Locations of the Automated External Defibrillators based on Emergency Disease Distribution in Prachinburi

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Abstract

Sudden cardiac arrest is unexpected, which can be fatal. Providing quick assistance to patients with the automated external defibrillator (AED) can reduce the risk of loss and increase the chances of survival. The objective of this research is to determine the optimal location of the automated external defibrillator in Muang Prachinburi district, which located in eastern part of Thailand. There are severe conditions which can be developed to sudden cardiac arrest such as severe trauma, acute cardiac arrest, respiratory disease and stroke. The maximal covering location problem (MCLP) is applied to find the location of electrical defibrillators based on the dispersion of incidences in need of urgent assistance in 2017. For disease distribution, top most incidences were in Na Mueng, Ban Phra and Dongkeelek sub districts. The largest increase in the number of diseases from 2015 to 2017 include strokes and heart attack account for approximately 27.75% and 24.26%, respectively. The number of emergency critical cases increase spreading to the center of urban area. From the result, the maximal coverage with 40 AEDs within 2 km. is approximately 90.09% of coverage.

Keywords
AEDs, cardiac arrest, EMS, Maximal Covering.

1. Introduction
A number of fast track that emergency medical care is needed in diverse circumstances, including cardiac arrest, major trauma, stroke and sudden cardiac arrest. Emergency patient assistance is an important step, especially by providing quick-accessible defibrillators. If help is delayed by one minute, there will be a 7% lower chance of survival. Current traffic conditions affect the travel of emergency rescue vehicle units in patient lead to hospitalized patients, especially sudden cardiac arrest patients. Dangerous atrial fibrillation can occur at any time. Urgent treatment is required. When an emergency occurs, CPR can help the patient's blood system circulate to the brain if the patient is stimulated by an automated external defibrillator (AED). Treat the illness immediately by shocking an electric defibrillator during which emergency rescue vehicles have not yet arrived, reducing the impact of the arrival distance of emergency rescue vehicles and increasing the chances of survival. The allocation of emergency medical service (EMS) resources and tools to cover the distribution of critical illness groups, likely to require emergency assistance, is an urgent need.

1.1 Objectives

To cover emergency incidences that lead to Out-of-hospital cardiac arrest (OCHA) as much as possible, the objective of this research is to find the optimal location for the AEDs with restricted resources based on geographic distribution in Prachinburi.

2. Literature Review

Sudden cardiac arrest is a condition in which the heart stops working. It is necessary to be helped with a rapid automatic defibrillator. Rescue slows down by 1 minute; this reduces the chances of survival by 7% (Mark 2011). The conduct of research on the location selection of important emergency medical resources. Research on the selection of key emergency medical resource locations, such as automatic defibrillators, has been widely researched, such as research on the location selection of OHCA patients outside the hospital (out-of-hospital cardiac arrest, OHCA) in Denver (Nassel et al., 2014), Taiwan (Wang et al., 2018), Sweden (Schierbeck et al., 2021), Scotland (Leung et al., 2021). To improve response time for emergency calls, covering location models are applied as well in Taipei (Huang et al.,2013) and Virginia (Chanta et al., 2014). Huang et al. (2013) applied geospatial analysis to access the EMS system in Taipei within 10 minutes. Chanta et al. (2014) proposed bi- objective covering for the EMS in Virginia to respond to emergency calls to cover maximum incoming calls and reduce inequalities by considering fairness between each area of different needs. Nassel et al. (2014) analyzed distribution data of out-of-hospital cardiac arrest patients in Denver. The authors also identified high-risk neighborhoods through spatial analysis methods. High-risk locations were found in the Lincoln Park area, the proportion of OHCA cases was 0.67 per 1,000 incidents. Wang et al. (2018) investigated the utilization of AEDs in Taiwan. The highest utilization rate of AEDs is in long-term care facilities, residential areas. Most of the first responders are the employees at the location and medical personnel. Schierbeck et al. (2021) applied a geographical information system to find the optimal area for AED-drones corresponding to a high incidence of OHCA in Sweden. The authors defined the number of drones needed to cover the incident within 8 minutes. To determine the location of AEDs to cover the crucial incidences as much as possible with limited resources, fast track calls and geographic distribution in Muang Prachinburi district, Prachinburi province, Thailand during 2017 are considered.

