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GIS IN THE STUDY OF THE SPATIAL ORGANIZATION OF MEDICAL TOURISM INFRASTRUCTURE: METHODOLOGY AND PRACTICAL APPROACHES

ABSTRACT

The article is devoted to analysing and assessing the possibilities of using the theoretical foundations of geographic information systems (GIS), the methodology, and techniques of GIS technologies in identifying trends and justifying strategies for the development and spatial organisation of medical tourism. It is shown that medical tourism is a dynamically developing sector of the global economy, which allows harnessing the achievements of medicine and the opportunities of tourism to strengthen public health and develop elements of healthcare systems, thereby forming the basis for the formulation of state and regional policies to stimulate the development of this type of activity in the country and/or region, thus enhancing their positions on the global stage, ensuring the interaction of medical and tourist institutions with authorities and business structures in their promotion on the world market. It is established that case studies analysis using GIS technologies allows for identifying spatial patterns in the provision of medical care and the provision of related services to patients from other regions and countries, visualising the geographical distribution of medical institutions, assessing the accessibility of medical care and recreational facilities for rehabilitation and recreation, analysing the travel routes of medical tourists, and ultimately providing recommendations for optimising the formation and subsequent development of medical tourism clusters. An illustration of visualising the obtained results based on heat maps, highlighting areas with high or low concentrations of medical tourism resources and densities of infrastructure elements, is provided. Singapore has been chosen as an experimental site to test GIS technologies' effectiveness in achieving this research's goal, where medical tourism has gained significant development and has become an important source of income for government and business structures.

KEYWORDS: health preservation, tourism industry, geosystems, medical tourism clusters, Singapore

INTRODUCTION

The medical tourism industry is one of the fastest-growing sectors in the global economy, catering to the population's demand for treatment of various illnesses, surgical interventions, dental care and other medical procedures outside the patient's country of residence. Medical tourism is developing amidst increasing global, national, regional and local competition.

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Prospective patients seek high-quality medical care at affordable prices for treatment, transportation expenses, post-operative rehabilitation and all types of services. Medical tourists contribute to the country and regional economies by paying for medical services and other amenities, promoting health preservation at various levels of societal organisation and governmental and municipal management.

For a long time, medical tourism has predominantly developed in European and North American countries. Still, in recent years, it has significantly accelerated in Asian countries, particularly Singapore, China, India, Turkey, Malaysia and Japan [*Barat*, 2022; *Chistobaev*, 2024]. The main focus of its development has been the establishment of medical tourism clusters, incorporating not only medical institutions but also other elements of the healthcare system. Similar progress in promoting medical tourism has been observed in Russia, facilitated by adopting two governmental documents: the "Federal Project for the Development of Medical Services Export"[1] and the "Concept of Technological Development until 2030"[2]. The coupled development of health preservation elements (infrastructure, staffing, accommodation tailored to service specifics, pedestrian access to hospitals and recreational facilities) ensures the successful advancement of medical tourism.

The process of developing and implementing strategies to develop medical tourism and optimise the flow of medical tourists to specific geographic regions or countries involves analysing geographic data, demographic characteristics, healthcare infrastructure and other factors that may influence the attractiveness of a particular location to medical tourists from different countries [*Sultana* et al., 2014]. The main goal of such geostrategic developments in medical tourism is to provide competitive advantages for a specific country or region in the medical care market: the development of specialised medical centres, attracting qualified specialists and creating comfortable conditions for the living and treatment of medical tourists. As a result of scientifically based strategies for the development of medical tourism, a country or region can receive economic benefits, strengthen its position in the global health arena, and interact with medical and tourism institutions with local authorities and business communities [*Abadi* et al., 2018].

A comprehensive approach to the development and territorial organisation of medical tourism involves analysing and forecasting its development using extensive data reflecting the specificities of healthcare systems at the country and/or regional levels. This task can be addressed by applying geographic information systems (GIS) theory and GIS technology methodology, allowing for the visualisation of the geographical distribution of medical institutions, assessment of service availability and analysis of medical tourists' travel routes [*DeMicco*, 2022]. Such analysis is necessary for spatially analysing the development of medical tourism, its impact on healthcare infrastructure, the country's economy, regions, municipalities and businesses. This approach expands the spectrum of research into factors influencing the overall development of medical tourism and the selection by medical tourists of the most suitable destinations for this type of tourism.

The study aims to analyse the possibilities of using GIS technologies in studying the basic situation of the spatial organisation of medical tourism.

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[1] Passport of the federal project "Development of export of medical services". Web resource: https://static-0.minzdrav.gov.ru/system/attachments/attaches/000/044/789/original/Pasport_FP_export.pdf?1558614408 (accessed 10.05.2024)

[2] The concept of technological development for the period until 2030. Approved by Order of the Government of the Russian Federation of May 20, 2023 No. 1315-r. Web resource: https://www.consultant.ru/document/cons_doc_LA W_447895/f62ee45faefd8e2a11 d6d88941 ac66824f848bc2/ (accessed 10.05.2024)

Brief Literature Review

Geoinformation technologies are actively penetrating various spheres of society, including scientific research in medical tourism [*Dar* et al., 2022; *Wang* et al., 2022; *Biswas*, *Rai*, 2023], including data collection and processing on provided services and database formation [*Beladi* et al., 2019], identifying peculiarities of organising medical care within the healthcare system [*Gokhman*, 2012; *Kim* et al., 2017; *Wang* et al., 2023], analysing the experience of developing strategies for forming medical tourism clusters in Russia [*Grudtsyn*, *Chistobaev*, 2023; *Chistobaev*, 2023a, 2023b] and other countries worldwide [*Page* et al., 2015; *Firza* et al., 2023], using modern analysis tools such as PCA [*Luna*, 2022], SWOT analysis, and other strategic planning tools [*Wong* et al., 2014; *Ganguli* et al., 2019]. Works dedicated to promoting medical tourism in Singapore identify specific conditions and development factors of this industry [*Pocock* et al., 2011; *Ebrahim* et al., 2019], assessing its contribution to economic development and the entire healthcare system [*Gan* et al., 2014; *Lianto* et al., 2020].

RESEARCH MATERIALS AND METHODS

Using a systems approach is necessary to consider the geostrategizing process as a set of interconnected stages, each contributing to a country, region or municipality's overall social and economic development goal. The example of Singapore is used as a case study for a detailed analysis of this country's territorial organisation of medical tourism infrastructure. The advantage of this approach lies in the ability to consider real data for a specific country. A noted disadvantage is that the results obtained may be limited in their applicability to other territories.

Quantitative analysis was conducted based on data published by Singaporean authorities. Medical institutions are represented by the Ministry of Health's data[1]. Hotels were selected based on data from the Hotels Licensing Board[2], while parks, sports facilities, and eateries promoting "healthy eating" were selected based on Health Promotion Board 3 data.

The following technical tools and their components were used in the work:

1. Tableau Desktop is used to display medical institutions participating in the CHAS scheme.
2. Google Maps for displaying travel time.
3. The matplotlib.pyplot library[3] for Python for visualising a series of maps with choropleth data representation, where various districts or zones (in this case, Singapore districts) are displayed with different degrees of shading or colour depending on the number of objects of a particular type (e. g., clinics, sports grounds, etc.) in each of these districts. This allowed to identify areas with high or low concentrations of medical tourism resources, determine infrastructure densities and develop management approaches.
4. The seaborn library for Python[4] for visualising a heatmap of lines (KDE) is a data visualisation method used to estimate the density distribution of points on a map. This study uses the coordinates of the medical tourism industry objects. The seaborn library provides the kdeplot function, which visualises kernel density estimation based on point coordinates. A two-dimensional kernel estimation is used since the data is presented as geographic coordinates (latitude and longitude).
5. The KMeans method and the sklearn library for Python for clustering medical tourism infrastructure objects (4–7 clusters) within administrative-territorial units.

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[1]   Data.gov.sg. Web resource: https://beta.data.gov.sg/collections/2036/datasets/d_65d11d02ab024 6cec53bfc995c782 628/view (accessed 11.03.2024)

[2]   Data.gov.sg. Web resource: https://beta.data.gov.sg/datasets?query=hotels&resultId=d_654e22f14e5 bb817423f0e0c9ac4f632 (accessed 11.03.2024)

[3]   Matplotlib: Visualization with Python. Web resource: https://matplotlib.org/ (accessed 12.02.2024)

[4]   Seaborn: statistical data visualization. Web resource: https://seaborn.pydata.org/ (accessed 20.02.2024)

6. The Adjusted Rand Index determines the correspondence of Singapore's administrative-territorial division to the clusters of medical tourism infrastructure obtained.

RESEARCH RESULTS AND DISCUSSION

Geostrategizing is a process of sequential stages (Table 1) aimed at structuring and systematising strategy development and implementation, which is important in strategic spatial planning and management of territorial development.

Table 1. Stages of geostrategising medical tourism

Stage	Description
Defining goals and methodology	Involves selecting the goals, tasks and methods for conducting geostrategy in a specific region or country. Ensures an understanding of the target functions of strategic planning in medical tourism. Determines approaches and tools
Baseline situation investigation and trend analysis	Integrated research in medical tourism allows for identifying trends in patient preferences and the competitive environment, demand for medical services in countries and/or regions, competitor offerings, and market segmentation based on needs and preferences
Strategy development	Defining target functions and tasks for management, financial, marketing and technological structures. Geospatial modelling of potential effects from the implementation of strategies. Cost, risk assessments and profit forecasting
Regulatory setting	Development of regulatory documents for strategic planning and strategy implementation
Strategy implementation	Creation or modernization of medical tourism clusters, introduction of new technologies
Quality and safety control	Achieving the standard of quality and safety in medical care, certification of institutions, staff training
Monitoring and results analysis	Tracking the effectiveness of servicing medical tourists, customer satisfaction, profitability, and other indicators
Strategy adjustment and update	Refinement of target functions and decision-making methods in accordance with changing conditions and customer expectations

At the second level, sub-stages of geostrategizing medical tourism are investigated. For example, management strategy, operational management strategies, personnel management, service quality improvement, enhancement of customer experience, staff attraction and training and creation of motivational systems to retain qualified specialists are developed. Marketing strategy is subdivided into pricing strategies — establishing competitive prices for medical services and tourist packages to attract clients; promotion — developing marketing campaigns and advertising initiatives to increase the region's recognition as a medical tourism destination; and market segmentation — identifying target audiences and adapting services to their needs and preferences. Financial management strategies involve investment attraction, financial stability, financial flow diversification, financial risk management, tax planning and liquidity management. Possible risks and challenges, threats and obstacles are identified in each direction, and corresponding measures for minimisation and/or prevention are developed. The key task is to assess the probability of risks occurring and mitigate them.

GIS can accompany almost each of the above stages of geostrategizing. While these technologies have significant advantages, it is also important to consider the possible risks of their use using risk and strategic analysis methods.

Spatial analysis of basic medical tourism conditions (based on Singapore data)

Singapore was chosen as the key country for this study, as it has demonstrated significant achievements in medical tourism for many years and consistently ranks among the best countries in global rankings. The healthcare system here has undergone comprehensive development, and the population demonstrates a keen awareness of their health, enhancing public health.

The first stage of the analysis involves visualising medical organisations participating in the CHAS[1] Clinics program (Fig. 1). This set of institutions covers the majority of healthcare providers in Singapore. Mapping them onto satellite imagery provides an overview of their locations and distribution and enhances understanding of Singapore's physical and geographical characteristics, which should be considered when examining subsequent cartographic materials.
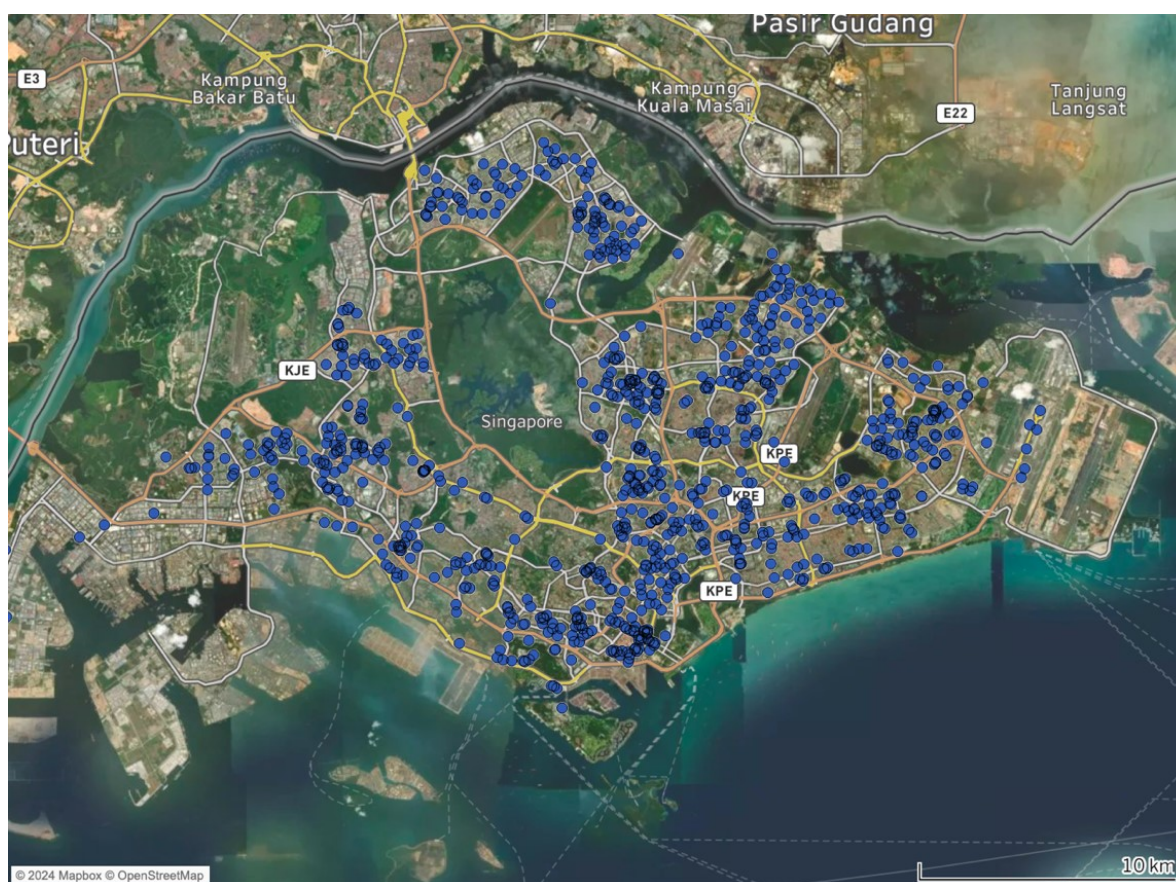
Fig. 1. Medical institutions participating in the CHAS scheme in Singapore

As mentioned earlier, analysing the medical tourism situation in a country or region requires considering the medical infrastructure and other factors that affect the comfort and convenience of medical tourists. One such factor is the transportation infrastructure, which determines the accessibility of medical services for patients from other regions and countries, the convenience of using airports, railway stations, bus and metro systems and the speed and comfort of intra-city or intra-region travel. In this regard, Singapore boasts a highly developed transportation system. Changi Airport is a major regional and international hub, consistently

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[1] CHAS stands for Community Health Assist Scheme, a public health initiative in Singapore. It provides all Singaporean citizens, including holders of Pioneer Generation (PG) and Merdeka Generation (MG) cards, with subsidies for medical and/or dental services at participating General Practitioner (GP) clinics and dental clinics. As of 2023, 1191 organizations were participating in this program, with one organization for every 3 thousand residents

recognised as one of the best in the world. In 2023 it served approximately 58.9 million passengers, representing 86.3 % of pre-pandemic 2019 levels[1]. The country also has a highly efficient public transport system [*Prathyusha* et al., 2021], which may be excluded when medical tourism infrastructure is considered. Fig. 2 shows an example of one of the longest routes in the country (less than 2 hours for bus/MRT and about 40 minutes for a taxi).

Fig. 2. Estimated travel time in Singapore (bus and metro — top, taxi/car — bottom)

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[1]   Traffic Statistics. Changi Airport group. Web resource: https://www.changiairport.com/corporate/our-expertise/air-hub/traffic-statistics.html (accessed 25.03.2024)

In addition to the transportation accessibility of medical institutions, the presence of accommodation, dining options, public parks and sports facilities within the medical tourism cluster is significant (Fig. 3). The quality and variety of services can significantly impact patient satisfaction and their decision to choose a specific medical tourism destination.

Fig. 3 displays over 3 800 objects, which complicates visualization but still provides an understanding of the density of the infrastructure. Below are visualisations for each group of objects separately (Fig. 4), followed by an assessment of the overall concentration of all selected objects for analysis across the administrative districts of Singapore (Fig. 5).
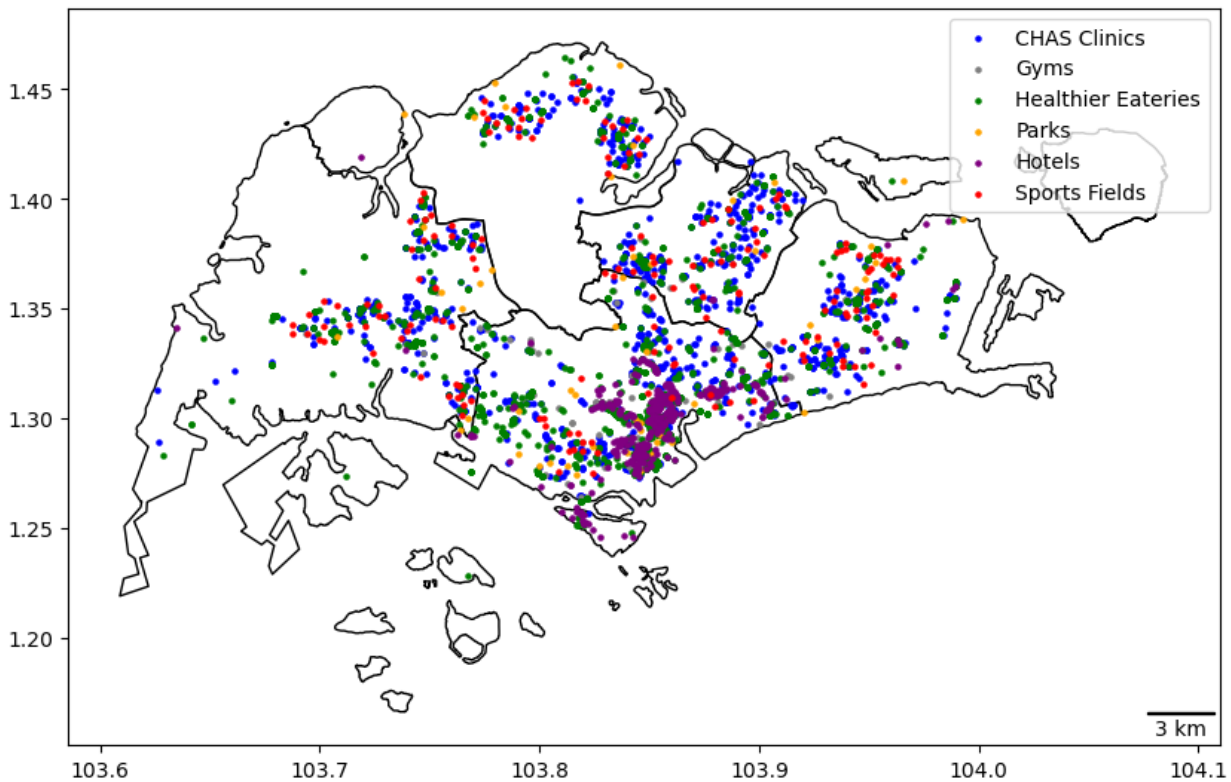
Fig. 3. Objects of accompanying and the healthcare infrastructure

The presented maps effectively illustrate the spatial characteristics of developing the basic components of Singapore's healthcare and tourism systems, which are essential for forming and developing medical tourism. The central district stands out prominently in terms of the concentration of medical tourism infrastructure (Fig. 6).

As an additional analysis tool, clustering of medical tourism infrastructure was carried out (Fig. 7). The results show a clear correlation between medical tourism infrastructure and internal administrative boundaries: the existing administrative division of Singapore into five districts best reflects the distribution of medical tourism infrastructure (adjusted Rand index (ARI) for 5 clusters — 0.75).

The cluster boundaries shown in Fig. 8 can be used from the point of view of zoning and managing the development of medical tourism, an important element of geostrategizing medical tourism. The clustering results allow us to conclude that developing a policy for developing medical tourism infrastructure in Singapore can be carried out within the framework of existing districts and does not require separate zoning.
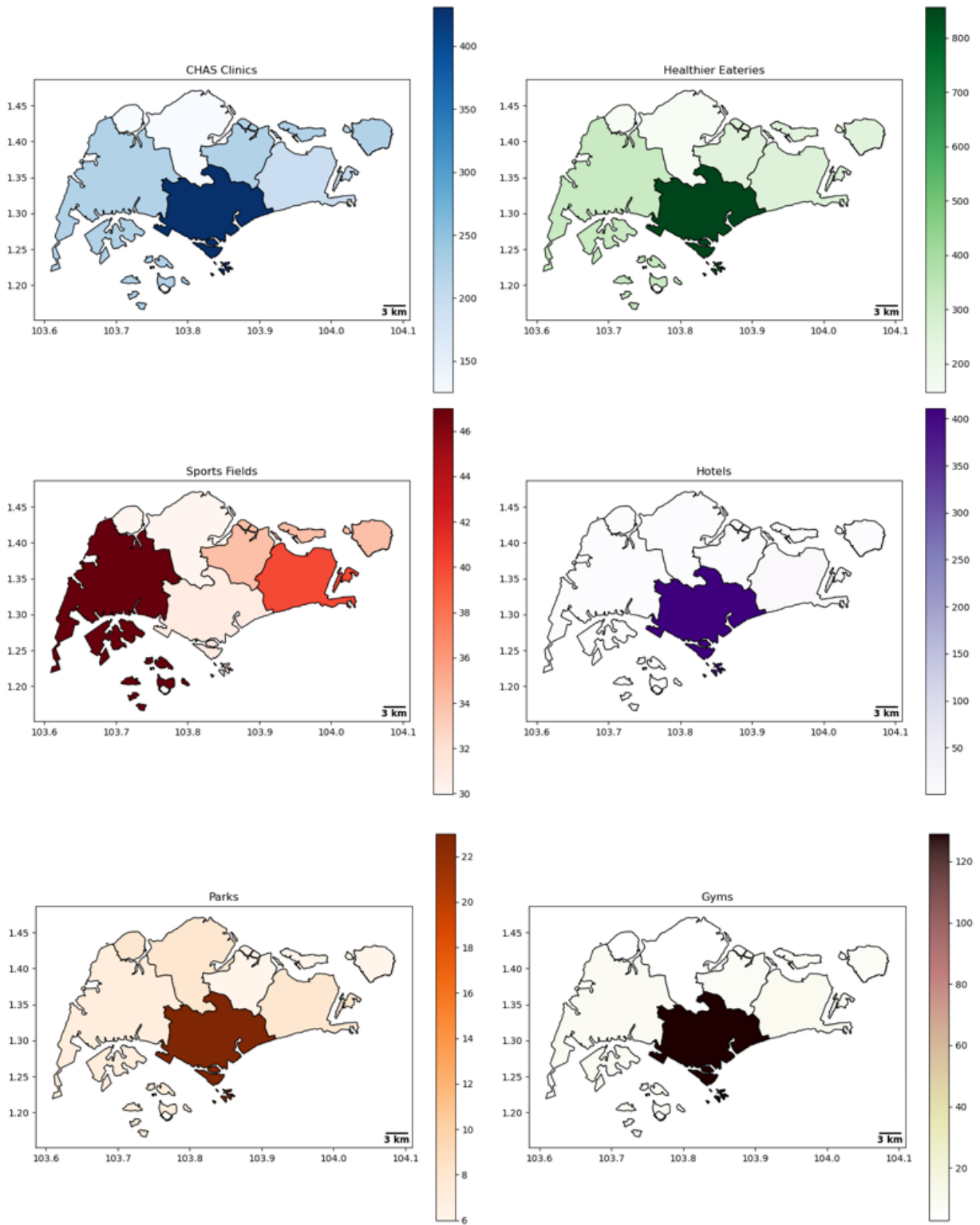
*Fig. 4. Number of medical and accompanying infrastructure facilities
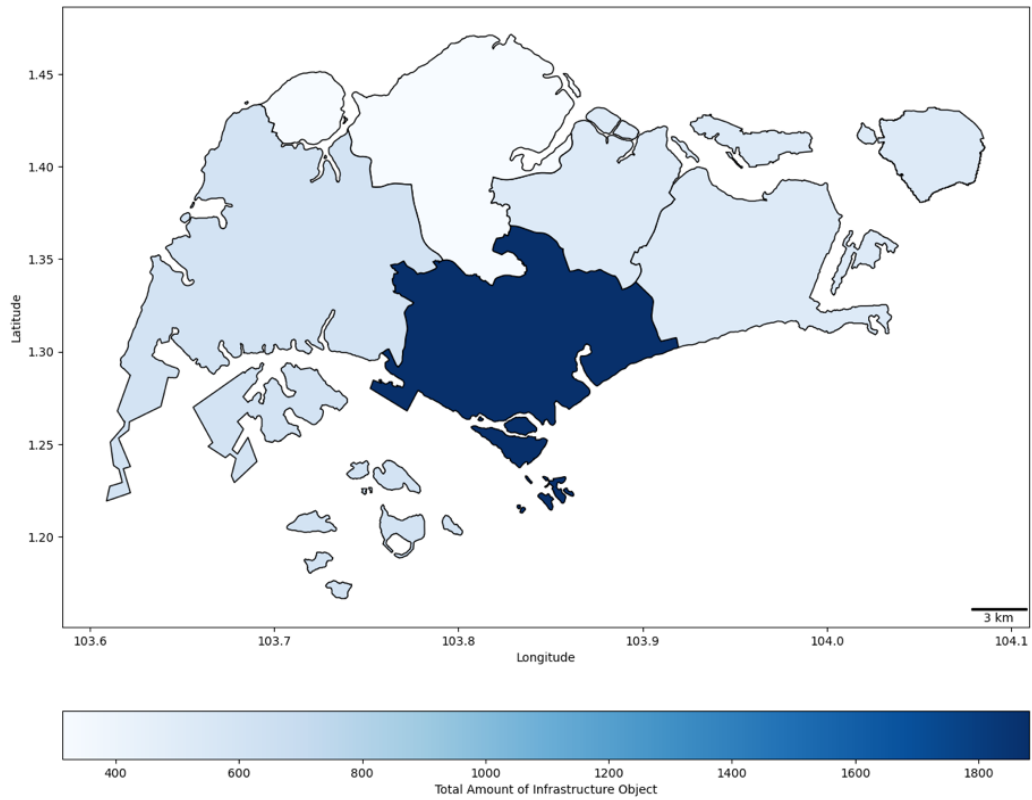in Singapore across the administrative division*

*Fig. 5. Number of medical and accompanying infrastructure facilities
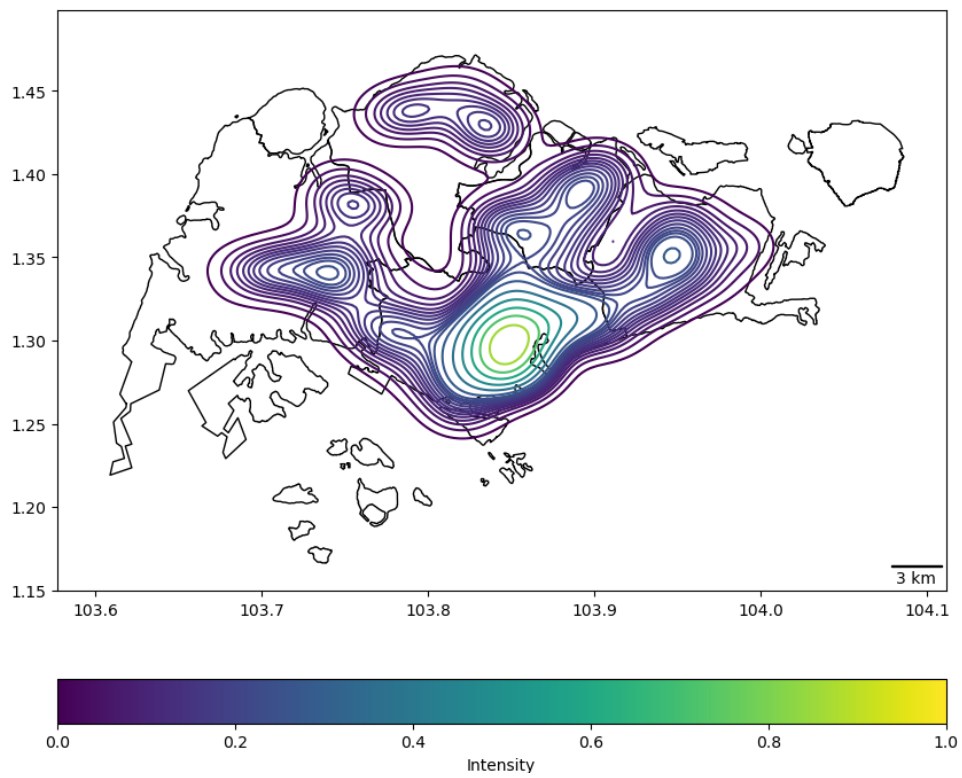in Singapore across the administrative division*

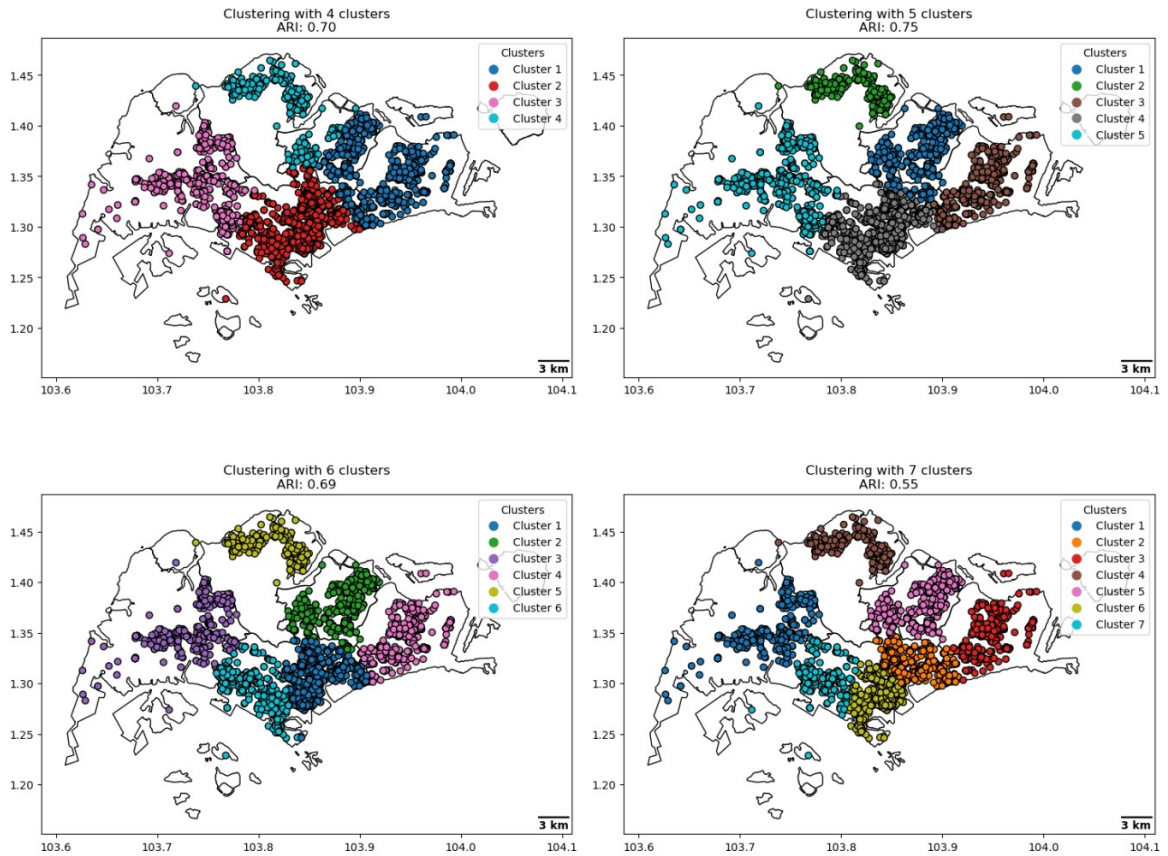*Fig. 6. Heat map of lines of intensity of medical and tourism infrastructure facilities*

