CHAPTER 1

Introduction

The integer programming problem is an important class of the optimization problems. A required condition of this problem is that some, many or all of the variables should be an integer. Generally, integer programming is an NP-hard problem. It is impossible to solve this type of problem in polynomial time, which has made it the focus of interest for many researchers. Although an integer problem is an NP-hard problem it has been shown that certain specific problems could actually be solved in polynomial time. For the problems associated with a totally unimodular constrained matrix such as assignment problems, an integer optimal solution can be found by solving its LP relaxation issues. But most of integer programming problems cannot be solved using a linear programing technique. In general, there are 2 major algorithms used to solve integral problems. The first one is the exact algorithm which is the method that is guaranteed to find the optimal solution for the problem but it takes a lot of time. The algorithms for this model are the branch and bound algorithm and the branch and cut algorithm which will be discussed in the next chapter. Another one of the algorithms is the heuristic algorithm which is different from the method in the exact algorithm because it is not guaranteed to find the optimal solution for the problem but uses the least amount of time. The algorithms in this group are local search, greedy and ant colony. Generally, integer problems are frequently big which makes it impossible to use an exact algorithm in finding the optimal solution. Therefore, most of the research studies have been created to develop heuristic algorithms. Nevertheless, it is crucial to verify the solution from the heuristic algorithm by comparing it with the optimal solution from the exact algorithm. As a result, the exact algorithm will also be taken into consideration.

There are many aspects that need to be considered when investigating the integral problem such as the pure integer problem and binary integer problem. The pure integer problem is a problem in which all the variables are integer variables. Commonly, the components for this problem will appear in a discrete model such as the product quantity and the people quantity. If the product variable is not examined in the integral format, the solution will not be practical. For instance, in cars production planning, it is likely to get the optimal solution if the problem is considered in rational number format. For example, one assumed company produces the type A car for 7.33 units and the type B car for 10.33 units. In some cases, the optimal solution is derived from the rounding-number technique but this method frequently renders the solution infeasible. Moreover, sometimes the solution is an integer but it is not found to be the optimal solution. The binary problem is the problem in which each variable is 0 or 1. Most of the binary problems are problems related to decision making. For this type of problem, it is significant to decide from which alternatives to choose. Normally, the decision variable will be 0 when choosing one alternative and will be 1 when choosing another. The instance of the assignment problem is the work or duty assignment problem for each personnel. If we consider the problem in linear programming format or solve the problem by using LP relaxation, the general optimal solution will not appear in integer 0, 1 which automatically affects the decision making process. Normally, the solution numbers for this problem are limited, but there appear to be a lot of decision variables. When the decision variable in a problem of interest equals the n unit, the possible solutions will be the 2^n unit. In the real-life problem, there normally are a lot of decision variables.

One of the interesting binary programming problems is the location problem. Therefore, this research study mainly focuses on the location problems. The location problem is a decision making problem used to locate a facility in the optimal place. The optimal place depends on a number of components, including the optimal cost, optimal distance, optimal population density, etc. Location problems consist of a set of demand or supply points (clients) that have to be assigned to an opened facility and a set of potential sites where these facilities can be located. This problem can be considered in discrete or continuous space. When facilities can be located at any place in an area, the problem is a continuous location problem. When facilities can be placed only at specific locations, the problem is a discrete location problem. The most famous continuous location problem is the Weber problem [54]. This problem aims to find a place to locate a facility in continuous space that minimizes the sum of the weighted Euclidean distance from the facility to the demand points. However, a continuous location problem can be relaxed to a discrete location problem by using a comprehensive Geographic Information System (ArcGIS) [12]. This method converts continuous space into a grid map, that then defines the grid reference into the candidate place. Many real world applications consider location as a discrete location problem. The discrete location problem is an integer programming problem. Generally, most real word problems consist of facility-location construction and a clients in discrete format. These are applied to evaluate whether the chosen location is appropriate for the construction. In terms of transportation or client distribution to the facilities, there are 3 aspects in considering the decision variables which are continuous variable, integer variable and binary variable. However, examining the problem in term of the continuous variable is not of significant interest to a broad range of people. That is to say, in terms of transporting the product or picking up the product from the clients to the facility location, the amount of traveling voyages are commonly counted. Therefore, the solution from the real-value model cannot be applied to solve real-world problems. The problem in counting traveling voyages conforms to the integer variable problem. For the binary variable, it relates to decision-making in terms of how to distribute the clients to only 1 facility location without counting the transportation voyage. The solution from the discrete model equates to clustering the clients to the facility location.

