

Efficient Utilization of Mobile Facilities in Humanitarian Relief Logistics

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What is a Mobile Facility?

A mobile facility is a piece of equipment that can be provide a service to a population while stationary at a location, but can be also quickly transported between locations to provide service where it is needed most.

Examples of Mobile Facilities



Portable Cellular Base Stations

Mobile Medical Clinics



Mobile Food Service Vehicles



Objective

We study the use of mobile facilities to provide a service in humanitarian relief. Given the locations where a mobile facility may be stationed and the demand profile of a population requiring service, we have created algorithms to generate routes for a fleet of mobile facilities that maximize the total service provided during the planning horizon. We furthermore compare the use of mobile facilities to the use of static facilities in simulated data.

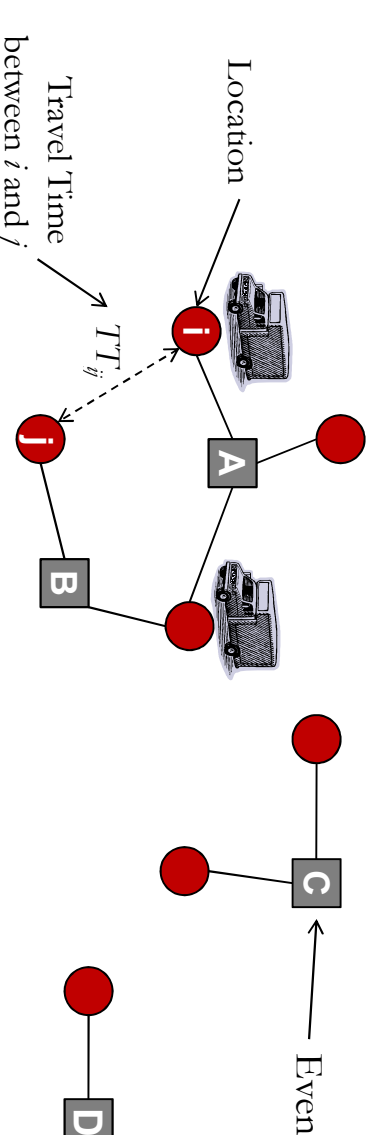
Why use mobile facilities?

- There are several distinct advantages that can be realized from utilizing mobile facilities.
 - Mobile facilities provide the ability to bring service to the location of an affected population. This eliminates the need for the population to have access to transportation to receive service.
 - Mobile facilities can provide aid to a population over a large geographic region where the establishment of more traditional fixed facilities is inefficient or cost prohibitive.
 - As the demand for a service changes, mobile facilities can be repositioned to maximize the service provided to a population.
 - Mobile facilities may be rapidly deployed after a disaster to provide relief quickly to an affected population.

Routing Mobile Facilities

Model Formulation

The problem of routing multiple mobile facilities is set in a continuous-time planning horizon, which starts at time 0 and ends at time T . The objective is to determine a set of routes for a fleet of mobile facilities that together service the maximum possible amount of demand. The model takes as input the following parameters:



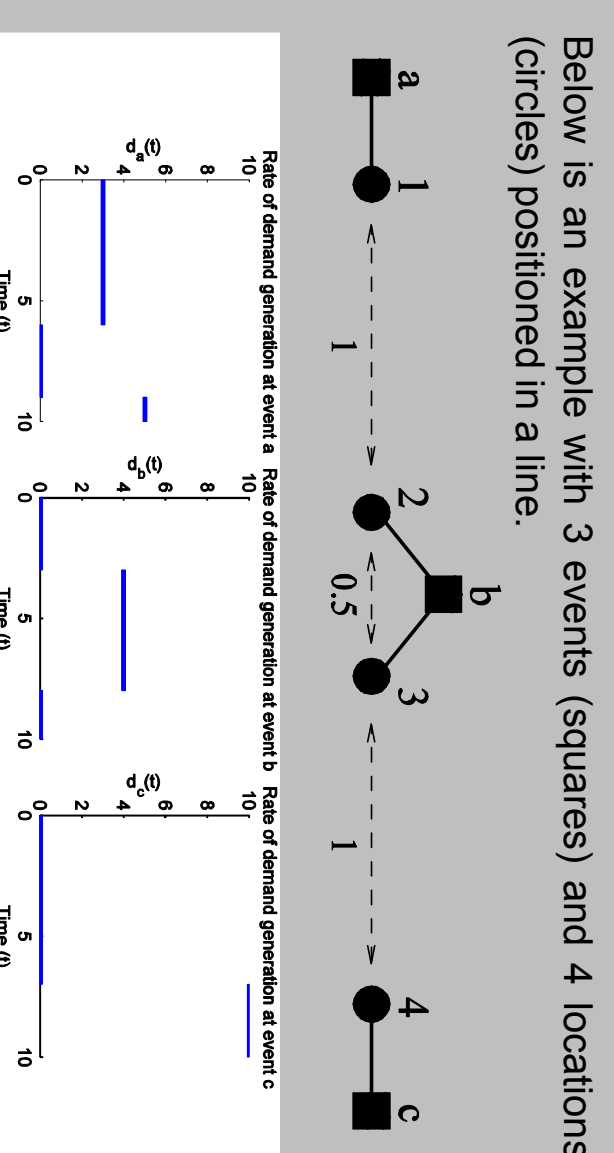
- M - The number of mobile facilities.
- L - The set of locations where a mobile facility may be positioned to provide service.
- E - The set of events generating demand for service.
- E_l - A subset of events nearby location l that can be serviced by a mobile facility at location l .

A route for a mobile facility consists of a sequence of locations for that mobile facility to visit, along with the arrival and departure times of the mobile facility at each location in the sequence. A mobile facility may arrive at a location or depart from a location at any time during the continuous-time planning horizon.

