Optimal Resource Allocation & Scheduling During Adversity Recovery Plan

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Abstract

The optimal Resource Allocation and Scheduling during Adversity Recovery (RASAR) is associated with the mobilization/execution of required resources of personnel/material within the affected area of relief operation. This is comprised of various facilities, equipment, methods, utilities to deploy, distribute, install and control between heterogeneous inflows and distribution to the victim and damaged location in the disaster area. An ICT driven system that can coordinate and collaborate multi-Resource mobilization to immediately improve the drastic conditions at all the levels has been identified as an utmost priority and need for the Society.

This work demonstrates both conceptual framework and the ICT implementation of an optimal generalized methodology. This methodology assesses and triggers the routing and scheduling of diverse resources at the defined operational area to efficiently and effectively target the damage control.

Index Terms—Resource allocation, routing, scheduling, recovery plans, heuristic search, disaster management.

1. Introduction

In the last decade, serious shortcomings during adversity management operations such as earth quake, tsunami explicitly illustrated the need for mobilization process improvement[1]. As a result, the development of a methodology that integrates diverseresources to more efficiently andeffectively plan and execute logistics support within a disaster area has become the utmost priority and immediate need for the entire society. Achieving better resource allocation efficiency mandates that we have to discard the conventional "just-in-case" approach and move to a rapid and reliable routing process that provides time definite deployment of resources to victims[2]. Responding to this requirement, various agencies initiated the development of Geo-ICT[3] based automated Disaster Management System which enables operators/planners to react to frequently occurring contingency situations.

They are also trying to develop a scalable model that meets the largefatal adversity management requirements. Resource distribution is the flow of personnel, materiel and services within disaster area to overcome the damaged caused. The Recovery Plan[4] is comprised of facilities, utilities, manpower, installations and procedures designed to assess, collaborate, receive, store, maintain, distribute and allocate the flow of resources between heterogeneous inflows and distribution to the victim and damaged location in the disaster area. Such a recovery system may be efficiently represented by a network where the associated physical entities are categorized as nodes, modes and routes.

This paper describes an improvised methodology that provides allocating, routing and scheduling of heterogeneous resources at the specified demand area to provide efficient time definite deployment of facilities to victims for generalized adversity situations. The model developed has been found to be robust, flexible, and capable of solving typical disaster problems (post disaster recovery plans).

Mathematical optimization[5] search was the underlying framework utilized in the development of this methodology and several other significant concepts were taken into account during the associated research.

2. Problem Statement

A Resource Allocation and Scheduling during Adversity Recovery (RASAR) methodology should
provide adversity management planners with a system that supports efficient resource routing and scheduling plans that achieve time constraint deployment of required facilities to victimized area. As explained below, modeling requirements for the RASAR extend well beyond those of the conventional resource management [6] in disasters. 

During a typical adversity, there are multifaceted resource requirements with differing characteristics such as medical services/ambulances, transportation (air, ground, and water), fire services, shelter homes, communication systems, food supplies. Resource allocation requirements include the ability to make multiple deployments during the planning horizon, the ability to perform direct services from outside the disaster area and the ability to retain at damage prone locations. Scheduling considerations include resource availability, service times, load times, and unload times. All resources operate from their control center or a hub.

Resource distribution network nodes are control centers, hubs and victim/victimized locations. Control centers are the supply nodes. The hubs or support areas in the vicinity of disaster area are intermediate nodes, which coordinate, collaborate and regulate resources. Victims are sink nodes that receive the facilities. All nodes have time critical constraints, sequencing and location constraints. Hubs have resource storage constraints and victims have time definite facility demands.

A RASAR has three types of time slot constraints: early time allocation (ETA), timely allocation (TA) and multiple time windows (MTW) for non allocation and non deployment. An ETA stringently defines a victim service starting time but does not constrain resource allocation or deployment times. A TA defines when a victim service must be complete but does not constrain service occurrence, or resource allocation and deployment times. MTWs restrict resource allocation and deployment at a node but do not stipulate when facilities are loaded or offloaded. There are two types of location constraints. A working location limits the number of resources that can simultaneously service a victim. A parking location limits the number of resources placed at a victimized location.

The RASAR has tiered distribution architecture. The first order tier contains the control centers and hubs/victims served by the control centers. Middle tiers consist of hubs that service hubs/victims. The last order tier consists of victim served by a hub. Each tier is a self-contained distribution network. However, they are not independent of each other. Lower ordered tiers are dependent on higher ordered tiers. For example, the hubs in a lower ordered tier receive facilities as victim within a higher ordered tier. Once a hub receives its resource supply, it can then distribute these to its victim.

Fig. 1 presents an example of a RASAR. There are four tiers within this network: Tier 0 is the HQ with victim (1, 2, Agency); Tier 1 is the Agency hub with victim (Dep.1, Dep.2, 3); Tier 2 is the Dep.2 hub with victim (Actor3, Actor4, and5); and Tier 3 is the Dep.1 hub with victim (Actor1, Actor2, and 4).

