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HEALTHCARE TRANSPORTATION PLANNING FOR SUB-DISTRICT HEALTH PROMOTING HOSPITALS: THE CASE OF CHACHOENGSAO PROVINCE, THAILAND

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Abstract

The application of health logistics to patient referral management, from the sub district health promoting hospital (SHPH), which is the primary healthcare provider, to the district hospital, which is the secondary healthcare provider, is very crucial for increasing the health service efficiency to save patients' lives in due time. This research aimed to study the patient referrals from the SHPHs to the district hospitals in Chachoengsao Province, Thailand based on the current operating conditions and to design a patient referral system with the shortest time period by conducting analysis with a geographic information system (GIS). The proposed method employed the analysis of positioning problems using the location-allocation analysis, so that the district hospitals cover the services of the SHPHs. Results indicate that the patient referrals from the SHPHs to the district hospitals under the current operating conditions took 1,999.12 minutes because it is required by the regulations that the patient referrals be within the same district. However, when analyzing the total time under the shortest time condition, the referrals took 1,893.34 minutes. Additionally, the comparison results of the patient referrals under the current operating condition showed that the referral time of 24 SHPHs decreased by 105.78 minutes or 20.61%. These research results can be useful for planning the patient referrals from the SHPHs to the district hospitals of Chachoengsao Province and to develop an efficient referral service for timely medical assistance.

Keywords: Healthcare Logistics, Healthcare Transportation, Primary Healthcare, Location-Allocation Analysis, Geographic Information Systems (GIS)

1. INTRODUCTION

Patient referral between hospitals is crucial for saving patients' lives [1] because they receive timely treatment and emergency care. The health system of Thailand is developed to provide accessibility to all people. The public health policy rules that the district hospitals and health centers must be available in all regions. Currently, the health center has been upgraded to the sub district health promotion hospital (SHPH) to provide treatment and rehabilitation services as well as promote prevention, so that people receive the primary and necessary health services. World Health Organization (WHO) promotes improving health systems and achieving the health-related Sustainable Development Goals (SDGs). Especially, SDG 3 aims to monitor in healthy and ensure the well-being of all ages. The agenda of SDG 3 address to achieve universal health coverage (UHC) in building better systems for health. By health-state distributions are one indicator to monitor health and injuries of populations [2].

This research studied the patient referrals between the hospitals in Chachoengsao Province, one of the eastern provinces of Thailand and the three provinces in the Eastern Economic Corridor (EEC). According to EEC policy, Chachoengsao Province is located in a livable industrial city and is the logistics hub. Moreover, it is the significant base of many industrial sectors [3]. Referring to the Chachoengsao Development Plan, the population as of August 2018 was 713,260 persons from 286,027 households. The province is well prepared for the changes in the basic structure of medical treatment due to the increasing number of patients at SHPHs, which increased by 4.4% from 2018 to 2019. This implies that each SHPH is essential to people because it is the primary service unit under the Ministry of Public Health that is close to the people and the community [4].

Nevertheless, when examining the operations of patient referrals from the SHPHs to the district hospitals, the SHPHs only provide the primary treatment to patients. In serious cases that require special medical equipment, the patient is referred to the district hospital to receive inclusive and appropriate treatment. The results of the study on the health service system development plan illustrated that the patient referral from the SHPH to the district hospital can only be done within the same district, which is the problem with the current referral operation. SHPHs cannot refer patients to a hospital in another district even if it offers a shorter referral time. As a result, patient referrals take a longer time, and this affects the patient’s life-saving emergency care [5].

For this reason, the aim of this research was to plan a patient referral system based on the transport time from the SHPH to the district hospital, which consisted of three main contributions. Firstly, the study on the patient referrals under the current operating condition only available at the hospitals within the same district was conducted to determine the patient referral time. Secondly, the hypothesis of the analysis under the fastest referral time condition to set the guidelines for referral based on the shortest time even though the district hospital is located in a different district to the SHPH was defined. Thirdly, the application of GIS to analyze and compare the data to determine the results of patient referrals from the SHPH to the closest district hospital, such as in the case of a patient with a serious injury but the SHPH has insufficient equipment, or when the SHPH needs the assistance from the closest district hospital to send an ambulance to the patient in a very short time.