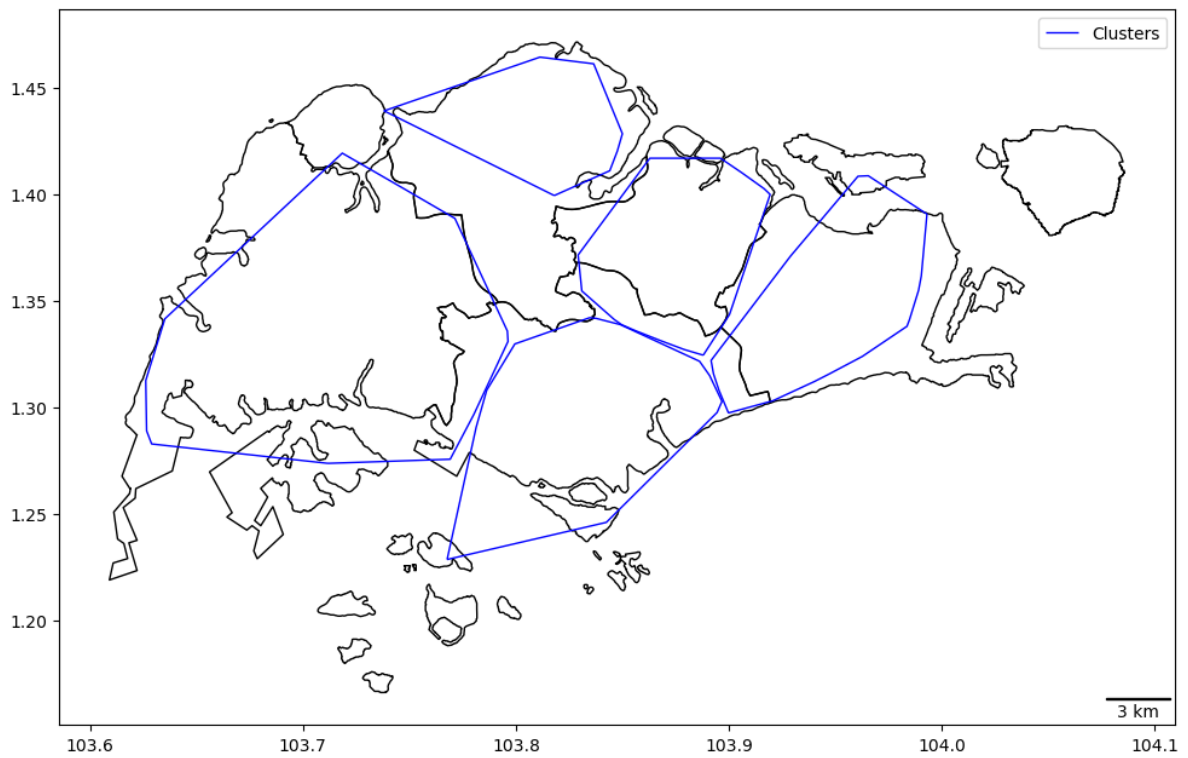*Fig. 7. Clusters of medical and accompanying infrastructure in Singapore*

Fig. 8. Boundaries of medical tourism clusters in Singapore across the administrative division

Not all healthcare institutions participating in the CHAS scheme have programs for working with medical tourists. However, they can be used both at the preparation stage for clinical intervention and after it and are also in demand among regional medical tourists from Malaysia or Indonesia [*Leng*, 2010]. At the same time, tourists may prefer large medical hospitals that are more ready to interact with patients from abroad (Fig. 9).

Several recent projects have been launched in Singapore to promote medical tourism. Some hospitals (Mount Elizabeth Hospitals, Raffles Hospital, etc.) have launched special programs for foreign patients that offer transportation, accommodation and translation services. Opened as part of an international project, SingHealth Duke-NUS Academic Medical Centre offers a wide range of medical services, and it has become one of the largest medical centres in Asia. One of the most important projects in the healthcare sector was the Raffles Hospital, which opened in 2019 in the city centre, which offers a wide range of medical services, including consultations with doctors, diagnostics, operations and rehabilitation, as well as special packages for medical tourism, including services for organising accommodation, transport and translator. Raffles Hospital maintains Singapore's regional and international healthcare hub leadership, offering complex clinical procedures such as neurovascular procedures, targeted cancer treatments, cardiac surgeries, orthopaedic surgeries and infertility treatments. More than 35 % of Raffles are foreigners from more than 100 countries.

As part of the study, groups of large medical institutions were identified, with pairs' distances not exceeding 500 m (Fig. 10).
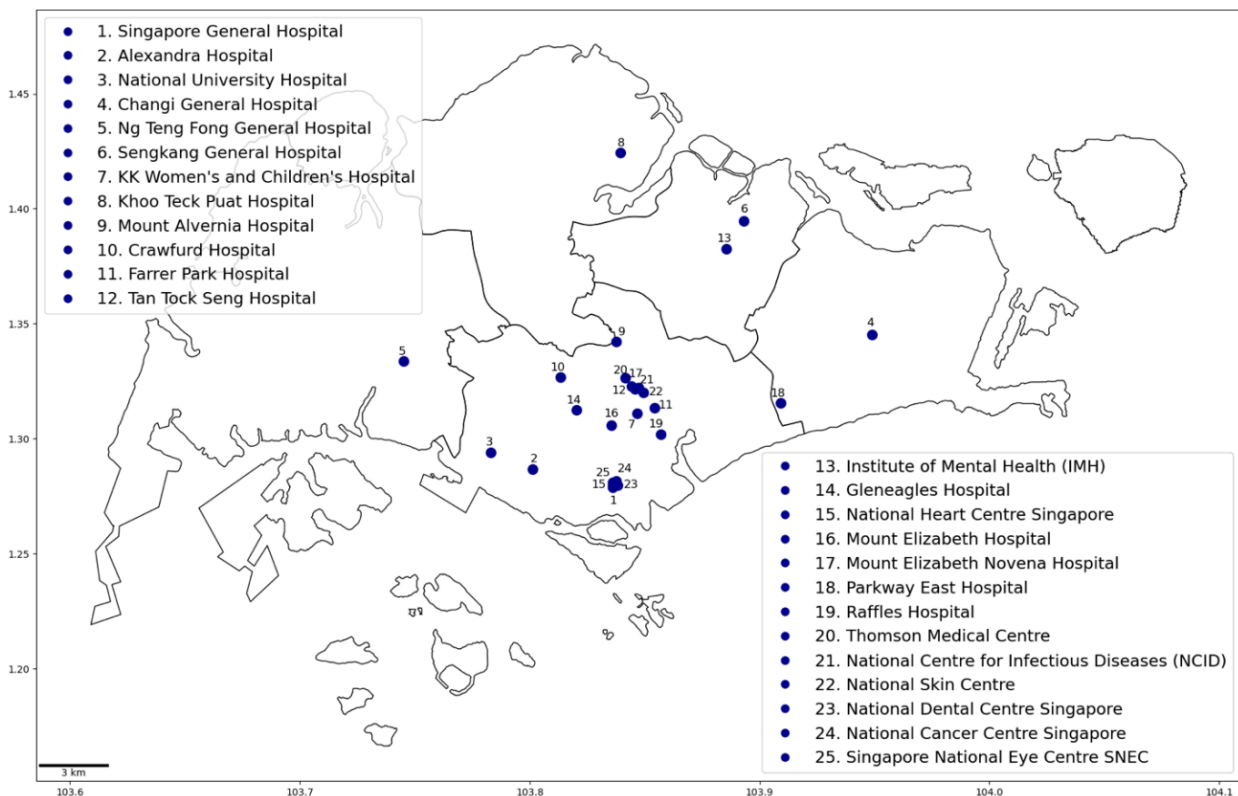

