Research Article *Science, Engineering and Health Studies 2018, 12(1), 47-58*

Evaluation of the establishment of health promoting hospital via geographic information system in the north-eastern area of Thailand

Anun Chaikoolvatana[1*] and Vachirasak Pakasit[2]

[1]*College of Medicine and Public Health, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand*
[2]*Faculty of Nursing, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand*
[*]*Corresponding author: kkjc5476@yahoo.com*

Received: July 23, 2017; Accepted: February 28, 2018

ABSTRACT

The health promoting hospital (HPH) has been established in Thailand since 2009. However, there have not been any documents indicated the evaluation of the appropriateness of HPH establishment. This applied-survey research aimed to develop a geographic information system (GIS) tool to assess whether the HPH establishment is appropriate. There were totally 31 HPH staffs enrolled into the study. A GIS database was created. The appropriateness and importance of HPH establishment were assessed via six components related to HPH establishment (6 questionnaire items). Also, weighing score summary was analyzed and interpreted via descriptive statistics (e.g., frequency, mean, percentage). The findings showed there were only three crucial components, including transportation, total population within responsible areas, and a number of healthcare workers, especially registered nurses, were highly appropriate for the HPH establishment via mean scores. In contrast, a total number of patients outside the area setting (per month), and a number of healthcare workers had low mean scores and need to be improved. Finally, the weighing scores indicated that most HPH were moderately appropriately established (53.33%). Overall, using GIS to visually represent the appropriateness of HPH establishment through the questionnaire evaluation, provided valuable information that assisted in facilitating primary care center management and organizational change.

Keywords: Geographic Information System; Health Promoting Hospital; Geographic; Positioning System (GPS); Primary Care Unit (PCU)

1. INTRODUCTION

The resolution of World Health Organization (WHO, 2008; WHO 1996) meeting in 1978 was the introduction of 'primary care unit (PCU)' as the pathway of health equality and development. Thailand has followed its health policy and strategy, including the establishment of public and community health centers. Nevertheless, there were still some limitations regarding lack of health care workers, especially physicians. It has been impacted both patient care quality and health service adequacy. As a result, in 2009 Thai government has modified the overall health services by improving a traditional public health center into a new center called 'Health Promoting Hospital (HPH)' (Auamkul et al., 1999). Its five missions include health promoting, patient care, disease prevention, health service improvement, and consumer protection. HPH is one of PCU services which provide public health services at village, subs-district, and local community levels.

ISSN Online 2630-0087 DOI: https://doi.org/10.14456/sehs.2018.5

Later Bureau of Health Administration (BHA), Ministry of Public Health Thailand has issued national strategies related to the quality of public health services. The strategies have been revised every 5 years. Regarding the HPH setting, Deputy Minister of Public Health assigns the policy to local authorities, including, Permanent Secretary, Chief Executive of Provincial Administration Organization, and Provincial Health Doctor to develop the standard protocol containing some crucial components of HPH setting. The Office of Thai Healthcare Reform (2005) issued the latest 5 standard components to evaluate the HPH setting, including 1) location, 2) transportation, 3) a total population, 4) an average number of patients (per month), 5) an average number of the outsiders living outside the catchment area (per month), and 6) a number of health care providers.

So far, it might be questionable whether the available health promoting hospitals have reached those key components. There have some limitations reported, including many local people went to the HPHs which are not responsible for their health areas (Auamkul et al., 1999). Also, it was revealed most HPHs lack of health care providers, especially physicians, as the financial benefit of working at a HPH is not temping enough compared to a provincial and or central hospitals (HPH Committee, 1999). As the HPH limitations occurred, BHA came up with the new approaches, including infrastructure development, HPH service distribution, geographic information system (GIS) implementation, and HPH potential enhancement.

Regarding the implementation of GIS in public health services, Bureau of Policy and Strategy, Ministry of Public Health Thailand used GIS tool to divide the levels of health care centers into 3 categories, including primary, secondary, and tertiary care levels. HPH is one of the primary care units as well. Office of Permanent Secretary, Thailand has also implemented GIS program to categorize health care levels based on the availability of the physician specialty. Additionally, the GIS program has been used to develop a model of primary health care services adapted from Christaller's theory and related to the distance to the hospital and catchment areas. The program could indicate the nearest hospital site to the residents, including public and private hospitals, primary care sectors. The program will help local people save time and money for the hospital visits (Sahachaisaree, 2002). Moreover, GIS tool has been used to improve patient care quality as well as care access. For example, a community health mapping (CHM) using GIS tool was developed to solve the patient health problems. It could indicate the resources of diseases and the responsibility of healthcare teams. The mapping data shows the population density, healthcare sectors, disease epidemiology, and health strategies in each area (Ghose, 2001; Treuhaft, 2007; Treuhaft, 2009; Musa et al., 2013). Moreover, GIS tool has been shown to improve alternative diagnostic placement strategies in limited resource settings by revealing deficiencies in health care access pathways, comparing relative costs, assessing benefits, and improving outcomes (Ferguson, 2016).

