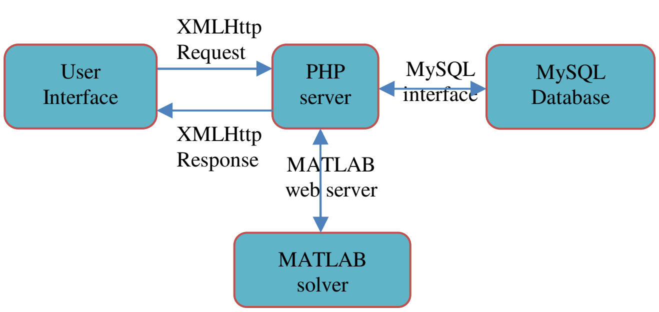

Figure 2. Implementation of RETRA

III. Decision Support System Algorithm

RETRA makes the following assumptions:

1. As localities enter into mutual aid agreements with neighboring localities, we assume that total available resources at all the depots are more than the requested resources at emergency sites. This means that there is no unsatisfied demand.

2. The demand and priority for a resource at a site is given by the incident commander or it is estimated by the resource manager based on the type and severity of incident. As per IS-703[1], "*MAC (Multi-Agency Coordination) Groups will be established to prioritize and coordinate resource allocation and distribution*". Priority is given on a scale of 10. With our model a given resource can have different priorities for different quantities. For example an emergency site can require 3 ALS (Advanced Life Support) units with priority 10 and 2 ALS units with priority 5.

3. Location of resource depots, quantity of available resources and the number of vehicles available to carry these resources is known.

4. Travel time between two locations is obtained from Google Maps API.

5. This optimization problem is solved per emergency resource.

<u>Decision Variable:</u>

x_{ij} - Quantity of a given resource to be allocated from Depot i to Emergency Site j

<u>Input Variables:</u>

S = {S_1, S_2…} denotes the set of Depots;
D = {D_1, D_2…} denotes the set of Emergency Sites;
R = {R_1, R_2…} denotes the set of Resources;

d_j - Number of resources requested from Emergency Site j

p_j - Priority for resource at Emergency Site j.

a_i - Total number of resources available at depot i. We assume that there are sufficient resources at all depots to meet the demand, i.e.

$$\sum_{i \in S} a_i \geq \sum_{j \in D} d_j$$

t_{ij} - Transfer time per transportation vehicle from depot i to emergency site j

n_i - Number of resources per transportation vehicle at depot i

N_i - Maximum number of resources accommodated by transportation vehicles at depot i

<u>Objective Function:</u> Minimize the duration of time to deploy resources to the emergency site.

$$Min\left(\sum_{i \in S}\sum_{j \in D} p_j t_{ij} \delta_{ij}(x_{ij})\right) \qquad (1)$$

$$\delta_{ij}(x) = 1 \text{ if } x > 0$$

$$\delta_{ij}(x) = 0 \text{ if } x = 0$$

under constraints:

1. Resources allocated should be a positive integer.

$$x_{ij} \geq 0 \qquad \forall i \in S, \forall j \in D$$

2. Allocate resources to meet the demand at each emergency site.

$$\sum_{i \in S} x_{ij} = d_j \qquad \forall j \in D$$

3. Number of required vehicles to carry the resources from depot i can not exceed the number of available vehicles, N_i

$$\sum_{j \in D} \left\lceil \frac{x_{ij}}{n_i} \right\rceil \leq N_i \qquad \forall i \in S$$

A summary of notations is provided in Table 1. The resource allocation problem is solved by using MATLAB's optimization toolbox. The output is transformed into a Google Map which graphically represents the resource deployment using Google Maps API.

Table 1 - Summary of notations

Notation	Description
x_{ij}	*Quantity of resource to be allocated from Depot i to Emergency Site j*
d_j	*Demand for resource to from Emergency Site j*
p_j	*Priority for the resource at Emergency Site j*
a_i	*Total amount of resource at depot i*
t_{ij}	*Time taken to transfer resource from depot i to Emergency Site j per transportation vehicle*
n_i	*No of resources per transportation vehicle*
N_i	*No of transportation vehicles at depot i*

IV. Hypothetical Disaster Scenario

In this section, we will describe a hypothetical disaster scenario and explain how RETRA deploys emergency resources in this scenario. Assume that there are three emergency sites and three EMS depots. For simplicity, let us assume that all emergency sites require Advanced Life Support (ALS) of type-1, leading to competition for this resource. Note that RETRA can solve resource allocation problem with any number of emergency sites and resource depots.

Table 2 represents the estimated time taken to travel from EMS locations to emergency sites. This information is obtained by finding the time taken to travel between the location of emergency sites and EMS locations using Google Maps. Traffic information obtained from Google Maps is also used while calculating this matrix.

Table 2 – Transport time matrix, t_{ij}

Resource Depot	Emergency site 1	Emergency site 2	Emergency site 3
EMS 1	10	15	10
EMS 2	5	9	8
EMS 3	12	10	6

Table 3 represents the available resource matrix at each EMS location. This information is obtained from the available resources database. Table 4 represents the demand matrix. This matrix is obtained from the Incident Commander at each emergency site or from the resource managers. Table 5 represents the output allocation of resources to various emergency sites from EMS centers. It represents how much of a resource should be moved from each EMS center to emergency sites. MATLAB's optimization toolbox is used to solve the problem.