Location problems can be classified into 4 categories using the objective function criteria: 1) facility location problems 2) p-median problems 3) p-center problems and 4) covering problems. The objective of the facility location problem is to find a place to locate a facility in order to minimize the total setup cost and the total cost of transportation between the clients and the facilities. For example, the problems that occur in selecting the location for the product distribution center in retail malls. The objective of the p-median problem is to determine the locations of p facilities and their assigned clients in order to minimize the total cost of transportation between the clients and the facilities. This problem is similar to the facility location problem in many aspects. The difference is that the p-median problem will determine the number of facility locations in advance that present both advantages and disadvantages. The good thing in determining the facility location number is that it helps to predict the budget in building the facilities, whereas it is hard to find the lowest budget. P-center problems have a specific objective function that is to minimize the maximum distance between each client and its assigned facility. This problem is applicable to on finding the location for the emergency events; and selecting the emergency parking spots for the wounded people in any area. Covering problems are used to find the minimum number of facilities to cover all clients or to maximize the number of clients covered by a given number of opened facilities. Another example is the selection of spots for telephone signal columns to evenly serve the longest number of clients. This problem can be separated into 2 types which include the set covering problem and maximal covering problem. 1) The set covering problem involves selecting the facility location by spending the least amount of capital to build the facility where it can widely provide a service to all clients. 2) The maximal covering problem involves selecting the facility location in p place in order to cover all customers needs and will be discussed in the next chapter.

Moreover, the location problem can be considered with or without the demands of the clients and the capacities of the facilities. If the demands (or supplies) of the clients and the capacities of the facilities are not in the model, the case is often called an uncapacitated case. When the demands (or supplies) of the clients and the capacities of the facilities are included in the model, the case is often called a capacitated case. In a capacitated case, each client has a certain demand to meet and the facilities have certain capacity restrictions i.e., the total demands of the clients assigned to a facility cannot exceed that facility's capacity. Both uncapacitated and capacitated facility location problems are considered NP-hard problems. This type of problem can also be classified as deterministic or stochastic. If all parameters in the problem are known, the problem is a deterministic problem. If some parameters are uncertain, the problem is considered a stochastic problem. The stochastic facility location problem can be considered under uncertain demands [44] or uncertain transportation costs [57] or both [48].

The location problem consists of 2 decision-making parts: the decision to build the facilities and the decision to distribute the clients to the facilities. Those mentioned factors have an enormous impact on the problem structure which is similar to the assignment problem. In the location problem, it is impossible to find the optimal solution by using the LP tool. However, "branch and bound" and "branch and cut", which are the algorithms used to solve integer problems, can be applied to solve this problem under the condition that the amount of clients does not exceed 200 persons and the number of facility locations is not more than 200 places. In general, the location problem can be considered a big problem such as with the Chaing Mai waste accumulation system. In Chaing Mai, there are 432 service nodes and the examined areas are made up of 432 nodes. Also, for the sugarcane transportation system in Phetchabun, there are 3,211 service nodes and the examined areas are comprised of 3,211 nodes. From those examples, it can be concluded that most of the problems have significant influences, on "branch and bound" and "branch and cut" algorithms. That is to say, the "branch and bound" and "branch and cut" algorithms cannot be used to seek the optimal solution for this problem. As a result, most of the researchers have paid a lot of attention to developing a heuristic algorithm to solve those huge location problems. The heuristic algorithm has, nevertheless, been designed for different-purposes problems. In some cases, it works well to solve p-center problems but sometimes, it is not useable for p-median problems.

There are lots of interesting location problems such as the selecting location for the product distribution center, fire station, police station, hospital, information-service center, casualties assisting center and so on. One of the interesting location problems is the waste management problem. According to economic factors and social expansion, goods production and product usage have been continuously increasing; this has an influence on the rise of household and other wastes. If there is no appropriate management for the increasing amount of waste, this may trigger the environmental and population hygiene problems. Consequently, selecting the suitable location for waste management is crucial in terms of reducing the waste problem. Finding the suitable location and management planning for waste is related to the location problem. Chaing Mai is one of the important centers of the economy, tourism, and education in Thailand. Each year, there are lots of domestic and international tourists who travel to Chiang Mai. Due to this fact, Chaing Mai is one of cities that is encountering a waste management problem. The waste in Chaing Mai is increasing by up to 250 tons each day and the future waste tendency is also rising. If the municipal solid wastes are not properly taken care of, it will affect the cleanness and tidiness of Chaing Mai. It will also increase the amount of environmental pollution such as water pollution and air pollution. For instance, the build-up of waste might result in the contamination for water resources or the contamination of the air that we breathe daily. It will also fertilize and spread out the bacteria resulting in the unwanted smells. Moreover, it might result in conflagration. At the present time, the method of solid waste elimination in Chaing Mai involves dumping it outdoors or in landfills. If those methods are still being used in the future, the waste toxin problem may increase and the toxic substances may spread to the soil and natural water resources. Besides, the landfill areas may not be sufficient for future waste eradication. Nevertheless, if the new method, systematic waste separation, is being used, it will help reduce the amount of solid waste. The solid waste might later be recycled instead of being destroyed. It is essential to find the appropriate location to hold the waste which will be then separated systematically. In the solid waste elimination process, it is not advised to wait until the waste quantity in each area fills up the truck on each voyage. It is necessary to frequently pick the up solid waste, systematically separate it from the originated area, and choose the best route for solid waste delivery to the facility location. Location and route selecting problems are considered the NP hard problems. As a consequence, this research study has presented the p-center problem in a discrete model because the solution for the p-center problem is similar to the one of the clustering problem which separates the information into the p group. Moreover, the furthest distance in each group has the least value which is appropriate in terms of selecting the best route.

Besides the municipal solid waste problem, the agricultural waste has also been taken into consideration in this research study. Since Thailand is an agricultural country, 41 percent of its areas are used for agricultural purposes. After harvesting the agricultural products, there will be lots of agricultural waste such as chaff, straw, corncobs, leaves, and so on. In the past, the agriculturists terminated those waste products by ploughing them and later recycling them into organic fertilizer. Nowadays, the chemical fertilizer is frequently used instead of the organic one. Most agriculturists then eliminate the agricultural waste by incinerating them which produces lots of toxic fumes and dust and results in causing air pollution. Air pollution created by destroying the agricultural waste is a huge problem in the northern part of Thailand including Chaing Mai. As a matter of fact, agricultural waste can be recycled and used again. For example, some of the waste can be used to produce fuel for electricity production. By doing this, the agricultural waste is eliminated and then can be used for electricity production which will help to address the domestic electricity-current deficiency. Presently, 30 percent of the electricity in Thailand has been imported from neighboring countries. We are, as a consequence, interested in studying the biomass power plant location problem.

Normally, the agricultural waste is not produced all at once since the harvesting period in each area is different. Therefore, the agricultural-wastes-transportation costs incurred when transporting the waste to the biomass power plant cannot be strictly predicted. We then have paid a great deal of attention to the in-system costs which involve the costs related to agricultural leftover delivery to the power plant and the biomass power plant construction costs. These problems are similar to the facility location problem. The problems mentioned here need to consider the costs related to transporting the clients to the facility without limiting the route and those related to the facility construction costs. As a result, we then have conducted research on studying the facility location problem.

This thesis aims to find ways to solve the discrete location problems. We propose an algorithm to solve the p-center and facility location problems. The algorithm used to solve the p-center problem is inspired by the fact that the optimal solution of this problem is related to the distance from the facilities to the clients. We have applied a covering problem and have combined it with a bisection method to solve the p-center problem. For the facility location problem, we have applied the p-center and p-median problems in order to provide a solution.

In general, the number of clients and candidate places are likely to be large in a real world application. When the amount of clients equals n and the number of candidate places equals m, the decision variable will be $(nm + m)$. With that fact, it takes a great amount of time to find the optimal solution for the answer or it might not be possible to find any optimal solution. Apart from the algorithm mentioned above, the relaxation methods, minimizing the size, and the bound of error acquired from the size reduction have been taken into consideration.

To test the proposed algorithms, 100 random case problems have been simulated. Moreover, to illustrate the proposed algorithm, municipal and agricultural waste management systems in Chiang Mai and 5 provinces of Northern Thailand have been studied. The biomass power plant and storage for municipal and agricultural waste management systems have been virtually constructed. The contents of this thesis are divided into 5 chapters. Chapter 1 is comprised of an introduction to this thesis. Chapter 2 deals with basic concepts, preliminary elements and a literature review. Chapter 3 contains the main results of this thesis. Chapter 4 shows the simulation result and the illustrative example. The conclusion is presented in Chapter 6.