3. Methods

The research applied the Maximal Covering Location Model (MCLP), the mathematical model for locating AEDs in Muang Prachinburi district, 127 villages, according to the distribution of emergency crisis diseases, 2059 incidences in 2017. The coverage distances are varied as 0.4, 1, and 2 km.

The Maximal Covering Location Model

The objective of the Maximal Covering Location Model is to select the number of *P* locations to cover as many incidences as possible. The MCLP is improved from the set covering problem, which is used in cases of limited service units (Church and ReVelle, 1974). The most comprehensive location assignment problem is choosing a location for the number of *P* service points to be able to cover the needs of as many populations as possible, which consists of the following decision variables:

X_j = 1, AED is located in facility j
= 0, otherwise
Z_i = 1, patients in zone i are covered
= 0, otherwise
w_i = Number of patients in zone i

The mathematical model:

$$\text{Maximize} \quad \sum_i w_i Z_i \qquad (1)$$

$$\text{Subject to} \quad \sum_{j \in N_i} X_j \geq Z_i \quad ; \forall i \qquad (2)$$

$$\sum_j X_j = P \qquad (3)$$

$$X_j \in \{0,1\} \quad ; \forall_j \qquad (4)$$

$$Z_i \in \{0,1\} \quad ; \forall i \qquad (5)$$

Objective (1) is to cover as many incidences as possible in the determined area. Constraint (2) to ensure that the patients' calls in zone *i* are covered only if they are within a coverage distance. Constraint (3) defines that the number of located AEDs is equal to *P*. Constraints (4) – (5) are binary variables.

4. Results and Discussion

4.1 Numerical Results

According to the collected data, the number of critical calls from 2015 to 2017, the result showed that the total number of emergency critical cases increased from 9.46% in 2017. The highest average increased critical calls are stroke and heart attack: 27.75% and 24.26%, respectively. As shown in Table 1, the highest number of diseases in descending order from 2015 to 2017 includes stroke, heart attack, sudden cardiac arrest, respiratory system, and major trauma, respectively.

Table 1. The total number of emergency critical cases in 2015-2017

Critical Cases	Yr 2015	Yr 2016	Yr 2017	Average change (%)
Respiratory Arrest	414	448	482	7.90
Heart Attack	77	104	118	24.26
Stroke	46	49	73	27.75
Sudden Cardiac Arrest	86	121	114	17.46
Major Trauma	1,258	1,233	1,272	0.59
Total	1,881	1,955	2,059	4.63

To determine the optimal location of AEDs using MCLP, we consider locating AEDs in educational institutions, government agencies, and temples, which are 10 gymnasiums, 45 schools, 2 colleges, 3 universities, 13 district administrations, 14 government offices, and 15 convenience stores (7-Eleven). The selection of places to install automatic defibrillators (AEDs) is based on the number of emergency critical illness cases in 2017. The coverage distances are varied as 0.4, 1 and 2 km.

Table 2. The results of the location of the AEDs based on the number of emergency critical calls in 2017

Coverage distance (km.)	*P*	% Coverage
0.4	10	25.92%
	20	36.45%
	40	43.02%
	60	47.11%
1	10	47.11 %
	20	60.36 %
	40	71.24 %
	60	74.62 %
2	10	74.62 %
	20	82.63 %
	40	90.09 %

From Table 2, maximal coverage critical incidences for coverage distances of 0.4, 1, and 2 km are 47.1%, 74.72%, and 90.09%, respectively. The suggested number of AED locations in a 2 km. coverage distance is 40 AEDs with coverage of 90.09%.

