Chapter 3
An Overview on Set Covering Problems With a Focus on Military Applications

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ABSTRACT

This chapter deals with the set covering problem, a specific type of a discrete location and representative combinatorial optimization problem, which occupies a huge space in military operations research with its various applications. After presenting a brief literature survey of set covering problems, the author provides a formal description and the mathematical model of the problem. Finally, the key position of those problem types in the military domain and with real-world applications is discussed.

INTRODUCTION

Location problems deal with the problem of determining the best locations of facilities to attain the highest possible level of service related to those facilities. Being an important element of strategic planning problems observed both in the public and private sectors, location problems assist decision-makers by considering many and possibly conflicting criteria such as cost, distance, level of service, etc. Interested reader can refer to studies such as Francis et al. (1992), Daskin (1995), Drezner (1995), Drezner and Hamacher (2002), Church and Murray (2009) and Farahani et al. (2012). Among several problem types, set covering is one of the commonly-used models and have been applied to many decision-making problems. Given a universe U consisting of n elements, assume that a number of subsets of U say $S = \{S_1, S_2,\ldots,S_m\}$ exists and each subset S_i is associated with a cost. The goal of the set covering model is to determine a minimum cost sub-collection of S that covers all elements of U.

Set covering models have been attracting many researchers from different disciplines due to their natural applicability to real-life problems, which generally deal with the location of service and emergency facilities. In some cases, the objective of the set covering problem can be satisfied when a service facility meets a demand in the determined critical range, even if it is not the nearest service point. The demands

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are usually met depending on the distance between the facility and the customer. This implies that the customer can be served by any facility whose distance is less than or at least equal to a predetermined distance away (Farahani et al., 2012). If the problem is to decide the location and the number of service facilities (e.g., fire stations, waste disposal plants, emergency facilities, public buildings, public schools, hospitals, post offices, military bases, radar stations, banks etc.), one can easily employ a set covering model to solve the problem. In the literature, set covering problems are generally applied to decide the placement and/or number of certain facilities in urban areas. There are very few studies on the location of facilities in rural areas.

The main objective of this chapter is to analyse the applicability of set covering models to different real-world problem types observed in various contexts. Previous studies, in general, have dealt with the search for optimal alternatives in the planning and allocation of resources for public support and service systems. This chapter, on the other hand, gives an overview of the set covering models with a focus on military applications. In the next section we first give the mathematical model for the set covering model. Next, we describe the criteria used to filter the papers included in our survey. Then, we report the related literature on the set covering problem applications and describe the military related problems.

METHODOLOGY OF SET COVERING OPTIMISATION

The set covering problem (SCP) covers the rows of an m-row, n-column zero-one matrix (a_{ij}) by a subset of the columns at minimum cost. The problem is defined as $x_j = 1$ if column j (with cost $c_j > 0$) is in the solution and $x_j = 0$ (Beasley and Chu, 1996).

The SCP is formulated with the following indices, parameters, objective function, and constraints described as below:

Sets:

i: the index of demand nodes,
j: the index of candidate facility locations,

Parameters:

S: the maximum service distance of a facility,
c_j: the cost of locating a facility at location j,
a_{ij}: a binary parameter that is 1 if the distance from candidate location j to a demand i is less than S. The customer can be served by any facility whose distance is less than or at least equal to a pre-defined distance (Farahani et al., 2012).

Decision Variable:

x_j: a binary variable indicating whether the facility is sited at candidate location j or not,

Mathematical Model: