A Mathematical Model of Local Drug Store Selection for Psychiatric Disorders in Thailand

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Abstract

This paper presents the mathematical model which considered the facility location problem for local drug stores for psychiatric disorders in Thailand. Due to the increasing number of patients in the hospital, Thailand has initiated several strategies and projects in order to reduce congestion in the hospital. A medicine distribution system is one of the projects to cope with hospital overcrowding. The initiative project especially focuses on the psychiatric patients who live in rural areas which is hard to access psychiatric services. The idea of this project is to select local drug store representatives as medicine distributors, so that psychiatric patients can directly go to pick up their medicine from those local drug stores according to hospital's prescriptions. Therefore, this paper studies on the design of a drug delivery system between hospital and local drug stores, and 7 provinces in Northern Thailand are chosen as a case study. The goal of a mathematical model is to determine the location of local drug store representatives that will be medicine distribution hubs for psychiatric patients. The objective of the model is to minimum number of local drug store representatives that can serve all patients in the system. The model is solved using LINGO 14.0 and the experimental results showed that the optimal solutions can be obtained for all provinces.

Keywords
Facility location problem, Mathematical model, Optimization problem, Medicine distribution system and Psychiatric disorders

1. Introduction
Currently, Psychiatric Disorders is a significant problem for population in Thailand. Most of patients with psychiatric disorders are found in the working-age population. The number of psychiatric patients is increasing each year according to data of Department of mental health of Thailand in 2016. However, there are less than 10 percent of patients who cannot reach the basic health care services. There are several factors that make patients cannot access the basic health care services. The people's attitude toward patients with mental health is awful since they do not have sufficient knowledge which lead to misunderstanding about Psychiatric Disorders. The mental health care services are not distributed among communities due to the shortage the psychiatrist and the professional mental health care team. There are only clusters of psychiatrists in the big city, and thus poor families can hardly access the mental health care service since the travel cost is high. For these reasons, patients cannot get medication continually which causes reoccurring of psychiatric symptom (Suraarunsamrith and Panyayong 2014).

Currently, Psychiatric Disorders is a significant problem for population in Thailand. Most of patients with psychiatric disorders are found in the working-age population. The number of psychiatric patients is increasing each year according to data of Department of mental health of Thailand in 2016. However, there are less than 10 percent of patients who cannot reach the basic health care services. There are several factors that make patients cannot access the basic health care services. The people's attitude toward patients with mental health is awful since they do not have sufficient knowledge which lead to misunderstanding about Psychiatric Disorders. The mental health care services are not distributed among communities due to the shortage the psychiatrist and the professional mental health care team. There are only clusters of psychiatrists in the big city, and thus poor families can hardly access the mental health care

service since the travel cost is high. For these reasons, patients cannot get medication continually which causes reoccurring of psychiatric symptom (Suraarunsamrith and Panyayong 2014).

A Facility Location Problem (FLP) is the analysis concerned with the location and allocation problem to reduce transportation costs. FLP can be classified into 3 main classes as follows: p-median, p-center, and covering. The p-median problem aims to find the optimal location of absolutely p facilities—the minimized distances between customers and their assigned facilities. The p-center problem involves locating p identical facilities on a network, for every demand can receive its service from the nearest facility and maximize distance between each demand node and its facility is as small as potential. The covering problem proposes the coverage radius which demands are involved in the selecting radius, aims to minimize the number of facilities to cover whole demand in the area that they are assigned and maximize the covered demand under a limited number of facilities (Francesca et al. 2016).

In addition, each class is also divided into 2 categories *i.e.,* metaheuristics and exact solution methods. The exact solution is the method regarding the uncomplicated small problems, consists of integer programming (IP) (Gábor and Saïd 2017, Dorrington and Olsen 2019 and Eren et al. 2017) and mix-integer programming (MIP) (Sibel et al. 2012, Mobina et al. 2018, Inmaculada et al. 2014, Guerrero et al. 2013, Eliana et al. 2017 and Hossein 2018). All of the mentioned research had the same purpose was to locate distribution centers for saving transportation costs, due to the increasing profits in the organization or company.