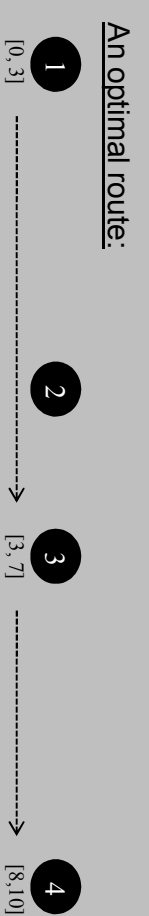
Routing Single Mobile Facility

A route for a single mobile facility on which it provides the maximal amount of service may be computed in **polynomial time** using dynamic programming. For a single mobile facility, there are a polynomial number of times when a mobile facility may either depart from or arrive at a location. These times are derived from the discontinuities of the functions $d_e(t)$ and the inter-service times between locations.

Example:



Suppose we have a single mobile facility with rate capacity 10. The mobile facility at location 1 between time 0 and time 5 would be servicing demand at rate 3 from event a, servicing a total of 15 units of demand.



An optimal route for a single mobile facility is to service demand from event a from location 1 from time 0 until time 1.5, service demand from event b from location 3 from time 3 until time 7, and service demand from event c from location 4 from time 8 until time 10. In total, 40.5 units of demand are serviced

Routing Multiple Mobile Facilities

- $d_e(t)$ - The rate event e is generating demand for service at time t . For computational results, we assume this function is piecewise constant.
- TT_{li} - The inter-service time for a mobile facility leaving location l to travel to location i ;
- c - The maximum rate a mobile facility may service demand.

We present three heuristics for generating routes for multiple mobile facilities. The heuristics draw upon the single mobile facility dynamic program when determining the route of each mobile facility.

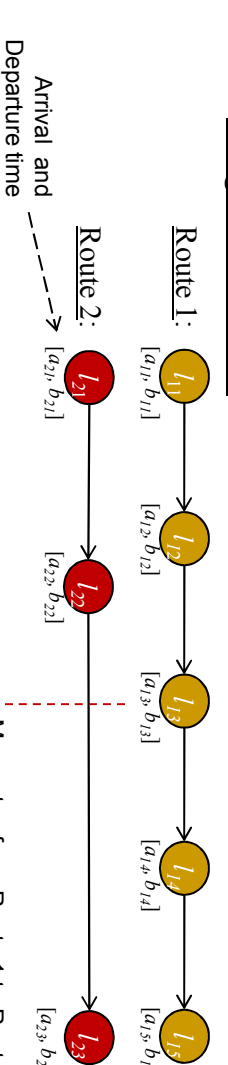
Routing Multiple Mobile Facilities

Sequential Routing Heuristic: The routes of the mobile facility are determined entirely at once and sequentially. Each route is generated to capture the maximum amount of unserved demand at the time of its creation using the single mobile facility dynamic program.

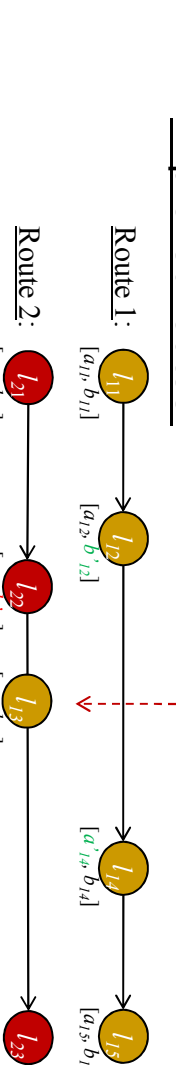
Insertion Heuristic: During execution, each mobile facility is allowed to visit only a subset of locations. The route of each mobile facility is determined by running the single mobile facility dynamic program using only the locations in the corresponding subset. The location with the most unserved demand is added to the subset for the mobile facility whose route it will improve the most. The process is repeated until no new improvements may be found.

Improving Routes: This local search algorithm looks for improvements in routes by trying to remove a stop from one route and insert it into a second route.

Original routes:



Improved routes:



During each iteration, we search for the best improvement. After the swap, the routes are recomputed using the dynamic program, with route 2 recomputed before route 1.

Simulating Data Sets

We test our heuristics on two types of simulated data. In both, locations and events are randomly positioned in the scenario area.

- The first type are intended to simulate realistic scenarios. The demand generated by each event simulates the demand from one of several types of events that might be expected to occur over the course of a day.
- The second type are intended to be mathematically challenging. In these scenarios, the demand for events is generated at random levels throughout the planning horizon.

Mobile vs. Fixed Facilities

How much extra service can be provided because of the capability of a mobile facility to be repositioned? We compared our heuristic solution for routing mobile facilities (the insertion heuristic with the route improvement procedure) with the optimal solution for positioning fixed facilities, which we computed using an integer program implemented in OPL.

Table 1: The average demand serviced in solutions generated by our heuristics and in the optimal static configuration of facilities. The results are averaged over data sets created with varying parameters.

Routing Heuristic	Demand serviced in scenarios simulating realistic events.	Demand Serviced in mathematically challenging Scenarios
Sequential Routing Heuristic with Local Search	140.93	2419.05
Insertion Heuristic with Local Search	140.02	2401.15
Optimal Static configuration of mobile facilities	121.77	2268.59

Conclusions

- The ability to relocate facilities yields the ability to provide significantly more aid to a population in need.
- Our algorithms produce routes that on average 15.7% more service may be provided. In some cases, as much as 49.8% more aid may be provided.
- Integrating application specific problem characteristics may produce the opportunity for further improvement.