Synopsis

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A mass casualty incident (MCI) is defined as an event that generates a number of casualties exceeding the capacity of local emergency medical services. Immediate treatment of MCI victims is critical, as delays in transport and care are associated with increased mortality among critically injured patients. An effective response requires coordinated allocation of patients to hospitals and strategic routing of ambulances through the road network, considering both congestion-induced travel delays and queuing delays at hospitals. However, existing studies only partially address these sources of delay. Models that incorporate hospital queuing typically rely on static traffic assignment, which fails to capture the dynamic buildup, propagation, and dissipation of vehicle queues or their spillback onto adjacent road segments. Also, the sole study employing a dynamic traffic model does not explicitly represent patient queuing at hospitals.

This thesis develops a simulation-based framework to allocate patients to routes and hospitals after an MCI, aiming to minimize total delay, defined as the sum of travel, waiting, and treatment times of all patients. The framework integrates a Link Transmission Model (LTM) for simulating traffic propagation and travel times with a Hospital Queuing Model for simulating patient waiting and treatment times. Because the relationship between patient allocation and total delay can only be evaluated through simulation and lacks a closed-form expression, commercial optimization solvers are unsuitable for this problem. Consequently, a genetic algorithm (GA) is proposed to identify a near-optimal allocation. Given the high computational cost of each simulation and the GA's need to evaluate numerous candidate allocations, a second-order polynomial regression model is developed as a surrogate and incorporated into the GA to reduce the number of required simulation evaluations.

Numerical experiments on the Sioux Falls network demonstrate that the GA with a surrogate model achieves state values comparable to those of the standard GA, while requiring significantly less computational time. This computational benefit becomes increasingly evident as the number of hospitals in the network grows. The study further investigates the sensitivity of patient allocation to both paths and hospitals, as well as total delay, in relation to patient demand and model parameters, including

free-flow speed, hospital treatment capacity, treatment time per patient, and the relative weights between travel time and hospital waiting and treatment time in the objective function. When hospital waiting and treatment times are small compared to travel time, the algorithm allocates a larger proportion of patients to hospitals closer to the accident node. Conversely, as waiting and treatment times become more substantial than travel time, patients are distributed more evenly across hospitals. These findings highlight the trade-off between minimizing travel time and reducing delays at hospitals.