2. LITERATURE REVIEW

2.1 Health logistics management

Health logistics management is the logistics process based on transportation that has the movement of people, medical equipment, and services. For this reason, effective transportation management is critical to the identification of a quick route for the efficiency of health logistics. Fathollahi-Fard et al.(2022) reported that quality transportation requires operational planning to control the transport on the return trip

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during the COVID-19 outbreak. In addition, Fathollahi-fard et al.(2020) discovered the issue caused by the COVID-19 pandemic worldwide with numerous infected people, which led to a shortage of patient rooms in the hospital. As a result, the measures indicated that a patient with mild symptoms should follow the home isolation approach, and the medical personnel would visit them at home at the scheduled time. For these reasons, a travel plan is needed for patient visits.

In addition, Liu et al. (2013) studied the drug and medical equipment transport from the hospital to the patient's house under three conditions: drug and medical equipment from a warehouse to the patient's home, drugs and medical equipment from a hospital to the patient's house, and referral of patients from their house to the hospital. Genetic Algorithms (GA) and Tabu Search (TS) methods were applied to determine the most efficient transportation. Additionally, Ouertani et al. (2019) examined the planning of the routes that the hospital used to deliver the medical equipment or nurses to the homes of patients to enhance the efficiency of route determination and transportation cost reduction by using Genetic Algorithms (GA). Similarly, Haddadene et al. (2019) investigated the route for the medical teams to visit patients at home and found that the problem of route planning and transportation of the medical teams was the high cost. Therefore, it was necessary to find an efficient route and reduce the cost by using the heuristic method for the route planning to visit the patients within the set time.

The number of relevant research studies on health logistics emphasizing the elderly has increased continuously. Fathollahi-Fard et al. (2022) found that more elderly needed to receive treatment in the hospital, so the number of rooms was insufficient. Consequently, home health care 4was the solution. Moreover, research was conducted on the solutions to the problems with patient service by applying the Lagrangian Relaxation method to obtain an efficient home patient model. Moreover, Demirbilek et al. (2019) studied home care for elderly patients. The number of elderly increased, but the medical personnel was still limited. Therefore, personnel management and route planning were critical to the medical services by applying the heuristic method to set the new patient care schedule. Additionally, Fathollahi-fard et al. (2020) examined the elderly patient care and physical therapy in which the nurses had to visit the patients at home in order to follow up. They needed to plan the route to provide them with inclusive care by using simulation and heuristics. Similarly, Shahnejat-Bushehri et al. (2021) investigated the home visits to treat patients by planning efficient accessibility using a simulation to plan the route. Likewise, Nikzad et al. (2021) researched the home care patient service to correspond with the sufficient number of medical personnel by developing a patient access plan and proposing the simulation to resolve the routing problems for better efficiency using the metaheuristic algorithm. Moreover, Lusiantoro et al. (2022) applied the maximal covering location problem (MCLP) to provide coverage of vaccination by minimizing the distance of vaccine distribution.

The studies applying the logistics management system to health planning have been widely acceptable since they enhance the efficiency of management and service, such as the route management of medical equipment transportation, home visit route planning, and accessibility planning for patient follow-up, by prioritizing the time and

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distance, which are the significant elements for assisting, treating, and rehabilitating the patients before receiving the proper treatment.

2.2 Geographic information systems (GIS)

This system uses spatial data that can identify locations by analyzing the coordinated references [15]. Spatial data is used in the analysis of an area's qualities, and the presentation is in a map format, so the reader easily understands it. Spatial data is classified into three models: Point, Line, and Polygon [16]. The analysis by GIS is different from other programs because it analyzes both spatial and non-spatial data [17]. Network analysis analyzes the spatial data network and the best route, as well as the distance and optimal time of the service area. Further, in the network analysis, the virtual analysis conditions, such as traffic conditions, can be set. There are many models of network analysis, such as the best route analysis, service area analysis, close facility analysis, origin-destination cost matrix analysis, vehicle routing problem analysis, and location-allocation analysis [18]. A number of studies foresaw the efficiency of this tool and applied it to examine the health system accessibility. For instance, Ursulica, (2016) investigated the travel time and distance to the hospital and found that the long travel time was the main issue. Therefore, the location of the hospital should be determined in order to facilitate the people in the remote areas by using GIS to find the optimal locations. Similarly, Bazargan, (2018) studied the distribution of hospitals to determine the health service accessibility using GIS to identify the closest hospital. Likewise, Ahmed et al. (2019) examined the accessibility of emergency medical treatment for the patients injured by burning and from coronary artery disease by applying GIS to analyze the data.