Fig. 9. The largest medical institutions in Singapore across the administrative division
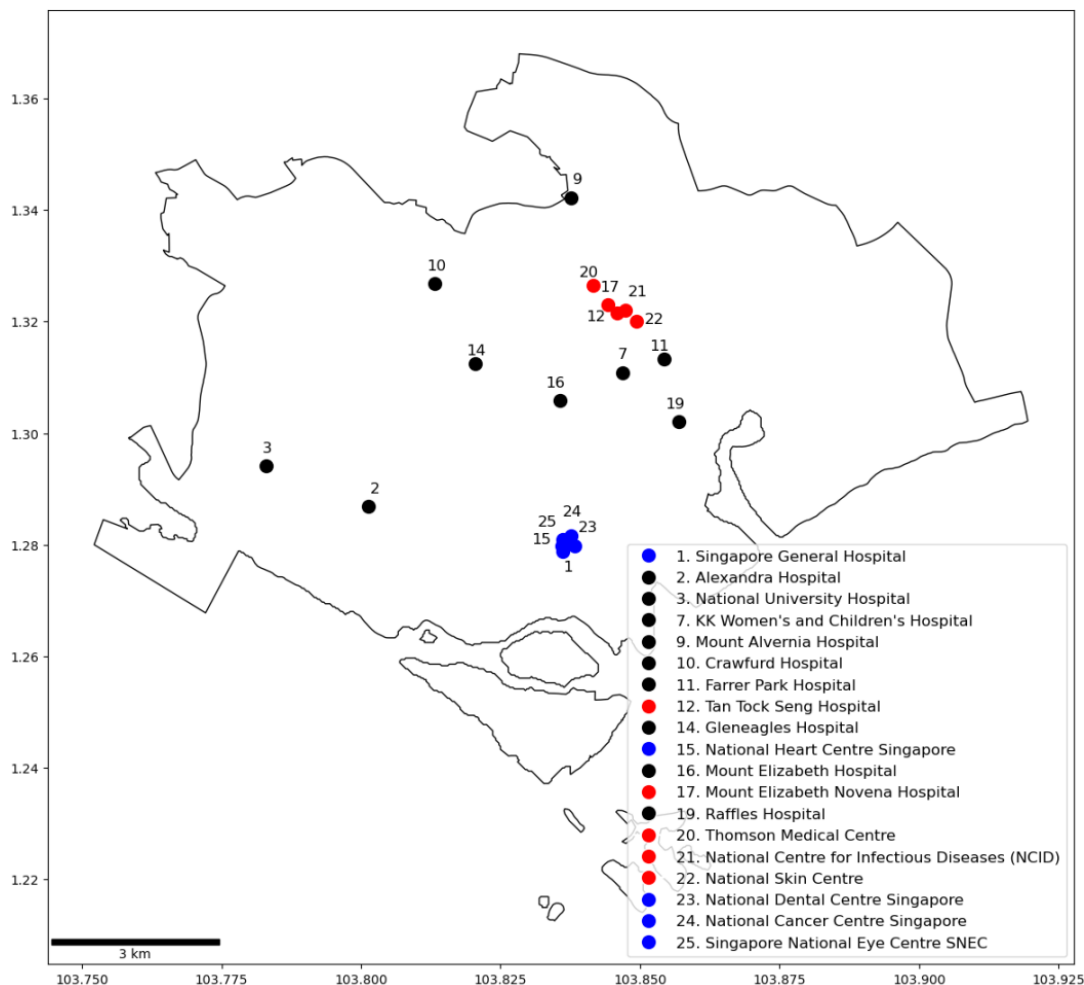
*Fig. 10. Groups of medical institutions in Singapore located within a distance
of no more than 500 m from each other*

There are only two such groups in Singapore, both in the central district. These groups are further presented with touristic infrastructure, forming the basis for identifying and developing local medical tourism clusters. The first group gravitates towards Singapore General Hospital (Fig. 11), while the second group gravitates towards Mount Elizabeth Novena Hospital (Fig. 12).

The presence of developed healthcare and health preservation systems, excellent transportation accessibility from abroad and within the country and extensive hotel and restaurant services create favourable conditions for tourists visiting Singapore. Based on the above, Singapore has all the necessary conditions for the successful development of medical tourism despite being one of the most expensive cities in the world.

Analysing the spatial distribution of health preservation infrastructure objects in Singapore demonstrates their concentration in the central district. This indicates key areas of demand and identifies potential for further development in this field.

Based on the above facts, Singapore has certain advantages for developing medical tourism. The spatial concentration of infrastructure provides a basis for strategic planning and strengthens its position in the global medical tourism market.