The research of Eren et al. (2017) will be described in detail here, due to the similarity of the problem with our research—that is the facility location problem. Mathematical models and GIS programs are the crucial tools which were selected for deciding where to locate a local drug store. This model method resulted in a convenience for the service: shortening the distance along with saving transportation cost. A set covering mathematical model was subjected to determine coverage ability of current and potential drug store warehouses and minimize the number of warehouses to be opened. p-center and p-median mathematical models were put on to open potential warehouses and to assign drug stores and hospitals to the opened warehouses for minimizing total distance and the demand's longest distance to the origin. The integer programming (IP) models were solved with a case study. The new potential drug store can cover wider areas than the current drug store to drug service.

This research focus on the design of a drug delivery system between the hospital and the local drug stores in 7 provinces in Northern Thailand, including Uttaradit, Tak, Sukhothai, Phrae, Phitsanulok, Phetchabun, and Nan. The concept of this research is to minimize the number of local drug stores which are the hospital representatives for medical distributors as shown in Figure 1. Determination of the location of local drug stores was found out as follows the method of Eren et al. (2017). The method of covering problem (Covering_HLP) was selected to solve this problem using the LINGO 14.0 programming solver. The advantages of this research are the reduction of congestion in the hospital, easy access to treatment of psychiatric patients who live in rural areas, shorten distance and saving time.

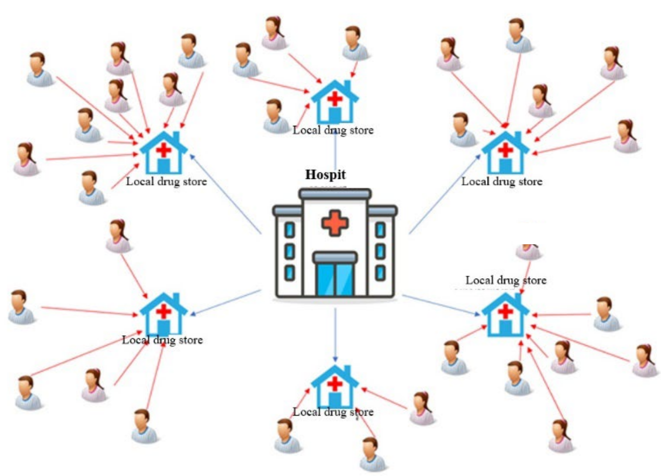

Figure 1. Diagram of drug delivery from hospital to local drug store and patients can pick up their medicine at a local drug store near their home.

2. Problem Description

This paper studies the problem of facility location for local drug stores in medicine distribution system for patients with Psychiatric disorders in the Northern part of Thailand. A mathematical model of Eren et al. (2017) was adopted to determine the location of local drug store representatives that will be medicine distribution hubs for psychiatric patients. The objective of the model is to minimum number of local drug store representatives that can serve patients in the system. In this model, the problem is solved by Covering Problem (Covering_HLP) that show in equation 1, and the problem is formulated using the following assumptions:

- The distance from local drug stores to the patient's home is predetermined in advance.
- The capacity of all local drug store that can serves are assumed to be equal.

Parameters and decision variables used in formulating the model are defined as follows.

Indices

I : A set of patients, where $i \in I$, $i = 1, 2, \dots, I$

K : A set of local drug store, where $k \in K$, $k = 1, 2, \dots, K$

Parameters

D_{ik} : Distance from patient i to local drug store k

r : Maximum distance radius of patient's home around the local drug stores

Decision Variables

$$Y_k : \begin{cases} 1, \text{if local drug store } k \text{ is selected as local drug store representative} \\ 0, otherwise \end{cases}$$

$$X_{ik} : \begin{cases} 1, \text{if patient } i \text{ is assigned to local drug store } k \\ 0, otherwise \end{cases}$$

The mathematical model of the problem can be formulated as follows.

Objective Function

This study considers the objective function which is minimum number of local drug store representatives (referred to as Covering_HLP) is shown in equation (1).

$$Min\ z = \sum_{k=1}^{K} y_k \tag{1}$$

Constraints

Constraint (2) is a conditional equation where all patients are assigned to local drug store.

$$\sum_{k \in K}^{K} X_{ik} = 1 ; \forall_{i \in I} \tag{2}$$

Constraint (3) is the equation ensuring that one patient is assigned to one local drug store.

$$X_{ik} \le Y_k ; \forall_{i \in I} \forall_{k \in K} \tag{3}$$

For constraint (4), the distance from patient's home i to local drug store k must not exceed the specified radius.

$$d_{ik} X_{ik} \le r ; \forall_{i \in I} \forall_{k \in K} \tag{4}$$

Constraints (5) and (6) state that the decision variables are binary.