4.2 Graphical Results

For distribution trends of critical diseases, the number of critical illnesses consist of cardiac arrest, major trauma, stroke, respiratory arrest, and heart attack in Muang Prachinburi. In 2017, the number of cases totaled 2,059, with the highest number of emergency critical illnesses, including severe injuries and respiratory diseases, sudden cardiac arrest, heart attack, and stroke, respectively. It found that the first 3 sub districts with the highest number of calls from 13 sub districts in Muang Prachinburi district in 2015–2017 were Na Muang sub district, Ban Phra sub district, and Dongkeelek sub district, prone to disease severity. It was found that the density of severe disease is distributed towards the center of the city, as shown in Figure 1. Changes in the total number of critical diseases from 2015-2017 also shown in Figure 2.

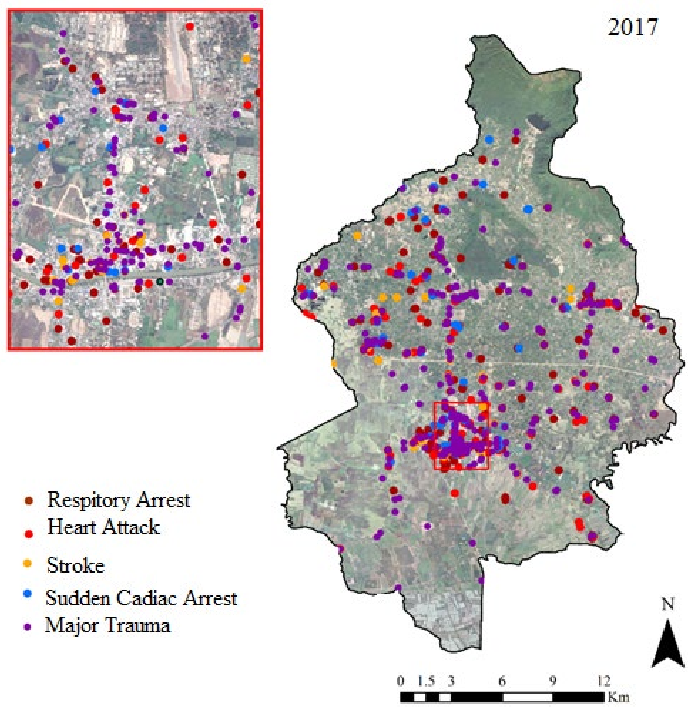

Figure 1. Emergency critical incidents in 2017

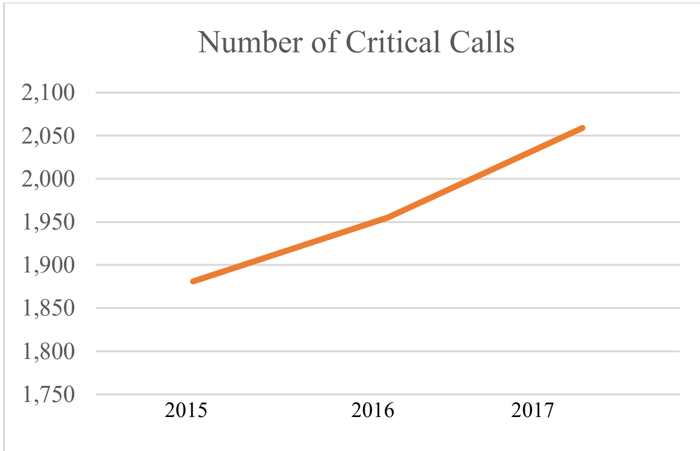

Figure 2. Total number of critical calls, 2015 – 2017

5. Conclusion

The location of the automatic defibrillators (AEDs) in Muang Prachinburi district, Prachinburi province consists of 13 subdivisions in accordance with the distribution of 5 emergency crisis diseases. In 2017, there were 2,095 cases, the highest number of diseases ever recorded, including severe trauma, respiratory diseases, sudden cardiac arrest, and stroke. The areas where the most disease occurs are Na Muang sub district, Ban Phra sub district, and Dongkeelek sub district. Diseases with the highest increase in the number of cases from 2015 include strokes and heart attacks, accounting for about 27.75% and 24.26%, respectively. The maximal coverage with 40 AEDs within 2 km. is approximately 90.09% of coverage.

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