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Sample Average Approximation Method for Chance Constrained Stochastic Programming in Transportation Model of Emergency Management

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Abstract

In this paper, an optimal model for the transportation of emergency resource is established on chance constrained stochastic programming. We use Conditional Value at Risk (CVaR) to approximate the chance constraint, and we get the approximation problem of the chance constrained stochastic programming by using the sample average approximation (SAA) method. For a given sample, the SAA problem is a deterministic nonlinear programming (NLP) and any appropriate NLP code can be applied to solve the problem. The model and method provide a new way for the emergency logistics management engineering.

Keywords: emergency managemen engineering; chance constraint; Conditional Value-at-Risk; sample average approximation; transportation model

1. Introduction

In recent years, frequent emergencies have brought immeasurable losses to our country. Public health emergency events such as the SARS outbreak in 2003, the bird flu outbreak in 2005 and the swine flu outbreak in 2009; major traffic accidents such as Jiaoji Railway trains collision in 2008, Wenzhou Railway High-speed rear-end events in 2011; major geological disasters such as Wenchuan earthquake in 2008 and so on, these emergencies have caused significant casualties and major property losses, damaged the ecological environment and caused serious harm to the society. Emergencies occur along with a large number of emergency material needs. How to use reasonable transportation routes and establish the optimal programming of emergency material scheduling in delivering the emergency material resources to the demand points in time directly affects the effectiveness of public incident rescue operation. The Research on emergency resources transportation can ensure the effective

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allocation and adequate supply of emergency resources transportation and can minimize the losses from sudden events.

Experts at home and abroad have studied the emergency resources transportation problems from different perspective, different objective functions and different constraint conditions. Knott (1988) established a linear programming model for a transportation problem of rescue food [1]. The aim of the rescue material transportation model was to provide easily understood decision tools, help the operation personnel to make decision, and provide the optimal combination on food, trucks and camps. George (1998) studied the transportation optimization model for radioactive dangerous articles and introduced the emergency problem in the research, but he only considered the nearest emergency locations to participate the emergency rescue, and he did not consider that the single saving point would not meet the demand of emergency [2]. Linet (2004) established an emergency relief goods transportation model based on integer programming [3]. He also proposed an algorithm to solve the model and used examples to verify the validity of the algorithm. Shi Qin and Huang Zhipeng (2006) considered a multi-objective transportation optimization model in [4] and they mainly considered minimizing the total transportation expense, i.e. minimizing the largest one-way expense from the supply stations to the demand points. They also provided a method for solving the optimization model with non-dominated solutions.

In this paper, we consider the problem of the rescue material transportation model in the emergency management engineering. Because there are so many uncertain parameters such as the time, the area, the number of the emergency resources, etc. which we should consider in the material transport model of emergency management, we will use the related theory of the chance constrained stochastic programming in the description of the model. Conditional Value at Risk (CVaR) will be used to approximate the chance constraint and a sample average approximation (SAA) method is applied to a CVaR approximated chance constrained stochastic minimization problem. Specifically, the optimal solutions and stationary points obtained from solving sample average approximated problems converge with probability one (w.p.1) to their true counterparts. For a fixed sample, the SAA problem is a deterministic NLP and there are many existed NLP code can be applied to solve the problem.

The rest of this paper is organized as follows. In Section 2, we discuss the chance constrained programming and the handling of the chance constraints. In Section 3, we establish the mathematical model of the emergency resources transportation problems. In Section 4, we give the approximation problem of the chance constrained stochastic programming by using the sample average approximation (SAA) method. Conclusion is given in Section 5.

2. Chance constrained stochastic programming and the handling of the joint chance constraints

Although many ways have been proposed to model uncertain quantities, stochastic models have proved their flexibility and usefulness in diverse areas of science and engineering. This is mainly due to solid mathematical foundations and theoretical richness of the theory of probability and stochastic processes, and to sound statistical techniques of using real data. Optimization problems involving stochastic models occur in almost all areas of science and engineering, from telecommunication and medicine to finance. This stimulates interest in rigorous ways of formulating, analyzing, and solving such problems. Due to the presence of random parameters in the model, the theory combines concepts of the optimization theory, the theory of probability and statistics, and functional analysis. Moreover, in recent years the theory and methods of stochastic programming have undergone major advances[5-12].

In this paper, we will consider the problem of the rescue material transport model with uncertainties in the emergency management. The main difference in our mode is that we use the chance constraints in the description of the stochastic demand for the rescue material transport model.

2.1 Chance Constraint

Consider the following chance constrained minimization problem[12]:

$$\min_{x\in X} f(x) \quad s.t. \quad P(x)\le \alpha, \tag{1}$$

where $X \subset R^n$ is a closed set, $f : R^n \to R$ is a continuous function, $\alpha \in (0,1)$ is a given significance level, and