Table 3 – Resource matrix

Resource Depot	Available number of ALS-Type1 ambulances a_i	Number of paramedics per Ambulance n_i
EMS 1	15	4
EMS 2	10	4
EMS 3	8	4

Table 4 – Demand matrix

	Resource Demand d_j	Resource Priority p_j
Emergency site 1	15	5
Emergency site 2	5	7
Emergency site 3	13	6

Table 5 – Resource allocation matrix, x_{ij}

Resource Depot	Emergency site 1	Emergency site 2	Emergency site 3
EMS 1	5	0	10
EMS 2	10	0	0
EMS 3	0	5	3

Graphical representation of the resource allocation matrix rendered on Google Maps is shown in Figure 3. It shows the ALS Type-1ambulances allocated to the Emergency Site-1 from various EMS locations. Timeline diagram showing the allocation of ALS Type-1 ambulances is shown in Figure 4.

RETRA solves the allocation problem for each resource that is required by the emergency sites. The information about the estimated arrival time of resources will be helpful to the Incident Commanders for better coordination of resources at emergency sites.

V. Conclusion

The proposed RETRA tool allocates resources to the emergency sites and renders the output onto Google Maps. This is the first model to take into account multiple emergency sites, multiple resource depot, the priorities of resources, and real time traffic information obtained from Google Maps. The proposed real time web based tool RETRA integrated with an emergency response information collection system like DIORAMA [5] can be a comprehensive solution for resource management in multiple complex emergency incidents.

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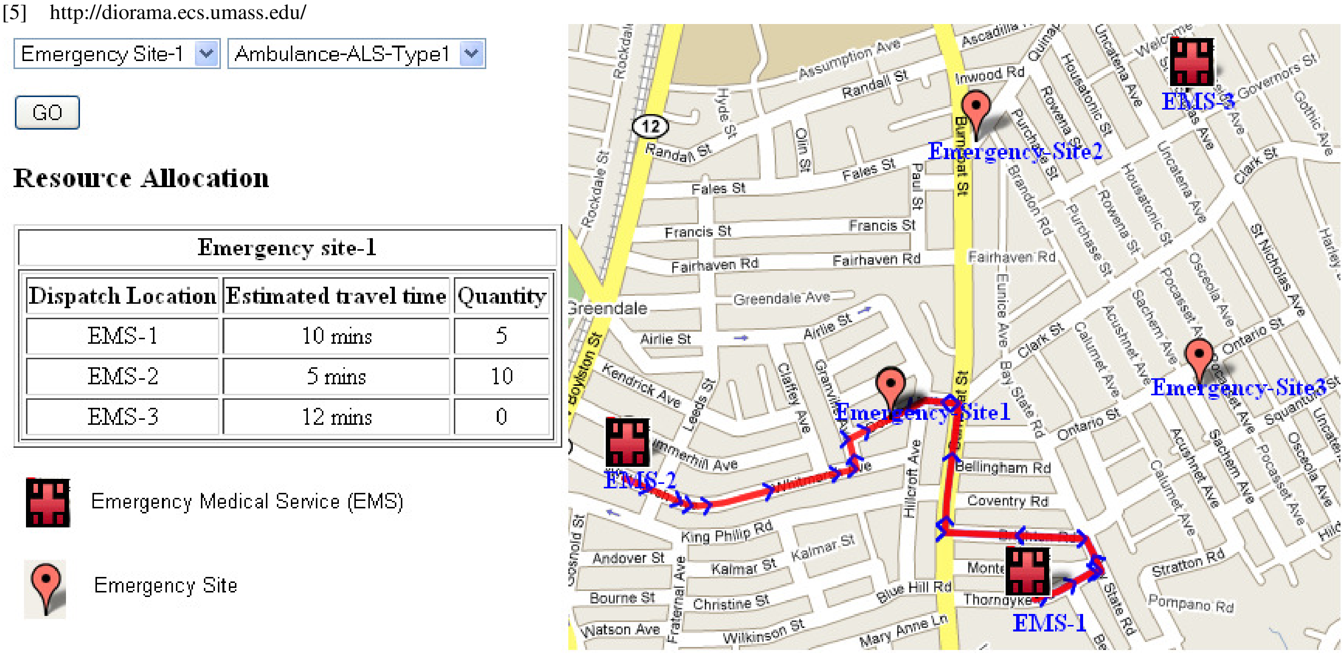

Figure 3. Resource Allocation for Emergency Site-1 for resource Ambulance-ALS-Type1

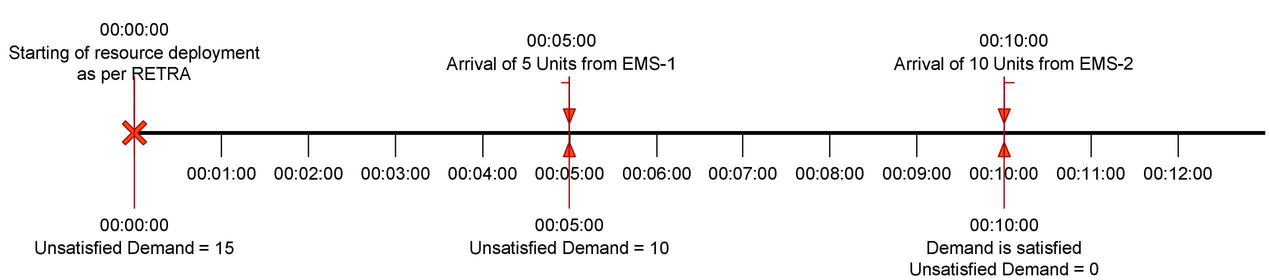

Figure 4. Timeline showing Allocation of ALS-Type1 Ambulances to Emergency Site-1