Thai Healthcare Reform Office has issued the latest document about HPH establishment. Nevertheless, there have not been any adequate information containing the appropriateness of HPH establishment since the beginning of the project. Some controversial issues, including budget spending, HPH setting area, population number, facility, and local politics have been raised over the years (Bureau of Health Policy and Planning, 1998). Additionally, there have been a few productive works in Thailand related to GIS utilization in local health setting, including HPH (HPH Committee, 1999). In order to minimize those limitations, HPH-GIS tool was aimly developed in this study to help the District Administration Organization to evaluate the local health services.

Additionally, this tool can assess whether or not the HPHs are appropriated regarding the key components of HPH establishment.

2. MATERIALS AND METHODS

2.1 Study design

It is a questionnaire survey research.

2.2 Study locations/samples

Khueng-Nai district, Ubon Ratchathani province was selected to be a study area based on the provincial government request. Totally the local population is equal to 108,810 residents currently living in 18 sub-districts. There are 31 HPHs located in this district. Two official personnels from each HPH, who are a head of HPH and a registered nurse, were selected to be the subjects in the study.

2.3 Population/samples

The healthcare workers of each HPH were assigned into the study. Those volunteers were selected based on their work responsibilities involved in HPH services. Totally, there were 31 HPH volunteers underwent the interview regarding HPH establishment components.

2.4 Research tool development

2.4.1 The development of GIS database of HPH by using QGIS (Diagram 1)

HPH-QGIS database was developed based on various types of computer software included. It used operating system computer (Window 7) from Microsoft® to run this database. A GIS database was created by QGIS software ver.2.8 (ESRI®) with applications, including digitizer, plotter, printer, and mapping data. Regarding the identification of target sites, Global Positioning System (GPS) and GPS navigator (Garmin®) were implemented to spot the locations of HPH.

2.4.2 Questionnaire items containing crucial HPH components

2.4.2.1 Questionnaire contents

The contents of the questionnaire items were modified from a guideline of Bureau of Health Policy and Planning (1998). They are divided into 2 sections including 1) six components related to HPH establishment (6 items) and 2) weighing score summary. For the first section, there were 6 questionnaire items reviewed from both some previous studies (Amiri et al., 2016; Khosravi et al., 2016; Auamkul et al., 1999; Auamkul and Keereewong, 1999) and the comments from the experts to identify the catchment area for HPH establishment. They include 1) distance and radius of HPH services, 2) transportation and convenience of HPH service access, 3) total population of area setting, 4) a total number of patients (per month), 5) a total number of patients outside the area setting (per month), and 6) a number of healthcare workers (per 10,000 population), including physician, registered nurse, public health worker, social worker, dentist, dental assistant, and pharmacy assistant. Another section contains weighing scores of each component in section 1.

2.4.2.2 Process and statistical analysis

1) Section 1 (R). Each questionnaire item represented whether it is appropriate for HPH establishment via *weighing scales* from 0 to 10 (Chokewiwat, 1999; Kazda, 2009).

If a questionnaire item is
not relatively appropriate → weighing scale = 0

If a questionnaire item is
slightly appropriate → 1-3

If a questionnaire item is
moderately appropriate → *4 -6*

If a questionnaire item is
highly appropriate → *7-10*

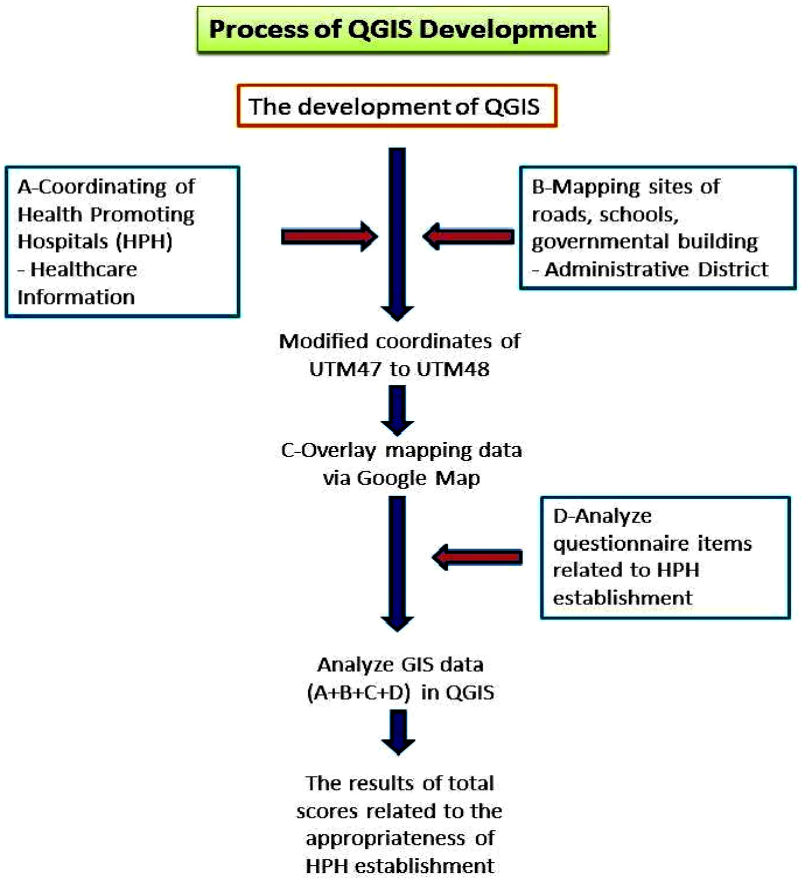

Diagram 1 The procedure of GIS database development

2) Section 2 (W). Each component was evaluated via *rating scales* (0 to 10) whether it is important for HPH establishment including;

If a component is not important → 0
If a component is slightly important → 1-3
If a component is moderately important → 4-6
If a component is highly important →7-10

Finally, the weighing score summary was calculated from 6 components in section 1 and 2 via Overlay Analysis (Chokwiwat, 1999; Kazda, 2009).

$$S = (W_1 R_{1j} + W_2 R_{2j} + \ldots + W_n R_{nj})$$

S = A total score of HPH establishment evaluation on each volunteer
W = Mean scores of the weighing scales
R = Mean scores of the rating scales.

Later, a total score would be divided into 3 categories, including;

- *Highly appropriate* (scores ≥ 30)
- *Moderately appropriate* (scores between 20 and 29)
- *Slightly appropriate* (scores < 20).

3. RESULTS

3.1 Demographic data

Khueng-Nai district, Ubon Ratchathani province has the population of 108,180 and 2,459 households located in the areas. It is far from a central city (Ubon) 38 kilometers, and has rainfall 1,258 milliliters per year. The Che river runs throughout the city. Regarding the nearby districts, it is closed to 'Khum-Khuan-Kaew' district in the north, and 'Muang-Sam-Sip' district in the east. Also, 'Khan-Tra-Rom' in the south and "Kho-

Wang' districts in the west are closed to this district. Totally, there are 18 sub-districts (tambol), 183 villages, 8 schools, and 1 university. Importantly, there are 31 health promoting hospital (HPH) responsible for the whole population (Figure 1). These are the examples of GIS database: 1) the population of the catchment area (Khueng-Nai district) and 2) the population density (Figure 2, 3).