Note that unlike a conventional network hierarchy, both Tiers 2 and 3 derive from Tier 1. Hubs distribute resource after it is received and executed. Resource, characterized by the facility delivered and time of delivery, is allocated and prepared for execution to its next victim. Resource is either supplied directly or kept for later delivery.

The RASAR primary objectives are to minimize unmet victim demand (demand shortfall), late supplies (shortfall), resource utilization costs and resource mobilization costs. Late supply times are weighted by the amount of facilities delivered late.

3. RASAR Methodology

Heuristic Search Optimization (HSO) has been used successfully to attack several difficult combinatorial optimization problems [7]. Based on previous results we are sure that it will provide an efficient and effective means to find quality RASAR solutions. Fig. 2 provides foundations and description of how the RASAR is represented in the...
HSO framework and a description of the HSO methodology employed.

3.1 Modelling Assumptions

It is a recognized fact that no “real-world” problem’s inherent complexities can be captured in a usable model of manageable size. For this reason, while preserving the methodology’s capability for practical planning purposes, number of assumptions has to be incorporated into the HSO representation of the RASAR e.g. sufficient supplies of required resources are available at time 0 at headquarter or control locations, resource utilization and forwarding are independent of victim and local conditions etc.

3.2 Overview Of HSO

In this section, the HSO architecture used to solve the RASAR is presented. Fig.3 graphically depicts this architecture which is partitioned into a Pre-HS phase and the HS phase. Figure 3 pictures an overview of the HSO for the RASAR with all the major components of each procedure within each phase.

3.3. The Pre-Heuristic Search Phase

The Pre-HS phase achieves the following:

(i) Sets parameter values and assimilates a file containing the victims and resource specifications for the current problem to be solved.

(ii) Generates the group neighbourhoods and

(iii) Creates and evaluates an initial solution. A greedy assignment heuristic [8] creates the initial solution by assigning prioritized victims to resources that best meet their demands.

Vic2mPriorityRating = \frac{\text{vict}_i \text{Demand}_i \times \text{periodLength}/\text{TDD}_i(n - i)}{\text{vict}_i \text{Dist} \times \text{avgDist}}

where

- \text{TDD}_i = \text{TDD} \text{ (Time Definite Delivery)} \text{ requirement index per victim}
- \text{n} = \text{number of TDD requirements per victim}
- \text{vict}_i \text{Demand}_i = \text{victim TDD requirement for index} \text{i}
- \text{vict}_i \text{Dist} = \text{distance of victim to nearest depot/hub}
- \text{avgDist} = \text{average distance of all victims to their nearest depot}
- \text{vict}_i \text{Demand}_i = \text{victim demand}
- \text{periodLength} = \text{total model time period}

Resources are ordered based on the ratio of their capacity and average delivery time.

\text{ResCapPerAvgDeliveryTime} = \text{resCap}/(2 \times \text{avgDist}/\text{speed} + \text{loadTime} + \text{unloadTime} + \text{rebuildTime})

where

- \text{resCap} = \text{resource capacity}
- \text{speed} = \text{resource shifting speed}
- \text{loadTime} = \text{time to initiate a resource}
- \text{unloadTime} = \text{time to unload a resource at victim site}
- \text{rebuildTime} = \text{time to rebuild a resource}

Once created, the initial solution, or first incumbent solution, is evaluated according to an objective function that assesses the demand filled shortfall,
TDD shortfall, fixed costs, variable costs and other penalties

3.4 The Heuristic Search Phase

Running until a termination criterion is satisfied[9], each iteration of the HS phase passes through five major components; move neighborhood generator, solution evaluator, strategy manager, list manager, and move operator. An iteration begins by generating and applying a move neighborhood to the incumbent solution and ends when the move operator creates a new incumbent solution. The move neighborhood generator creates and applies move neighborhoods to the incumbent solution. Move neighborhoods are generated and employed based on solution attributes and data collection. This neighborhood extracts victim letters from cycles in order to reduce fixed and variable costs. It is specifically called when excess victim letters reside in cycles and when the strategy manager dictates implementing super diversification measures.

Working closely with the list manager, the solution evaluator determines the objective function value for each neighbor. The goal of this process is to find the best non-Heuristic objective function to replace the incumbent solution. The list manager uses the orbit and move lists to interact with the solution evaluator to prevent cycling within the HS process. The orbit list tracks traversed orbits and the move list tracks recent diversification moves. Both lists allow an element’s heuristic status to be determined and changed.

The strategy manager determines whether to continue with normal HS processes, to intensify or to diversify the search. Decisions are based on collected search data and search parameters.

4 Concluding Remarks

The development of an automated solution methodology to the RASAR problem has been characterized as a major priority and immediate need for the society. This paper documents groundbreaking new conceptual outcome based in a flexible heuristic search optimization (HSO) framework and presents a plausible implementation of this. This combination of theory and application will result in a robust, efficient, and effective generalized resource allocation and scheduling methodology. This methodology evaluates and suggests the routing and scheduling of multi-modal resource sets to provide economically efficient time definite delivery of these to victims of the disaster. Many programs are available that “perform” resource allocation and scheduling. However they do not prescribe highly effective, near optimal routes and schedules for all resources. Therefore, this model is the unique of its kind to offer this functionality.

References


