GENETIC ALGORITHM APPROACH IN SOLVING MINISUM FACILITY LOCATION PROBLEM WITH FIXED LINE BARRIER

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Specially dedicated to my beloved family
and those people who have support and guide me.

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ABSTRACT

Facility location problem is a field of study in Operational Research that required in considering locating a facility or a set of new facilities on the plane to serve a finite set of existing demand points. A facility location problem usually formulated as a minimization or maximization problem with an objective function involving distances between the facility and demand points. Generally, facility location problems can be classified into several problems. However in this study, minisum facility location problem involving fixed line barrier is considered since line barrier is the most applicable one in real life problem. This is because the line barrier such as rivers, highways, borders or mountain ranges are frequently encountered in practice or real problem. The main objective of this study is to concentrate on solving the minisum facility location problem with fixed line barrier using meta-heuristic approach namely as Genetic Algorithm (GA). The basic concepts of facility location with barrier as well as formulation of the problem are also had been discussed in this study. Subsequently, the developed genetic algorithm for solving the problem is proposed in this study. The procedure is coded using C++ programming and implemented on generated data of 50 fixed points.

ABSTRAK

Masalah lokasi fasiliti adalah salah satu bidang kajian dalam Penyelidikan Operasi yang diperlukan dalam pertimbangan untuk mencari sesebuah fasiliti ataupun satu set fasiliti baru diatas satah dalam memenuhi permintaan satu set titik permintaan yang tehingga yang sedia ada. Masalah lokasi fasiliti kebiasaannya dirumuskan sebagai masalah meminimumkan atau memaksimumkan dengan fungsi objektif yang melibatkan jarak antara fasiliti dengan titik permintaan. Secara umumnya, masalah lokasi fasiliti boleh dikelaskan kepada beberapa masalah. Walau bagaimanapun, dalam kajian ini, masalah minisum lokasi fasiliti yang melibatkan halangan garis yang tetap di ambil kira dalam permasalahan ini disebabkan halangan garis merupakan halangan yang paling berkenaan dalam masalah kehidupan sebenar. Hal ini adalah kerana halangan garis seperti sungai, lebuh raya, sempadan atau banjaran gunung sering dihadapi dalam situasi atau masalah sebenar. Objektif utama kajian ini adalah untuk menumpukan perhatian kepada penyelesaian masalah lokasi fasiliti minisum dengan halangan garis tetap menggunakan pendekatan meta-heuristik iaitu Algoritma Genetik (GA). Konsep asas lokasi fasiliti dengan halangan serta perumusan masalah juga telah dibincangkan dalam kajian ini. Selepas itu, algoritma genetik yang telah di bina untuk penyelesaian masalah juga telah dicadangkan dalam kajian ini. Prosedur ini dikodkan menggunakan pengaturcaraan C + + dan dilaksanakan pada data yang dijana 50 titik tetap.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Facility Location Problems

A facility location problems occur when we need to consider locating a facility on the plane to serve a finite set of existing demand points with different demand levels. The majority of traditional location problems in continuous space assume that a new facility is a point in space that is to be located with respect to some objective defined by its distances to a set of demands at specific fixed points in that space. In other words, a facility location problem usually formulated as a minimization or maximization problem with an objective function involving distances between the facility and demand points.

When a distance between two points is defined on the plane, minisum and minimax criteria have been used in location problems [1]. Generally, one of the most popular objectives would be to find a location such that the sum of the distances from the facility to the demand points is minimum. It is known as the minisum criterion or more known as the minisum location problem. This problem can also be classified as the classical Weber problem [2]. This criterion is used in location problems for the public facilities such as shopping malls, libraries, banks, movie theatres and others. Alternatively, the objective may be to minimize the smallest time to emergency facilities (minimize the maximum distances from the emergency facilities to the demand points), or to maximize the minimum distance to an obnoxious facility. These problems are known as the minimax and maximin location problems, respectively [3].

1.2 Background of Study

When locating a facility on the plane to serve a finite set of existing demand points with different demand levels, one of the objectives would be to find a location such that the sum of the distances from the facility to the demand points is minimized. As been stated earlier, this problem is known as the minisum facility location problem or was more specifically known as the classical Weber problem. In the past, most work on the facility location literature focused on locating a facility on a continuous plane. If the facilities were assumed to be located at any point on a continuous location plane, it means that the solution space is continuous, that is, it is feasible to locate facilities on every point in the plane without any restrictions or barriers.

However, realistic facility locations problems always involve the consideration of restrictions imposed by barriers. Barriers are regions where travelling as well as locating new facilities is prohibited. Examples of barriers include lakes, parks, military areas, and many more. Barriers also take place because of disasters and accidents that cause damage to road networks. Apart from that, the other examples of barriers would be impassable areas on the shop floor like machines, subassembly areas, input–output docks, and others.

Most of the restricted location problems that are studied in the literature fall in one of the three categories. The first category considers forbidden regions where no facility placement is allowed or possible; however travelling through these regions is not restricted. The second category considers congested regions. A congested region is a region where placement of a facility is forbidden but travelling through is possible with some penalty. The third category deals with barrier regions. Mountains, lakes, military zones, existing facilities, railroads, highways, and others can be given as the examples of barrier regions where neither travel through these regions nor placement in a region is possible. However in this study we will only focus on the third category only. Although facility location problems in the presence of barrier regions have more practical relevance than general facility location problems, they have not been given much attention until lately, due to the computational complexities associated with these problems [2]. The introduction of barrier regions significantly entails different treatment since the objective function is not convex as in the classical facility location problem especially in the Weber problem.

In addition, the available literature on location problems in the presence of barriers can also be classified according to the following criteria such as shape of barriers (arbitrary, polygonal, circular, rectangular, polyhedral etc.), size of new facility (infinitesimal or finite size), travel metric used (Euclidean, rectangular, etc.), type of objective (median or center) [4]. Literature has so far only treated some particular types of metrics and barrier shapes such as one circular barrier, and the Euclidean distance or closed polyhedral barriers.

The literature in this area started with Kartz and Cooper [5] that considered the Weber problem as well as Euclidean distance and one circular barrier regions. The author used a heuristic based approach in finding the solution. Later, some properties of the problem were analyzed by Klamroth [6] that divided the feasible region into some convex regions. However, construction of these convex regions becomes cumbersome hence is not desired. Then, Bischoff and Klamroth [7] proposed a heuristic approach which was the genetic algorithm in finding the solution to the problem in order to get over this difficulty.

For polyhedral barrier, the literature also included the work from Aneja and Parlar [8] that considered the Weber problem with convex or non convex polyhedral barriers. The authors also used heuristic approach that is Simulated Annealling (SA) to generate some candidate location and find its shortest path between any candidate locations using Dijkstra’s algorithm. Then in 1996, Butt and Cavalier [9] developed an algorithm that could find local optimal in Euclidean distances for Weber problem. However it has problem with this approach since it was generally nonlinear. Therefore, Klamroth [10] suggested a slightly different approach to overcome the difficulty. It means that the author also used optimal approach in order to solve the problem.

Next, Klamroth [11] introduced a linear line barrier with given passages for Weber problem. He considered a fixed line barrier with passages that divides the plane into two sub-planes and he used optimal approach in solving the problem. Then in year 2010, Canbolat and Wesolowsky [2] had considered the probabilistic line barriers in location problem and it was also solved optimally. In 2012, Canbolat and Wesolowsky [12] also proposed their new work in facility location problem area by considering the fixed line barrier region and provide an optimal solution methodology based on an Outer Approximation (OA) algorithm.

Hence, we can conclude that measuring distances in the presence of barriers plays an important role in location problems with barriers, specifically in minisum facility location problem. Despite a large number of works concerning the shortest path problem in the presence of barriers, a few studies have employed an analytical approach. Analytical expressions for the barrier distance are necessary to examine relationships between variables, for example, how the location and the size of a barrier affect the barrier distance.

To the best of our knowledge, there are a few models of facility location problems with barriers in the literature. We observed that facility location problems with barriers naturally and majorly take place in the real life. Barriers may have random existence, random size or random location. However, there are only a few researches that concentrated in studying the minisum problem in the presence of line barrier with fixed barrier. As we can summarize, there are only Klamroth [11], Canbolat and Wesolowsky ([2], [12]) that studied the minisum problem with line barrier since most of the researches are more interested to find the solution for minisum problem in the presence of convex polyhedral. Apart from that, Klamroth [11] had stated that the idealized case of barriers is that it is linear since it is frequently encountered in practice or in real life.

In many applications, the solution for the problem is not feasible because of its complexity due to large number of variables and also too long computations times. Hence, if we solve the problem optimally, it will be computationally expensive to be obtained. Based on the works discussed earlier, it can be seen that most of the problems are solved by using exact method or optimally for small size problem. The scenario leading to the research problem can be summarized as in Figure 1.1.

1.3 Statement of Problem

In this study, minisum facility location problem involving fixed line barrier is considered since it is the most practical in practice. Based on previous researches, most of these problems were solved optimally. However in many applications, solution for the problem is not feasible because of its complexity and sometimes, there exist ill-structured problem that cannot be solved optimally. Therefore, this research will concentrate on solving the minisum problem with fixed line barrier using heuristic approach namely Genetic Algorithm (GA) method since heuristic approach can approximates the optimal solution by exploring various parts of the feasible region and gradually evolving toward the best feasible solutions.

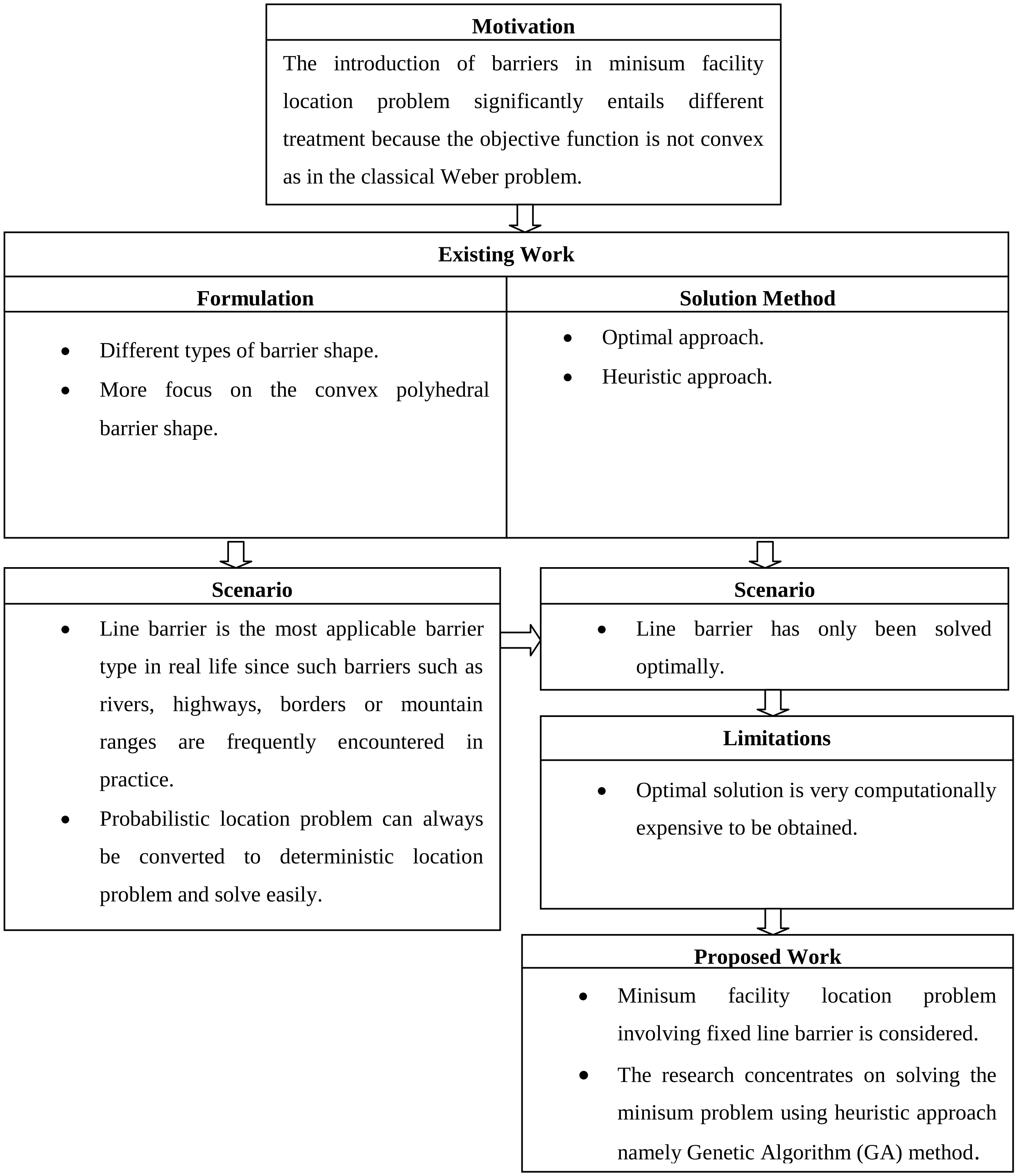

Figure 1.1: Scenario leading to the Research Problem

1.4 Objectives of Study

The objectives of the study are as follows:

(1) To solve the Mix Integer Non Linear Programming (MINLP) model of the problem for single facility using LINGO software.

(2) To develop basic Genetic Algorithm (GA) procedure for solving the minisum facility location problem with fixed line barrier.

(3) To implement the developed Genetic Algorithm procedure to the generated data using C++ programming.

(4) To investigate the performance of population size of parameter settings in the Genetic Algorithms.

1.5 Scope of Study

This study will focus on solving a facility location problem with fixed line barrier for a continuous planar location problem. This research discusses the usage and implementation of Genetic Algorithm (GA) to solve the problem. The objective criterion in this study is to minimize the sum of the distance (minisum). This study will also focus on the implementation of Genetic Algorithm into the C++ programming in order to solve large size of data as well as the investigation of parameter settings in GA such as population size and the choice of operators used. The performance will be measured based on the solution quality (fitness value).

1.6 Significance of Study

This research focuses in developing the Genetic Algorithm procedure for solving minisum problem with fixed line barrier. The proposed technique will be able to solve large size problem with less computational effort. The main contributions of this research are summarized as follows:

i) Development of Genetic Algorithm procedure for solving minisum problem with fixed line barrier.

ii) Evaluation of the performance of the proposed algorithm in solving the problem.

iii) As a reference for solving real minisum facility location problem involving fixed line barrier.

1.7 Outline of Report

In general, this dissertation is divided into five chapters. In Chapter 1, an overview of this study had been addressed. This chapter includes the introduction of problem, background of study, statement of problem, objectives of study, scope of study, and also the significance of study.

In Chapter 2, the literature review of facility location problem in general and also the review about facility location with barrier are discussed. This chapter also includes the definition of minisum problem, the minisum problem with barrier as well as some review of the basic concepts and main parts of Genetic Algorithm.

Meanwhile in Chapter 3, it includes the research methodology of the problem and also the operational framework of the study. This chapter also briefly discusses the solution method that we used to solve the minisum facility location problem with fixed line barrier namely genetic algorithm.

In Chapter 4, the implementation of genetic algorithm to minisum facility location problem with fixed line barrier using C++ programming as well as exact solution of the MINLP model for single facility location problem that we get using LINGO 13 will be presented. Lastly, Chapter 5 will include the conclusion and recommendations for future research.

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