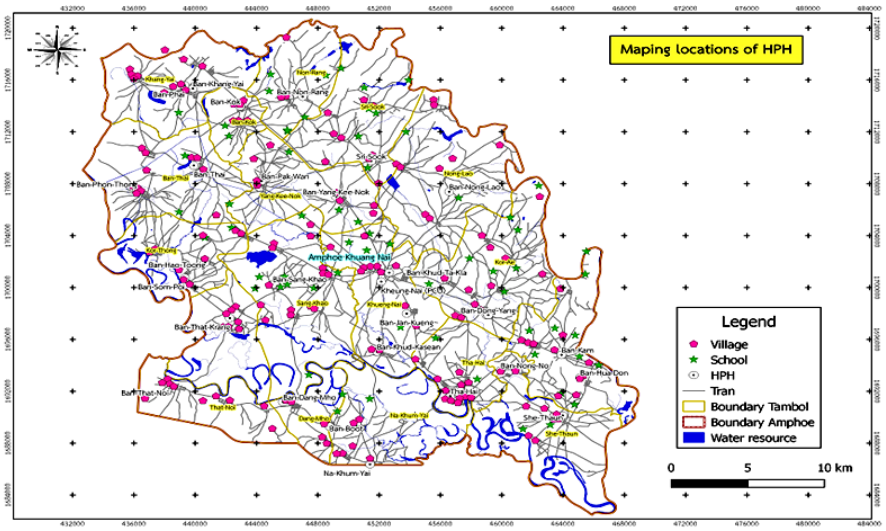

Figure 1 Demographic data of Khueng-Nai district

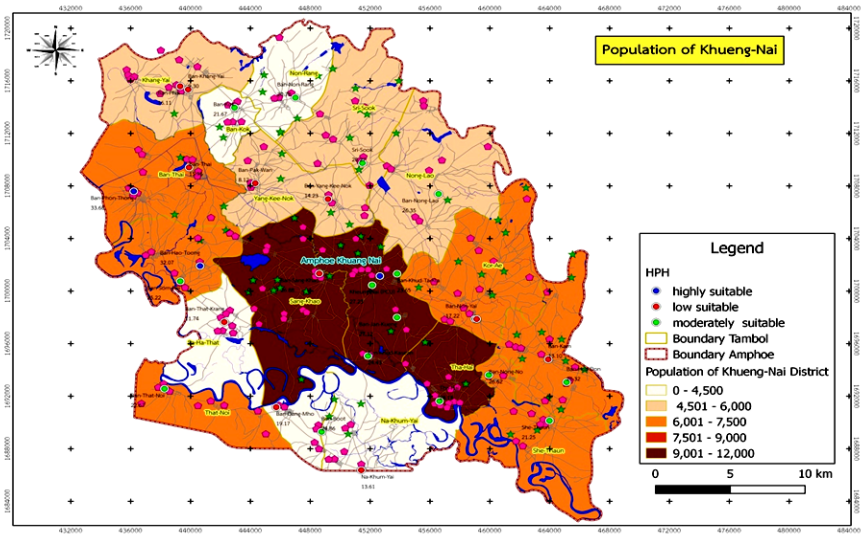

Figure 2 Population of Khueng-Nai district

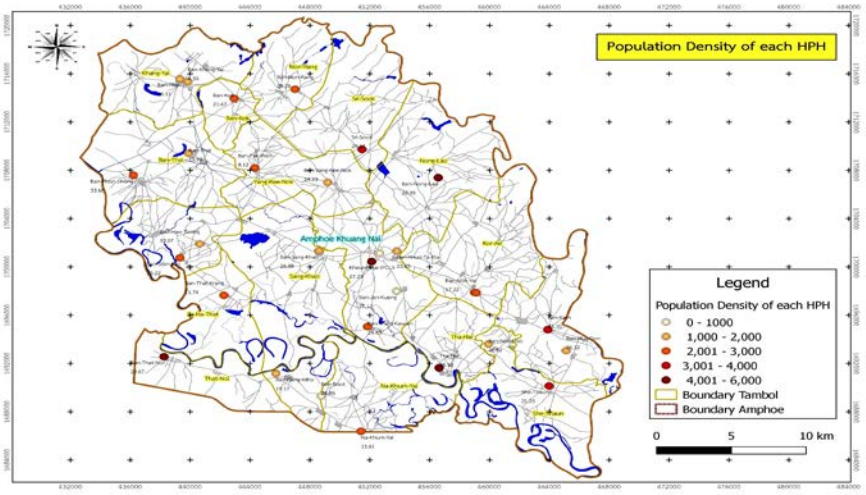

Figure 3 Population density of each HPH

3.2 Process of using HPH-GIS tool

HPH-QGIS tool has multi-functions, including 1) data inserting, 2) data editing, 3) data analyzing and representing. If some new data are needed to be added into data sheet, the user can press 'toggle editing' and click 'add feature' to add new data (Figure 3). Sometimes, there might be some mistakes occurred during data processing, the user could make some changes in data sheet via 'editing data' by either 'adding' or 'deleting' data from either 'attribute table' or 'identify feature' icon. Later, all collecting data from data sheet are evaluated via GIS analysis. The process of overlaying map layers with mapping data is required to evaluate all collecting data from data sheet. This process is called 'data analyzing and representing'. The first step is to add more map layers, then weigh scores of data layer based on the mentor recommendation. After, all scores collected from questionnaire papers and HPH-GIS data sheet are analyzed and represented on the maps.

