ABSTRACT

Well-responsive and efficient emergency medical services are in great demand across the world. The emergency services system guarantees safe transportation of a patient to the hospital and provides on-site stabilization to the patient. Researchers worldwide have been investigating multiple solution methods and approaches to improve the timeliness and operations of these services. What aggravates the situation is the lack of suitable ambulance fleet size, severe road congestion, and lack of proper positioning of ambulances to deal with fluctuations in demand and travel times. India has a very fragmented nature of emergency services, having different services for each state with no set operational standards for these services. The lack of response time standards poses a problem in analyzing the level of service of these services and their subsequent improvements.

This thesis works on two significant aspects of emergency services in Delhi. The first aspect is to analyze the current level of service of the system and the second is to build an efficient system by optimally locating the available fleet of ambulances. In this regard, first, the thesis estimates the variability in response times due to congestion. An important contribution of this study is formalizing a new model for estimating survival probability for life-threatening cases in Delhi. What distinguishes this study is that it addressed each of the life-threatening and non-life-threatening calls using separate performance measures. Secondly, the study tries to maximize the number of non-life-threatening calls attended by ambulances (coverage) by providing multiple backup ambulances for each call site. Thirdly, the study builds a new time-dependent survival model to incorporate the effect of varying demand and congestion on survivability. Lastly, trade-off solutions are obtained for the two performance measures (coverage and survivability) and the emergency service system.

The study quantified the effect of incorporating variability in response times and demand on these performance measures. Besides, the difference in performance measures with deterministic and stochastic versions of the problems was evaluated. The thesis was motivated to find a single set of ambulance locations for the day to cater to varying demands and avoid extra relocation costs. Therefore, previous approaches with relocations and the current methodology were also compared. Due to the larger problem size, the study also explored various metaheuristic techniques. It developed a new problem-tailored greedy heuristic approach for a quick solution to the problems at hand. These approaches were evaluated and analyzed for several test instances to observe their closeness to the optimal solution.

The study acquired six months of call records and existing ambulance locations from Centralized Accidents and Trauma Services (CATS), the public emergency services in Delhi. The calls dataset was pre-processed, segregated into high and low priority, and finally clustered for incorporation as destination sites into the optimization model. New optimal ambulance locations gave a 20% improvement on the existing system and were more homogeneously distributed across the city. Moreover, the incorporation of uncertainty in travel times showed a dip in the coverage and survival parameters by 8% and 16%, respectively. This study also showed that previous research that relocates ambulances across multiple periods of the day lead to higher relocation cost. It was also noted that the two methods to address vehicle unavailability, i.e., estimation of busy probability and providing backup coverage, both give a similar performance on the coverage. The application of models to a large dataset of Delhi required the use of metaheuristic approaches that not only reduced the runtime significantly but also provided near-optimal solutions with a marginal gap. The study has provided the policymakers with a set of feasible ambulance locations and the best feasible solution to be implemented in Delhi.

Keywords: Emergency Medical Services, Double Standard Model, Integer Programming, Stochastic, Robust