Furthermore, Abdullahi & Abdullahi (2019) investigated the hospital location and network to locate the hospital service area using GIS to identify the hospital distribution. Results showed that the hospital distribution was inadequate for the local people, and as a result, they needed to travel to a hospital in another region, which took a long time and affected the loss of life. Also, Rudolfson et al. (2020) observed the travel from home to the hospital that took a long time by using GIS and compared the patient transportation model to find the shortest route. Additionally, Sushma & Reddy (2021) surveyed the optimal location for establishing the hospital in India to deal with emergencies, such as COVID-19, using GIS to analyze the data under the shortest route condition and the closest facilities.

In addition, GIS can be applied to other transportation businesses to analyze transport planning because transportation is essential for business operations. Inefficient transportation planning leads to higher costs. Thus, the current route and the route analyzed using GIS under the shortest distance and time should be compared. For example, Simoni et al. (2018) studied goods transport using GIS by simulating a route to plan efficient transport and reduce the cost of transportation. Similarly, therefore, the GIS to simulate a transport route was created to resolve the problem. Similarly, Suraraksa & Shin (2019) investigated fresh fruit transportation and discovered that the transport must be quick to maintain the quality of the fruit. Therefore, the shortest and fastest route was determined by analysis with GIS. Moreover, Georgise et al., (2020)

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analyzed the location of the coffee processing factory using a mathematic model and processing with GIS to select the best location based on future growth. The previous research studies illustrate that analysis with GIS is efficient and can be applied to industrial businesses to determine the shortest routes and reduce transportation costs. Moreover, it can be the guideline for route planning for goods and services.

The review of previous research illustrated that the number of studies on the health service accessibility model relating to a patient referral from the district and sub district hospitals was low, especially the study of the routes and locations of the district hospitals and SHPHs. For this reason, this research applied the guidelines for route planning to improve the shorter time and distance of patient referral efficiency in the health logistics plan of Chachoengsao Province, Thailand, in order to enhance the potential of patient referrals of SHPHs to save people’s lives, and analyze the data with GIS to refer the patient within the shortest time under the current situation conditions and simulate the situation under the short time and distance conditions to find the optimal route leading to the efficient patient referrals for the quick treatment and emergency care.

3. RESEACH MATHODOLOGY

3.1 Data collection

The relevant data, which were the location of the district hospitals (one hospital in one district), and the location of the sub district health promotion hospital (SHPH) (one SHPH in one sub district) (Organizing a Comprehensive Health System, 2012) were collected, as shown in Figure 1.

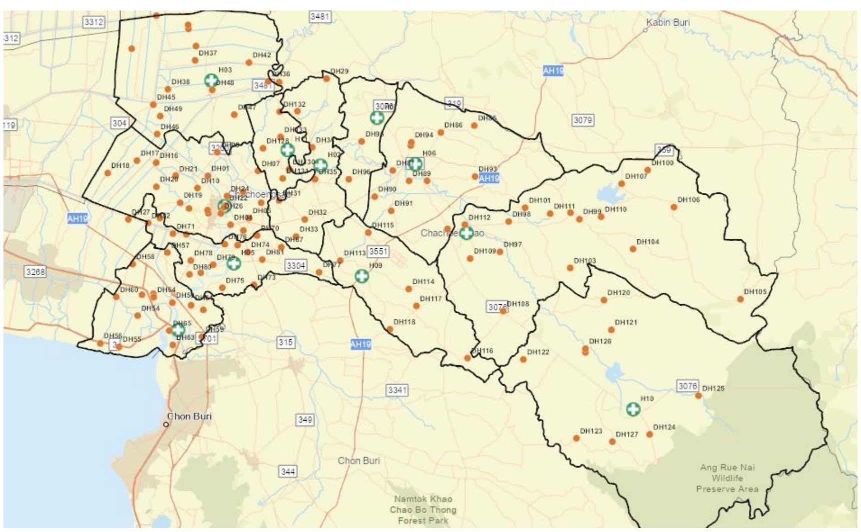

Fig 1: Locations of hospitals in Chachoengsao Province

As seen in Figure 1, the administration of Chachoengsao Province is divided into 11 districts and 93 sub districts, with the sub districts under the municipality area that include two sub districts, 892 villages, and 34 municipalities (one city municipality and 33 sub district municipalities), one provincial administrative organization, and 74 sub