3.3 The crucial components related to HPH establishment

There are 6 components of HPH establishment investigated in the study, including HPH setting and radius of HPH services, transportation, total population within responsible areas, a total number of patients (per month), a total number of patients outside the area setting (per month), and a number of healthcare workers (per 10,000 population), including physician, registered nurse, public health worker, social worker, dentist, dental assistant, and pharmacy assistant. Noticeably, only three crucial components were *highly* appropriate for the HPH establishment via mean scores. Those components included transportation, total population within responsible areas, and a number of healthcare workers, especially registered nurses. Nevertheless, the components, including distance and radius of HPH services, a total number of patients (per month), and a number of public health workers were *moderately* appropriate for HPH establishment. Finally, some components were *slightly* appropriate for the HPH establishment and need to be improved, including a total number of patients outside the area setting (per month), numbers of healthcare workers, especially for physicians, dentists, dental assistants, and pharmacy assistants (Table 1).

Regarding the weighting score summary of 6 components of HPH establishment, the findings showed most volunteers agreed most HPH establishments in Khueng-Nai district were moderately appropriate (53.33%) (Table 2).

Table 1 Numbers, mean scores of 6 crucial components related to HPH establishment (n=30)

Key component(s)	Numbers of HPH volunteers (%)	Mean scores ($\overline{X}$)	Definition of each mean score
1. HPH setting and radius of the service	22 (70.96)	5.82	Radious between 3 and 5 km
2. Transportation	22 (70.96)	7.00	Main roads made from either concrete or macadamized materials.
3. Total population within responsible areas	22 (70.96)	7.50	Responsible for patients from 2,500 to 5,000 persons
4. A total number of patients *(per month)*	22 (70.96)	6.77	Between 1,000 and 1,500 patients
5. A total number of patients outside the area setting *(per month)*	9 (29.03)	4.55	More than 200 patients
6. A number of healthcare workers *(per patients)*	19 (61.29)	4.39	
6.1 Physician (1:10,000)	5 (16.12)	1.55	More than 17,500
6.2 Registered nurse (1:1,250)	22 (70.96)	7.45	Between 5,000 and 7,500
6.3 Public health worker (1:1,250)	22 (70.96)	6.91	Between 3,700 and 5,000
6.4 Social worker (1:1,250)	19 (61.29)	6.27	Between 3,700 and 5,000
6.5 Dentist (1:20,000)	6 (19.35)	1.50	More than 30,000
6.6 Dental assistant (1:1,250)	16 (51.61)	4.05	Between 3,700 and 5,000
6.7 Pharmacy assistant (1:1,250)	9 (29.03)	3.00	Between 18,000 and 20,000

Table 2 Frequencies, percentages of weighting scores of HPH establishment (n =30)

Weighting scores of HPH establishment	Numbers of HPHs (f)	Percent (%)
Slightly appropriate (scores < 20)	12	40.00
Moderately appropriate (scores between 20 and 29)	16	53.33
Highly appropriate (scores ≥ 30)	2	6.67
Total	30	100.00

Note: One HPH setting was unqualified due to data incompleteness. Thus, there were 30 HPH settings underwent this process

f *means frequency*

4. DISCUSSION

Regarding the use of GIS tool in local health services in recent years, GIS has been increasingly used within the realm of health care as a tool to better understand spatial relationships of health and illness (Kazda, 2009; Hsu, 2004; Cutts et al., 2009; Blake et al., 2001; Bazemore et al., 2010). GIS has also become a valuable tool in assuring access to hospitals, palliative care, and primary care for vulnerable and underserved populations (Koutelekos et al., 2007; Cinnamon et al., 2008; Dulin et al., 2010; Pollack et al., 2009; Tanser, 2006). For example, using GIS as a tool to determine where health centers can be placed to maximize access to care is particularly relevant for primary care services associated with ongoing changes to our health-care system.Therefore, GIS may serve as a tool to aid decision makers in strategizing health center placement and managing the forthcoming demand on health-care resources. Regarding, a primary care setting called "HPH" often serves as "the first outpost for vulnerable and underserved populations" (Beitsch et al., 2006), and may face a heavy portion of the burden of increasing health-care demands due to expanded coverage expected as a result of health-care reform (Newhouse, 2010). Studies of GIS' use in local or county public health centers are scarce except for those conducted in international settings (Cinnamon et al., 2008; Tanser, 2006; Wong et al., 2012; Hadjichristodoulou et al., 2005). Also, the majority of these GIS studies are concerned with disease surveillance and environmental health. More examples of how GIS can be used at the local public health setting in Thailand are needed, particularly regarding how GIS can be leveraged for administrative decision-making (Bernstein et al., 2004; Amiri et al., 2016; Miranda et al., 2005; Miller, 2007). This study also provides such a key message HPH often predominantly provides primary care services to low-income populations, local public health decision makers will need to maximize the efficiency of operations when managing the upcoming primary care demands. Importantly, GIS has the potential to serve as a valuable tool to aid in local public health administration and decision making. Given our findings, GIS can be used as a tool in administrative decision-making on how to most efficiently assure that the HPH is established appropriately.

The facts revealed HPHs play an important role in coordinating essential public health activities, such as monitoring community health, informing and educating the public about health issues, mobilizing community partnerships, and developing policies and plans that support individual and community health efforts (Reissman et al., 2001). To determine whether

these services are meeting local population needs, HPHs use a variety of formal and informal assessments, including community health assessments and community-wide-health improvement plans. Despite such efforts, the services offered by HPH do not always meet local health needs. Mismatches can occur for many reasons, including competing funding priorities, political mandates, and natural shifts in population makeup and health concerns. Geographic information system (GIS) provides a promising tool to enhance priority-setting and resource allocation. HPHs can use GIS technology to communicate complex geospatial information in an integrated and visual way, enabling staff to compare the geographic distribution of population health in a community (e.g., HPH distances, transportation, number of local population) with the geographic distribution of HPH programs and expenditures (e.g., manpower, facilities, salaries, etc.). Using such an approach, the HPH administrators can evaluate their health settings regarding the readiness and appropriateness of health services. Some improving issues, including lack of manpower, population overload are detected through this technology. Noticeably, few HPHs have employed GIS tool for HPH planning, for a variety of reasons, including lack of data, resource constraints, and technological complexity (Auamkul et al., 1999; Auamkul and Keereewong, 1999; Nesbitt et al., 2014).

Some noticeable issues were discussed, including the appropriateness of the local transportation. Most local roads in rural areas were made from either concrete or macadamized material. Therefore, the local people could easily travel from the community to the HPH settings. If the emergency cases occurred, the patients could be referred to the HPH within time. The basic total populations within the responsible areas (2,500 and 5,000 persons per village) were appropriate. Nevertheless, the reality is opposite, in fact the overload population from other areas accessing other health service settings causes the burden of hospital responsibilities, and increases budget spending. Thus, the overall health service quality might still be questionable and unachievable as we expect.

Interestingly, only a number of registered nurses are appropriately sufficient for HPH services (1:1,000 population per village) (Nesbitt et al., 2014). Nevertheless, a previous population census in 2010 reported only 130,388 registered nurses have been working, whereas the hospital requirement is expected to be approximately 170,000 nursing positions between 2010 and 2019. Obviously, there has been a shortage of nurses inevitably (Srisuphan et al., 2015). Importantly, the finding showed the medical doctors were seriously insufficient, especially in rural health sectors (HPH). This is probably due to high demand in the expanding private health sector, and some drop out of practicing physicians to other business sectors (Nishiura et al., 2004). Additionally, lack of affordable and accessible medical technology, money resources, and misunderstanding of medical specialization for Thai medical doctors were reported as the important keys of the physician maldistribution. As a result, most Thai physicians would rather prefer to work in urban, private sectors than in rural sectors (Tonkerdmonkon et al., 2001; Van Dromael et al., 1999). To minimize the shortage of healthcare personnel, Thai government needs to change some health policies, including, providing sensible, regular work schedule, using compulsory service and optimal incentives for rural sectors, and revising Medical Curriculum focusing on primary care doctors.

Although GIS offers valuable information for decision making of HPH establishment, there were a few limitations associated with this study. First, we used the straight-line method of estimating the distances from patients' homes to their primary care centers. As straight-line can only estimate approximate actual travel distances. Thus, using a network analyst software to measure drive time would have improved the precision of our analysis. Furthermore, using

patients' residences may be a limitation given that some patients may travel from their workplaces or schools to a primary care center. The issue of inappropriate or less appropriate elements such as catchment area, which currently determined be village boundary, should be improved by using buffer distance or transportation data to adjust the catchment area. The reason is to receive the precise catchment areas for the overlay function step of GIS-HPH database. Next, only one target area might not be adequate to represent the whole picture of the HPH setting situation. Therefore, it could be possible to undergo the multidisciplinary centered studies in some other areas for accuracy and reliability of the results. Lastly, healthcare administrators and staff need to routinely practise knowledge and skills of a new technology that can be applied into their routine work.

5. CONCLUSION

Overall, using GIS to visually evaluate the appropriateness of HPH establishment provided valuable information that assisted in facilitating primary care center management and organizational change. This information provides a valuable example of the usefulness of GIS for local public health decision-making. GIS and other innovative analytical tools will be essential for keeping public health sectors on managing some key components related to HPH establishment. Further GIS studies should provide the examinations of the reliability and validity of GIS tool. Also, cost-effectiveness of using GIS in the local HPH setting is needed, especially considering it as a tool in myriad public health activities (e.g., environmental management, community health intervention mapping).

ACKNOWLEDGMENTS

Many thanks go to Department of Information Technology, Provincial Health Office, Ubon Ratchathani province for data and support. Thanks all representatives of each Health Promoting Hospital from Khueng-Nai district, Ubon Ratchathani province for cooperation. Finally, the gratefulness goes to the Higher Education Research Promotion (HERP), Office of Higher Education Commission (OHEC), Thailand for financial support.

REFERENCES

Amiri, M., Khosravi, A., Riyahi, L., Naderi, S. (2016). The impact of setting the standards of health promoting hospitals on hospital indicators in Iran. *PLoS ONE,* 11(12), e0167459.

Auamkul, N., Kanshana, S., Phirangapaura, A. (1999). Development of health promoting hospitals in Thailand. *FACT SHEET - Health Promotion*, 2(8), 1-6.

Auamkul, N., Keereewong, P. (1999). "Five prospects towards health promoting hospital". *Thailand Journal of Health Promotion and Environment Health*, 22(2), 12-19.

Bazemore, A., Diller, P., Carrozza, M. (2010). The impact of a clinic move on vulnerable patients with chronic disease: a geographic information systems (GIS) analysis. *Journal of the American Board of Family Medicine*, 23, 128-130.

Beitsch, L. M., Grigg, M., Menachemi, N., Brooks, R. G. (2006). Roles of local public health agencies within the state public health system. *Journal of Public Health Management and Practice*, 12, 232-241.

Bernstein, K. T., Curriero, F. C., Jennings, J. M., Olthoff, G., Erbelding, E. J., Zenilman, J. (2004). Defining core gonorrhea transmission utilizing spatial data. *The American Journal of Epidemiology*, 160, 51-58.

Blake, B. J., Bentov, L. (2001). Geographical mapping of unmarried teen births and selected sociodemographic variables. *Public Health Nursing*, 18, 33-39.

Bureau of Health Policy and Planning. (1998). "Ministry of Public Health and Health Development Plan in Thailand", Nonthaburi.

Cinnamon, J., Schuurman, N., Crooks, V.A. (2008). A method to determine spatial access to specialized palliative care services using GIS. *BMC Health Services Research*, 8, 140.

Chokewiwat, W. (1999). Health care reform in Thailand 1888-2000. In: Chungsathientsub, K. and Muksong, C. editors. History of Thai Medical and Health System: Border of Knowledge. [Thai] Nonthaburi: Thailand: Health Systems Research Institute. Watana Press, Bangkok.

Cutts, B. B., Darby, K. J., Boone, C. G., Brewis, A. (2009). City structure, obesity, and environmental justice: an integrated analysis of physical and social barriers to walkable streets and park access. *Social Science & Medicine*, 69, 1314-1322.

Dulin, M. F., Ludden, T. M., Tapp, H., Smith, H. A., de Hernandez, B. U., Blackwell, J. (2010). Geographic information systems (GIS) demonstrating primary care needs for a transitioning Hispanic community. *Journal of the American Board of Family Medicine*, 23, 109-120.

Ferguson, W., Kemp, K., Kost, G. (2016). Using a geographic information system to enhance patient access to point-of-care diagnostics in a limited-resource setting. *International Journal of Health Geographics*, 15, 10.

Ghose, R. (2001). Use of information technology for community empowerment: transforming geographic information systems into community information systems, *Transactions in GIS*, 5(2), 141-163.

Hadjichristodoulou, C., Soteriades, E. S., Kolonia, V., Falagas, M. E., Pantelopoulos, E., Panagakos, G. (2005). Methodological aspects of a GIS-based environmental health inspection program used in the Athens 2004 Olympic and Para Olympic Games. *BMC Public Health*, 5, 93.

HPH Committee. (1999). "Health promoting hospital: From policy to practice", Ministry of Public Health, Nonthaburi.