This study mainly focused on the infrastructure aspects of geostrategizing medical tourism. We did not consider factors such as treatment and accommodation costs, destination climate conditions, the destination's image and brand, promotional effort, etc. Comprehensive geostrategizing goes beyond the scope of individual research.
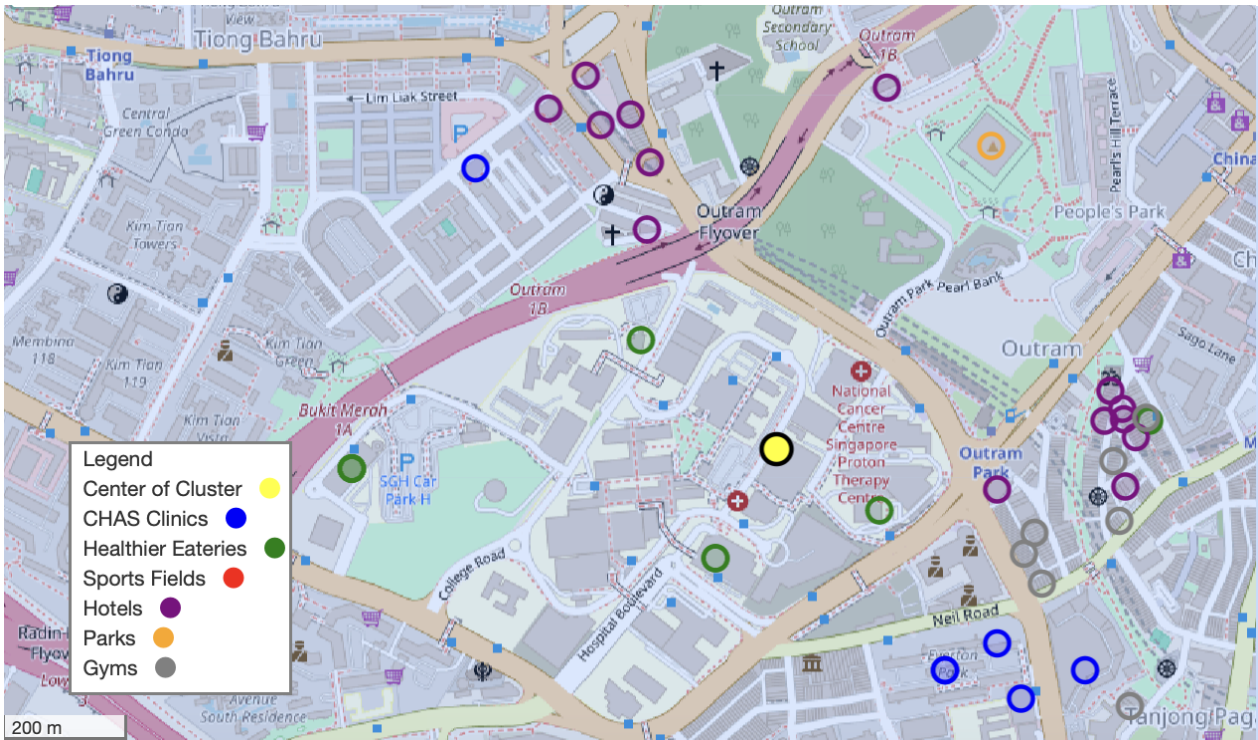
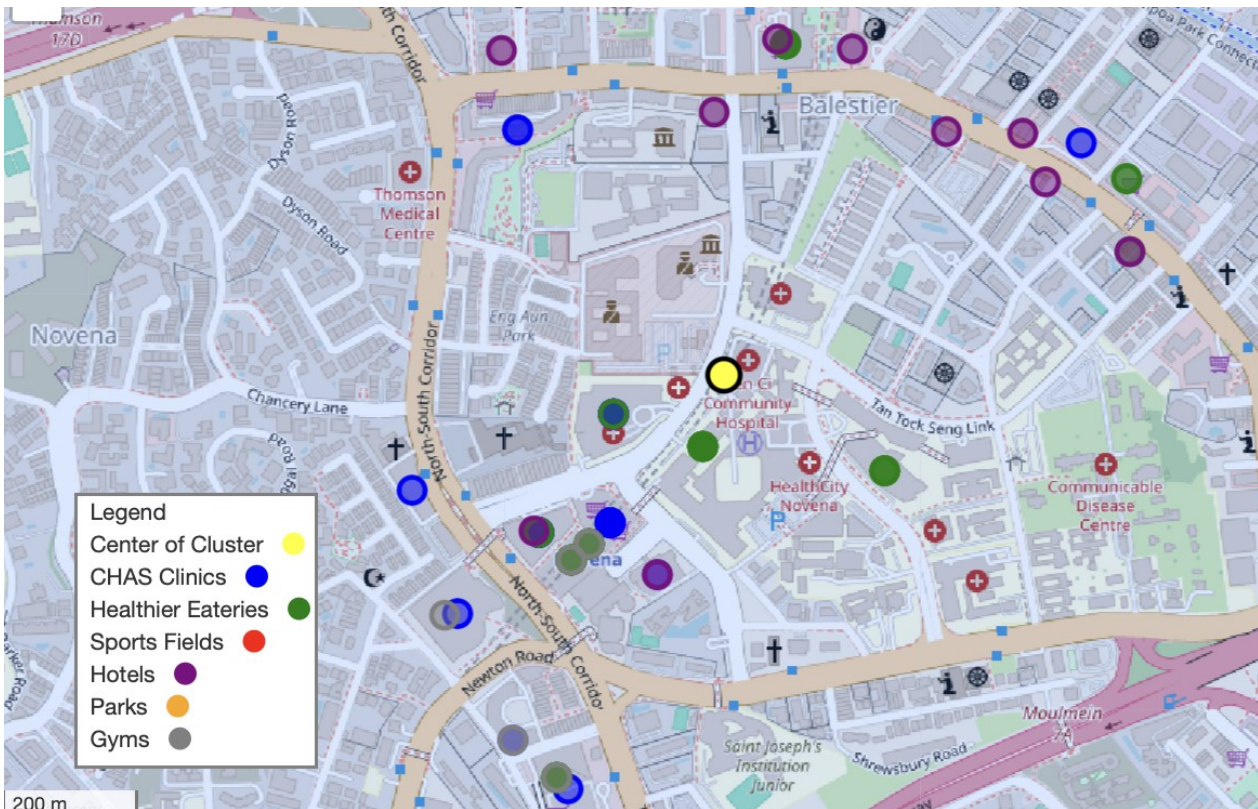*Fig. 11. Medical-tourist infrastructure gravitating towards Singapore General Hospital*

Fig. 12. Medical-tourist infrastructure gravitating towards Mount Elizabeth Novena Hospital

CONCLUSIONS

Research in medical tourism represents an important direction in promoting healthcare and developing the service sector economy. One of the management tools for this type of activity is geostrategising, which allows for the analysis of the provision of medical care and wellness services and the territorial organisation of medical tourism, one form of which is medical tourism clusters.

GIS technologies in developing strategies for medical tourism allow for the visualisation of processed arrays of geographic data, identification of patterns and trends and integration of economic, medical and geographic information impacting medical tourism's development and territorial organisation.

The two main groups of medical organisations in Singapore identified in this study, with the potential to serve as the basis for forming medical tourism clusters, are attractive destinations for medical tourists as they possess the necessary infrastructure and expertise to provide quality medical and wellness services. The creation of medical tourism clusters can contribute to developing other elements of the healthcare system in the region and country, attracting more clients.

The central district of Singapore is the main centre for the concentration of medical institutions and tourist attractions. The geographical distribution of medical infrastructure, largely following administrative divisions, allows for more effective planning and development of medical tourism at the governmental and business community levels interested in developing this direction.

Further research in the field of involving GIS in the development and territorial organisation of medical tourism involves focusing the attention of specialists on studying the influence of socio-geographical factors on the choice of medical tourists where to receive medical care, depending on factors such as the cost and quality of medical and health services, the availability of related infrastructure, sociocultural aspects. It is equally important to draw the attention of researchers to such unresolved issues as assessing the potential for the development of medical tourism in regions and countries of various types, determining the most effective strategies for attracting medical tourists to medical tourism clusters that provide high-quality medical care and health services at affordable prices. Additional research may include analysis of the competitive environment and identification of key success factors in the development of medical tourism.

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