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district administrative organizations. The Ministry of Public Health is responsible for the people's health care by establishing the health services at various levels. The primary care service is the SHPHs, and the secondary care is at the district hospitals. The tertiary care is the provincial hospital. Each level has different roles and responsibilities that are all connected via the referral system to provide quality service. In Chachoengsao Province, there are 11 district hospitals and 133 SHPHs.

3.2 Framework

In this research, the patient referral model was studied under the current operating condition, which limits the referrals to within the same district only, although the SHPH may be located far from the district hospital. This model is shown in Figure 2.

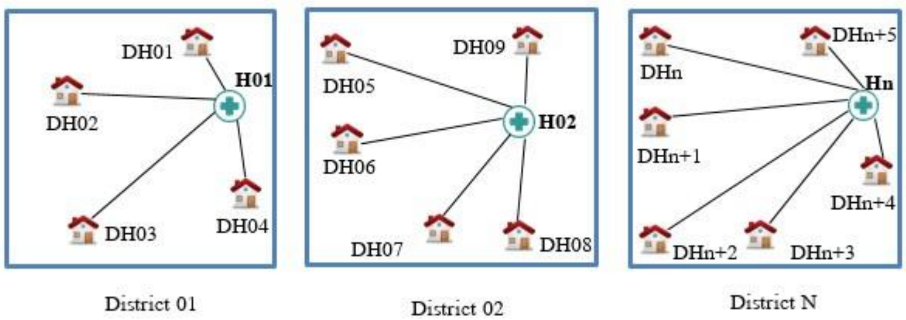

Fig 2: Patient referrals under the current operating condition

The patient referrals under the current operating condition are from the SHPHs to the district hospitals located in the same district only shows that Figure 2. For example, District 01 consists of four sub districts, so there is one district hospital (H01) and four SHPHs (DH01, DH02, DH03, DH04). Thus, the patients from the four SHPHs must be referred to H01 only because they are located within the same area as District 01, regardless of the shortest distance of patient referral.

The researcher compared the patient referral times from the SHPHs to the district hospitals with the referral times under the conditions set in this study, using the shortest referral time and across districts if the SHPH is closest to a hospital in another district, in order to analyze the change of referral time, as shown in Figure 3.

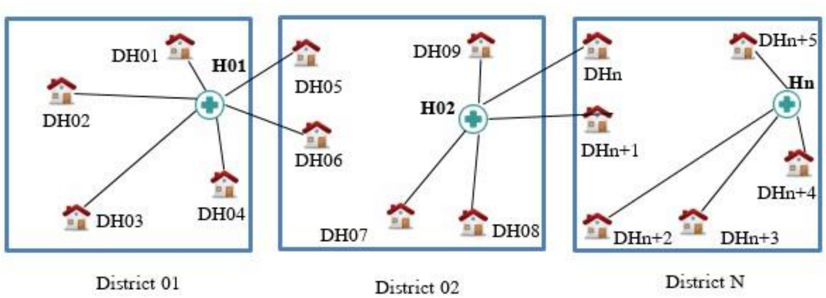

Fig 3: Patient referrals under the shortest referral time condition

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The condition based on the shortest referral time by omitting the limitation of the same district restriction, but instead using the closest hospital in any district shows Figure 3. For instance, DH05 and DH06 must refer the patient to H01, which is located in another district because it would take less time than going to H02, which is located in the same district. Thus, the patient referrals from the SHPH to a hospital in another district should be considered in order to enhance the efficiency of patient referrals. Consequently, the patients would receive timely treatment and the mortality rate would be reduced.

3.3 Network analysis to determine the location-allocation of the district hospital

The location-allocation method is a position analysis from the potential information that is set [28] to analyze the optimal location. The location might be the position with facilities or considered from the ideal location to determine the most appropriate and efficient route. This research aimed to create an efficient patient referral model with the fastest referral time. Therefore, the mathematical model of deterministic location-allocation with the maximal covering problem condition, which is the problem that corresponds most closely to the objective and application, was applied [29]. The mathematical equation may be as follows:

Maximum Covering Location Problem (MCLP)

$$\text{Maximize} = \sum_{i \in I}^{n} a_i y_i \quad (1)$$

$$\sum_{j \in N_i} x_j \geq y_i \quad ; \forall i \quad (2)$$

$$\sum_{j \in N_i} x_j \quad (3)$$

$$x_j \in \{0, 1\} \quad ; \forall j \quad (4)$$

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

Where

a_i is the number of SHPH at a location i

i is the location of SHPH

j is the location of the district hospital

P is the number of district hospitals

x_j = {1 if choosing the district hospital at location j; 0 if not.}

y_i = {1 if the SHPH at the location j is correct; 0 if not.}

Equation (1) is intended to cover most SHPHs, whereas Equation (2) assures that the SHPH will receive the service from the district hospital located within the determined distance. Equation (3) shows the limitation of the number of locations to be selected, which is P only. Equations (4-5) are the numeric limitations.

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4. RESULTS AND DISCUSSION

4.1 Study results of the patient referral time under the current operating condition

According to the current operations, if the patient receives the primary treatment at the SHPH but has serious symptoms and the SHPH cannot handle the case, the patient will be referred to the district hospital because there are more medical personnel and efficient equipment. However, the SHPH can only refer the patient to the district hospital within the same district and does not consider the referral time in terms of whether or not it takes a long time. As a result, there may be a delay in a referral because some SHPHs are distant from the district hospital within the same network, as shown in Table 1 and Figure 4.

Table 1: **Patient referrals under the current condition of the hospitals in Chachoengsao Province**

DH_ID	**H_ID**	**District**	**Latitude**	**Longitude**
DH01 -DH26	H01	Mueang Chachoengsao	13.6861755	101.073125
DH27 -DH35	H02	Bang Khla	13.7462494	101.21881
DH36 -DH49	H03	Bang Nam Priao	13.8721279	101.0529
DH50- DH65	H04	Bang Pakong	13.5024971	101.002138
DH66- DH82	H05	Ban Pho	13.6012577	101.087006
DH83-DH94	H06	Phanom Sarakham	13.7483479	101.363156
DH95-DH96	H07	Ratchasan	13.8170404	101.304792
DH97- DH112	H08	Sanam Chai Khet	13.6463031	101.4411
DH113- DH118	H09	Sanam Chai Khet	13.5822438	101.281798
DH119 -DH127	H10	Tha Takiap	13.384846	101.694614
DH128 -DH133	H11	Khlong Khuean	13.7693343	101.16865

Table 1 shows that 133 SHPHs in total (DH01-DH133) need to refer the patients to a total of 11 district hospitals in each district (H01-H11) under the condition of referring to only the district hospital within the same district. For instance, the SHPHs that are located in Mueang District, Chachoengsao Province (DH01-DH26, 26 SHPHs in total) must refer the patients to the district hospital, H01 (Mueang Chachoengsao Hospital). Meanwhile, the SHPHs that are situated in Bang Khla District (DH27-DH35, 9 SHPHs in total) must refer the patients to H02 (Bang Khla Hospital). When the practitioner at the SHPH assesses and concludes that the SHPH does not have enough medical equipment or the specialist to provide the treatment, the patient is referred to the designated district hospital only.