Hsu, C. E., Jacobson, H., Soto, M. F. (2004). Evaluating the disparity of female breast cancer mortality among racial groups-a spatiotemporal analysis. *International Journal of Health Geographics*, 3, 4.

Kazda, M. J., Beel, E. R., Villegas, D., Martinez, J. G., Patel, N., Migala, W. (2009). Methodological complexities and the use of GIS in conducting a community needs assessment of a large U.S. municipality. *Journal of Community Health*, 34, 210-215.

Koutelekos, J., Photis, N. Y., Manetos, P. (2007). Geographic information analysis and health infrastructure. *Health Science Journal*, 1, 1-7.

Miller, C. (2007). The introduction and expansion of GIS into a small local health department drinking-water program. *Journal of Environmental Health*, 69, 35-40.

Miranda, M. L, Silva, J. M., Overstreet, G. M. A., Brown, J. P., Campbell, D. S., Coley, E. (2005). Building geographic information system capacity in local health departments: lessons from a North Carolina project. *American Journal of Public Health*, 95, 2180-2185.

Musa, G. J, Chiang, P. H., Sylk T., Bavley, R., Keating, W., Lakew, B., Tsou, H.C., Hoven, C.W. (2013). Use of GIS mapping as a public health tool-from cholera to cancer. *Health Services Insights*, 6, 111-116.

Newhouse, J. P. (2010). Assessing health reform's impact on four key groups of Americans. *Health Affairs*, 29, 1714-1724.

Nesbitt, R. C., Barysch, S., Laub, A., Soremekun, S., Manu, A., Bret, K. W. (2014). Methods to measure potential spatial access to delivery care

in low- and middle-income countries: a study in rural Ghana. *International Journal Health Geographics*, 4, 11-25.

Nishiura, H., Barua, S., Lawpoolsri, S., Kittitrakul, C., Leman, M. M. (2004). Health inequalities in Thailand: geographic distribution of medical supplies in the provinces. *Southeast Asian Journal of Tropical Medicine and Public Health*, 35(3), 735-740.

Pollack, C.E., Gidengil, C., Mehrotra, A. (2009). The growth of retail clinics and the medical home: two trends in concert or in conflict? *Health Affairs*, 29, 998-1003.

Reissman, D. B., Staley, F., Curtis, G.B., Kaufmann, R.B. (2001). Use of geographic information system technology to aid health department decision making about childhood lead poisoning prevention activities. *Environmental Health Perspectives*, 109, 89-94.

Sahachaisaree, N., Pimolsathien, Y. (2002). The application of geographic information system for public health services: the first gate of Bangkok. [OnlineURL: http://kb.hsri.or.th/dspace/bitstream/handle/11228/1265/hs0898.pdf] accessed on December 10, 2017.

Srisuphan, W., Sawaengdee, K. (2012). Recommended policy-based solutions to shortage of registered nurses in Thailand. *Thai Journal of Nursing Council*, 27(1), 5-12. (in Thai)

Tanser, F. (2006). Methodology for optimising location of new primary health care facilities in rural communities: a case study in KwaZulu-Natal, South Africa. *Journal of Epidemiology and Community Health*, 69, 846-850.

The World Health Report. (2008). Primary health care - Now more than ever. World Health Organization 2008. Pascale Broisin and Frodorique Robin-Wahlin, Switzerland.

Treuhaft, S. (2007). Bridging the innovation divide: An agenda for disseminating technology innovations within the nonprofit sector. Policy Link & BCT Partners 2007.

Treuhaft, S. (2017). Community mapping for health equity advocacy. Opportunity Agenda and Health Policy Institute, New York; 2009. [OnlineURL:http://opportunityagenda.org/files/field_file/Community%20Mapping%20for%20Health%20Equity%20%20Treuhaft.pdf] accessed on February 6, 2017.

Tonkerdmonkon, D., Yen, L. (2001). Review of optometry status in Thailand: supply and demand. Thai Optometric Volunteers, Bangkok.

Van Dromael, M., Blaise, P. (1999). Performance management of first line medical doctors in Thailand. Department of Public Health, Institute of Tropical Medicine, Antwerpen.

Wong, L.Y., Heng, B.H., Cheah, J. T., Tan, C.B. (2010). Using spatial accessibility to identify polyclinic service gaps and volume of under-served populations in Singapore using geographic information systems. *International Journal of Health Planning and Management*, 29, e173-185.

World Health Organization. (1996). "Development of an informal supranational network of promoting hospitals: Final report", WHO Europe, Copenhagen.