$$Y_k \in \{1,0\} \tag{5}$$

$$X_{ik} \in \{1,0\} \tag{6}$$

3. Computational Experiment

3.1 Experiment Setup

The experiment is conducted to determine the local drug store representatives for 7 provinces in the Northern Thailand which are Uttaradit, Tak, Sukhothai, Phrae, Phisanulok, Phetchabun, and Nan. The number of psychiatric patients and local drug stores for each province are shown in Table 1

Table 1. Total number of psychiatric patients and local drug stores for each province

	Provinces						
	Uttaradit	**Tak**	**Sukhothai**	**Phrae**	**Phitsanulok**	**Phetchabun**	**Nan**
Total patients	29	55	49	102	28	11	34
Total local drug stores	48	50	54	55	127	70	44

Each province is considered separately, thus, a psychiatric patient will be assigned to a local drug store in his/her own provinces. For all provinces, the maximum distance radius of patient's home around the local drug stores were set as the same. The maximum radius starts from 10 km., and the next radius is increasing every 10 km, up to 70 km. Different radius are considered in this experiment to provides a decision maker several scenarios, and then a decision maker can select the most appropriated solutions. According the data, each local drug stores can serve patients unlimited per day. The mathematical model was implemented on the LINGO optimization program version 14. The computational experiment was executed using a personal computer of Intel® Core™ i5-8250U CPU 1.60GHz 1.80GHz processor with 4GB RAM memory.

3.2 Experiment Results

Table 2 shows the experimental results of minimum local drug store representatives for different radius.

Table 2. The experimental results of local drug store representatives

Radius (km)	**Province**						
	Uttaradit	**Tak**	**Sukhothai**	**Phrae**	**Phisanulok**	**Phetchabun**	**Nan**
10	N/A	N/A	17	N/A	5	5	N/A
20	3	6	5	N/A	2	2	6
30	3	4	4	4	2	3	4
40	2	4	3	2	2	2	3
50	2	3	2	2	2	2	2
60	2	3	2	2	1	2	2
70	1	2	1	2	1	2	2

According to the results obtained in Table 2, the optimal solutions can be obtained from the mathematical model for most scenarios. The scenarios with no feasible solutions are represented as "N/A" since there are no patients in the specified radius. For maximum radius of 10 km, there are 4 provinces with no feasible solution: Uttaradit, Tak, Phrae and Nan. For maximum radius of 20 km, there are only one province, Nan, with no feasible solution. When the maximum radius is at least 30 km., the optimal solutions of minimum local drug stores are obtained for all provinces. The solutions tend to be stabilized as the radius increases. The solutions from different scenarios help a decision maker or policy maker to further select the most appropriated solutions.

4. Conclusion

This paper presents the mathematical model which considered the facility location problem for local drug stores for psychiatric disorders in Thailand. Due to increasing number of patients in the hospital, Thailand has initiated several strategies and projects in order to reduce congestion in the hospital. A medicine distribution system is one of the projects to cope with hospital overcrowding. The initiative project especially focuses on the psychiatric patients who lives in rural area which is hard to access psychiatric services. The idea of this project is to select local drug store representatives as medicine distributors, so that psychiatric patients can directly go to pick up their medicine from those local drug stores according to hospital's prescriptions. Therefore, this paper studies a design of drug delivery system between hospital and local drug stores, and 7 provinces in the Northern Thailand are chosen as a case study.

The goal of a mathematical model is to determine the location of local drug store representatives that will be medicine distribution hubs for psychiatric patients. In this research, the facility location problem are solved by Covering Problem (Covering_HLP) equation. They adopt the mathematical model based on research by Eren et al. (2017). The objective of the model is to find the minimum number of local drug store representatives using LINGO 14.0 programming solver and the experiment results show that the mathematical model yields the optimal solutions of minimum local drug stores for all provinces.

Based on the results of this experiment, this paper is the first phase of the project, the next research will continue toward a complete design of medicine distribution system between hospital and local drug stores in Thailand. The emphasis will be the design of hospital's drug distribution cycle which highly depends on different patient's medical cares. This decision must be carefully made to ensure the correct treatment protocols of patients while the total cost must be minimized.

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Biography
Napatsawan Dedkhard is a master student in Logistic Engineering and Supply Chain Management, Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand. Her main aim in this research is to improve quality of metal health and psychiatric service systems project of Suanprung Hospital. Her research interests include optimization problem, location-allocation problem and medicine distribution system.

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