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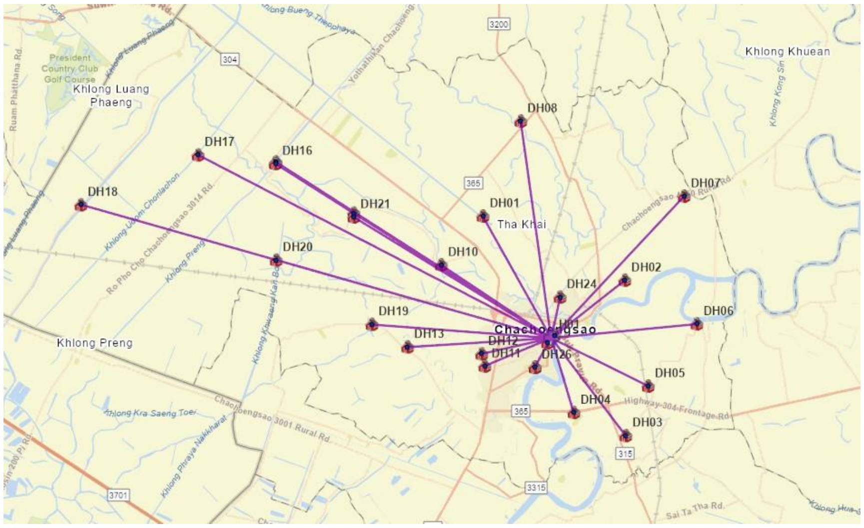

Fig. 4 **Sample of patient referrals under the current operating condition of the SHPHs in Mueang District**

Figure 4 exhibits the sample of patient referrals under the current operating condition of 26 SHPHs that are located in each sub district of Muang District. One district hospital, H01 (Mueang Chachoengsao Hospital) showed that the current patient referral system has the locations of this hospital in the time period of travel that are different. Therefore, the current model results in the long patient referral times from the SHPHs that are distant from the district hospitals, or there might be a district hospital that would take a shorter time to reach from the SHPH.

4.2 Study results of the patient referral times under the shortest referral time condition

Study results of the patient referral times under current conditions can be applied to improve the patient referral system. Thus, the researcher proposed the analysis guidelines using GIS to respond to the patients' needs and facilitate the practitioners in the SHPH to make a quick decision on patient referral. GIS was used to determine the district hospital to which the referral would take the shortest time, as shown in Table 2 and Figure 5.

The patient referrals of the SHPHs presents on Table 2 that have decided to transfer a patient to the district hospital in another district as appropriate for the shortest referral time condition. Twenty-four SHPHs, which were DH27, DH32, DH33, DH46, DH57, DH66, DH69, DH71, DH76, DH78, DH82, DH96, DH80, DH100, DH107, DH116, DH120, DH122, DH77, DH07, DH28, DH30, and DH36, changed from the patient referral to the district hospital in the same district because they sent the patients to hospitals in another district that was located closer and thereby took less time. For example, DH27, DH32, DH33, DH46, DH57, DH66, DH69, DH71, DH76, DH78, and DH82 could quickly refer patients to H01 (Mueang Chachoengsao Hospital) instead of DH96. When considering the shortest referral time, DH96 used the shortest time by going to H02 (Bang Khla).

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Table 2: **Patient referrals under the shortest referral time condition of the hospitals in Chachoengsao Province**

ORIGIN_DH_ID	DESTINATION _H_ID	DISTRICT	DRIVING TIME (Minutes)
DH01, DH02, DH03, DH04, DH05, DH06, DH08, DH09, DH10, DH11, DH12, DH13, DH14, DH15, DH16, DH17, DH18, DH19, DH20, DH21, DH22, DH23, DH24, DH25, DH26, **DH27, DH32, DH33, DH46, DH57, DH66, DH69, DH71, DH76, DH78, DH82**	H01	Mueang Chachoengsao	399.8
DH29, DH31, DH34, DH35, **DH96**	H02	Bang Khla	58.18
DH37, DH38, DH39, DH40, DH41, DH42, DH43, DH44, DH45, DH47, DH48, DH49	H03	Bang Nam Priao	214.07
DH50, DH51, DH52, DH53, DH54, DH55, DH56, DH58, DH59, DH60, DH61, DH62, DH63, DH64, DH65, **DH80**	H04	Bang Pakong	184.31
DH67, DH68, DH70, DH72, DH73, DH74, DH75, DH79, DH81	H05	Ban Pho	73.91
DH83, DH85, DH86, DH87, DH88, DH89, DH90, DH91, DH92, DH93, DH94, **DH100, DH107**	H06	Phanom Sarakham	175.38
DH95	H07	Ratchasan	5.26
DH84, DH97, DH98, DH99, DH101, DH102, DH103, DH104, DH105, DH106, DH108, DH109, DH110, DH111, DH112, **DH116, DH120, DH122**	H08	Sanam Chai Khet	442.59
DH77, DH113, DH114, DH115, DH117, DH118	H09	Sanam Chai Khet	66.14
DH119, DH121, DH123, DH124, DH125, DH126, DH127	H10	Tha Takiap	168.8
DH07, DH28, DH30, DH36, DH128, DH129, DH130, DH131, DH132, DH133	H11	Khlong Khuean	104.9
TOTAL			**1,893.34**

Fig. 5 **Patient referrals under the shortest referral time conditionof Chachoengsao Province**

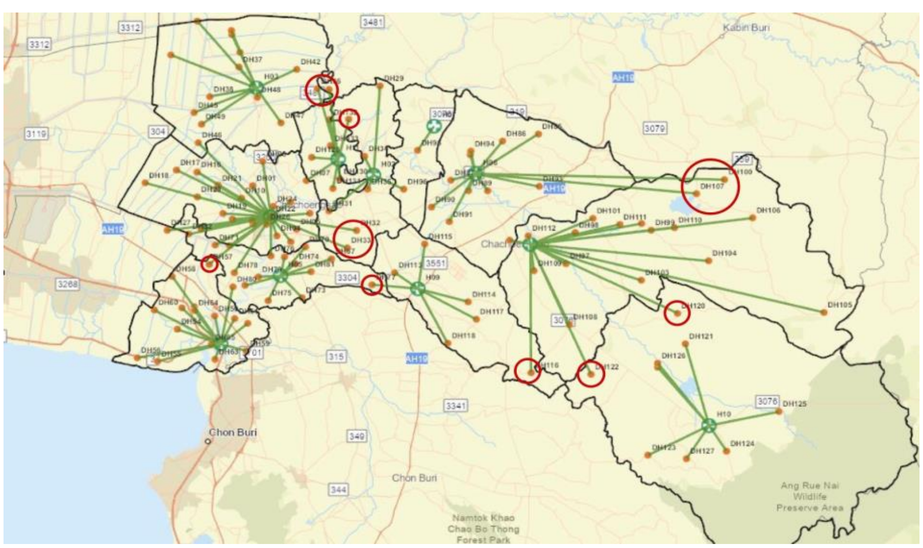

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Figure 5 shows that some SHPHs in Chachoengsao Province referred a patient to the district hospital without considering the referral time. In emergency cases where the patient has a risk of death, the patient referral time is vital and limited. Therefore, traveling to the district hospital based on the shortest travel time should be prioritized. When considering the patient referral under the shortest referral time condition in Chachoengsao Province, SHPHs changed the practice by sending the patient to another hospital that offered a shorter referral time. For example, DH07 is under H01; however, with the shortest referral time condition using GIS, it would take a shorter time if DH07 referred the patient to H11, thus increasing the possibility of survival.

4.3 Comparison results of the patient referral times under the current operating condition and the shortest referral time condition

Analysis results of the health logistics planning of SHPH in Chachoengsao Province using the data analysis from GIS from 08:30 am to 4:30 pm on Monday to Friday, in terms of time and distance were compared with the patient referral times under the current operating condition and the shortest referral time condition to determine the change, as shown in Table 3.

Table 3: Comparison results of patient referrals from the SHPHs to district hospitals

Origin_DH_ID	Destination_H_ID (Present)	Destination H_ID (Min Time)	Driving Time (Minutes)		Difference	
			Operation (Present)	Operation (Min Time)	Minutes	Percent (%)
DH27	H02	H01	38.52	20.43	18.09	46.96%
DH46	H03	H01	25.77	16.46	9.31	36.13%
DH76	H05	H01	13.33	9.61	3.72	27.91%
DH33	H02	H01	19.97	16.27	3.7	18.53%
DH71	H05	H01	13.47	11.28	2.19	16.26%
DH69	H05	H01	16.04	13.85	2.19	13.65%
DH78	H05	H01	9.28	8.02	1.26	13.58%
DH32	H02	H01	12.92	11.26	1.66	12.85%
DH82	H05	H01	19.73	17.54	2.19	11.10%
DH66	H05	H01	20.3	18.11	2.19	10.79%
DH57	H04	H01	15.15	14.46	0.69	4.55%
DH96	H07	H02	18.19	10.93	7.26	39.91%
DH80	H05	H04	13.09	10.13	2.96	22.61%
DH107	H08	H06	32.96	30.73	2.23	6.77%
DH100	H08	H06	40.69	38.46	2.23	5.48%
DH84	H06	H08	15.15	6.61	8.54	56.37%
DH120	H10	H08	41.32	31.06	10.26	24.83%
DH116	H09	H08	35.44	28.32	7.12	20.09%
DH122	H10	H08	35.22	34.52	0.7	1.99%
DH77	H05	H09	14.34	9.17	5.17	36.05%
DH07	H01	H11	8.71	6.22	2.49	28.59%
DH30	H02	H11	21.37	15.65	5.72	26.77%
DH28	H02	H11	16.79	13.58	3.21	19.12%
DH36	H03	H11	15.47	14.77	0.7	4.52%
Total			**513.22**	**407.44**	**105.78**	**20.61%**

