Health Care Manag Sci
DOI 10.1007/s10729-015-9332-4

Iterative optimization algorithm with parameter estimation for the ambulance location problem

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Received: 25 February 2015 / Accepted: 19 June 2015

Abstract The emergency vehicle location problem to determine the number of ambulance vehicles and their locations satisfying a required reliability level is investigated in this study. This is a complex nonlinear issue involving critical decision making that has inherent stochastic characteristics. This paper studies an iterative optimization algorithm with parameter estimation to solve the emergency vehicle location problem. In the suggested algorithm, a linear model determines the locations of ambulances, while a hypercube simulation is used to estimate and provide parameters regarding ambulance locations. First, we suggest an iterative hypercube optimization algorithm in which interaction parameters and rules for the hypercube and optimization are identified. The interaction rules employed in this study enable our algorithm to always find the locations of ambulances satisfying the reliability requirement. We also propose an iterative simulation optimization algorithm in which the hypercube method is replaced by a simulation, to achieve computational efficiency. The computational experiments show that the iterative simulation optimization algorithm performs equivalently to the iterative hypercube optimization. The suggested algorithms are found to outperform existing algorithms suggested in the literature.

Keywords Optimization · Iterative Approach · Hypercube · Simulation · Reliability Level

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1 Introduction

In an emergency medical service system (EMS), the ambulance location problem (ALP) is a critical issue. Locating ambulances is crucial to providing timely emergency medical services, affecting patients' lives intimately. The ALP can be defined as the problem to find the number and locations of ambulances needed to provide a certain level of timely service. The location set cover problem (LSCP), which is to minimize the number of vehicles required to cover all demand sites within a specific distance, is an effective approach used to model the ALP. However, the LSCP is not able to capture the most important characteristic of the ALP: unavailability of an ambulance, such as when it is occupied by a patient, which leads to the late arrival of the ambulance at the target location, thus decreasing the patient's chances of survival. Therefore, it is important to build a reliable ambulance location model.

In 1980s, the term *reliability* emerged regarding the ALP to address the issue of unavailability of ambulances. It can be defined as the probability that a patient who calls for an ambulance will be provided with one: reliability=(total calls—lost calls)/total calls. Thus, to ensure the reliability of demand sites, ambulance unavailability must be controlled in the ALP. ReVelle and Horgan [1–3] suggested the probabilistic LSCP (PLSCP) in which a reliability factor was embodied as a constraint. This problem seeks to find appropriate locations for the ambulances to ensure that the reliability levels of all demand sites are higher than required while minimizing the total number of vehicles. However, the probabilistic nature of the reliability constraint makes its modeling in mathematical terms very complex, which has been a significant

Published online: 05 July 2015