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Table 3 indicates the change in patient referral times under the shortest referral time condition, and the destination was changed to 24 district hospitals. Eleven SHPHs (DH27, DH46, DH76, DH33, DH71, DH69, DH78, DH32, DH82, DH66, and DH57) referred the patients to H01. Moreover, four SHPHs (DH84, DH116, DH120, and DH122) changed to refer the patients to H11, and five SHPHs referred patients to H02, H04, H06, and H09. It is noticeable that when the shortest referral time condition was applied, the referral time was reduced, and the travel time to the closest destination could be determined. Therefore, it was concluded that the shortest time condition enhanced the efficiency of the patient referrals of the SHPHs in Chachoengsao Province. The five samples of SHPHs, DH84, DH27, DH96, DH46, and DH77 could reduce the referral time the most, by 56.37, 46.96, 39.91, 36.13, and 36.05%, respectively. Overall analysis results using GIS implied that it reduced the referral time by 105.78 minutes in total, or 20.61%.

5. CONCLUSIONS

This research study examined the patient referral planning under the current operating condition, in which 113 SHPHs refer patients to only the 11 district hospitals within the same district as the SHPH. The research was designed to eliminate this limitation by allowing the SHPHs to refer the patients by analyzing the referral under the shortest referral time condition to reduce the travel time from the SHPH to the district hospital by using GIS. Further, the search showed the comparison results to determine the quickest referral from the SHPH to the closest district hospital for swift treatment. The main contribution of this research was to set the patient referral plan from the SHPH to the district hospital based on the travel time for efficient referral time and timely treatment by using the network analysis from GIS.

Research results illustrated that the patient referral time from the SHPH to the district hospital within the same district caused the issue in the service accessibility by requiring longer travel times. The total time was 1,999.12 minutes. From the limitation to the referrals within the same district that affected the accessibility of the patient Zhang et al. (2021) examined the satisfaction with the medical service and reported that the patients emphasized the quick accessibility. For this reason, the researcher designed the framework to study the patient referrals from the SHPHs to the district hospitals under the shortest referral time condition to enhance the efficiency of patient life-saving. Study results using GIS clearly showed that the total referral time under the shortest referral time condition was 1,893.34 minutes. In addition, the comparison results between the patient referral time under the current operation and the shortest referral time condition showed that when 24 SHPHs changed the referral system, from the district hospital in the same district to that in another district, it took a shorter time. As a result, the total referral time was reduced by 105.78 minutes or 20.61%.

For the consideration of time and distance to refer the patients of an SHPH to a district hospital using the shortest route planning, it was found that the application of the Geographic Information System (GIS) to analyze the data has potential. This was in line with the research of Abdullahi & Abdullahi (2019) who analyzed the location of a hospital and network to determine the hospital's service area in each area. Additionally, it was consistent with Jin & Zhang (2018) who applied GIS to analyze the location of the goods distribution center and transportation route of the construction equipment in China to increase transportation efficiency and shorten the transportation time.

In this research, the guidelines for referring patients from the SHPH to the district hospital under the same district only condition were studied in order to compare them with the shortest referral time condition. The analysis of transportation costs or the number of personnel at the district hospital were not addressed regarding whether or not they are sufficient for the system change. Therefore, further studies should examine the route planning that takes the transportation costs, operational costs, and the number of ambulances into consideration so as to enhance the operations and service efficiency.

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