

A Study on Spatial Distribution and Supply-Demand Relationship of Medical Facilities

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A Study on Spatial Distribution and Supply-Demand Relationship of Medical Facilities

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Abstract

ABSTRACT

The need to consider the location of medical facilities in the future compact city is increasing. The purpose of this research is to analyze the existing distribution of medical facilities, explore the relationship between hospital and clinic, and find out how they influence each other from a location analysis perspective.

Firstly, we attempt to analyze the types of basic discrete location focusing on each medical department. In this paper, we develop a Visual Basic for Applications programs based on the longitude and latitude, it measures the distance between each feature and its nearest neighbor, and then builds a cumulative frequency distribution function, also we choose Multi-Distance Spatial Cluster Analysis (Ripley's K Function) to make further analysis. In addition, it is believed to be considered significant to expand to a Mutual-K Function, that can be applied to determine whether different types of features or the values associated with features, exhibit statistically significant clustering or dispersion over a range of distances.

Public service facilities play a vital role in meeting the growing material and cultural needs of people and improving the quality of life in an all-round way. However, the contradiction between the growing demand for public services and the short supply of public services in urban areas is becoming more prominent. Medical facilities, an important part of ensuring the normal and orderly operation of urban functions, are attracting more attention.

In chapter 3, two-step floating catchment area (2SFCA) method with distance-decay function is applied to examine the proportion of the service supply range and population demand of each medical department, to give a "relative ratio of supply and demand" index, and provide reference value for the establishment and location of future clinics. The relative abundance and lacking area of medical services, and comparison of supply and demand in every category of medical departments are shown by GIS for all 7 distances of Fukuoka City.

Finally, in urban analysis, how to grasp the coverage of service facilities is

an important issue. The concept of the station circle, the commercial circle has been repeatedly discussed and widely applied. However, for medical facilities, scholars have rarely touched it. In chapter 4, we selectet comprehensive hospitals that introduced the DPC system in Fukuoka, Japan, for a total of 52 general hospitals. The research methods and procedure of this chapter are organized as follows: 1) Based on the initial supply-demand ratio relationship, the priority selection function is introduced, and continuous iteration is performed to obtain a relatively stable, ideal supply-demand ratio relationship. 2) Apply a 2SFCA method that introduces the distance decay function and the priority selection function, and calculate the theoretical service population of each facility, then set 70% of the theoretical service population to be the medical service circle. 3) Count the number of clinics with the same medical subject in the medical service circle of the hospital, investigate whether the clinics play a role in sharing the medical pressure of the hospital to a certain extent, and make clear what subjects the clinics have the potential to replace hospitals.

Keyword: *Medical facilities; Two-step Floating Catchment Area Method; Distance Decay Function; Supply-demand ratio; Priority Selection Function; Medical Service Circle*

Chapter 1

GENERAL INTRODUCTION

Chapter 1

GENERAL INTRODUCTION

1.1 Research Background

1) Most distinct problem In Japanese society reduction and aging of the population

There are major problems that must be overcome in the future of Japan. To name a few, there are issues such as reduction and aging in its population, as far as the author is concerned. In 2010, Japan still had a population of 128 million, and the figure has gradually been declining ever since. Post-war Japan witnessed an increase of income due to economic growth, and all of its citizens had access to insurance and pension among other rich social securities, which made abundant living environment complete adding elements such as improvement in medical technologies. Since around 1960, there has been a transition in population from births outnumbering deaths to small numbers of births and deaths. By the time around 1975, the population replacement rate of the total fertility rate reached around 2.1.1^[1]

After the first baby boom from 1971 to 1974, due to the impact of the first oil crisis, economic chaos and increase in population, and the popularization of the idea taking static population as the objective, the number of newborn babies kept declining. In 1975, the total special birth rate dropped below 2.0, to a level as low as 1.91. The consistently lowering total special birth rate recovered slightly at the beginning of 1980, but it became consistently low again since the mid-1980s, and the gap with the population replacement level was also widened.

According to the prediction of National Institute of Population and Social

Security Research^[2] in March 2013, during the three decades before 2040, the overall population will be reduced by 16%, the population at special reproductive age will be reduced by 29%, and the population of kids will be lowered n 37%. By contrast, the aged population will be increased by 31%. Japan is rapidly entering an aging society.

2) Urban Construction Plan Coping with Reduced Population and Aging Society

In marching toward an aged society with few kids, due to the expansion of urban functions, as for projects such as void downtown areas and low rate of available land area, “intensive urban construction” is expected to be built in the downtown area taking intensive urban functions as the goal. ^[3]The construction of intensive cities takes inhibiting urban expansion as the principle and transforms the structures into function-intensive ones. Japanese cities and streets have exposed the void downtown area in various central cities in 1990 after the consistent expansion of high growth. With the completion of road networks such as main lines, large shopping centers settle in the suburbs with an increasing speed, the opening of store along the roads and the transfer of public facilities and hospitals to the suburbs further dramatize the expansion of urban functions and the downtown area in central cities becomes spirally less noisy. In an ever-progressing aged society with few kids and reduced population, shrunk cities like these have evolved into an expanded urban structure that makes life impossible without cars.

The progression of suburbanization creates inconvenience in areas where automobiles are taken as the major measure of mobilizing for the underprivileged groups of people such as elders with limited access to traffic, causing low population density and thin utilization of land and architecture in existing urban areas, while public object management such as the management of roads and installing sewers become inefficient and produce a lot of maintenance cost, presenting many problems. In order to cope with such problems with limited financial resources, it is necessary to employ existing financial resources perspectives flexibly. Therefore, further intensification of urban functions through public transportation networks of the downtown

area with complete social capitals is a must, so as to keep the downtown area in a small scope, and most people including the aged can take “constructing intensive cities” where life is easy as the goal.

3) Existence Forms of Medical Facilities Beneficial for the Construction of Intensive Cities

Most of the public service facilities in Japan started to be constructed and completed in the 1960s. Therefore, in order to cope with the aging and diversity of facilities and the needs of the development of residents, rearrangement or facilities has become an important project, especially with medical facilities, where the reform of medical systems makes it an urgent task to expand each sickbed or provide complete diagnosis and treatment functional system. With it, needs for overall cancellation and combination, overall reconstruction, transfer, and new construction are also on the rise. In the downtown area, due to the guaranteed coverage and movement of hospitalized patients, medical facilities presented a distinct tendency to move to the suburbs, and administratively likewise. In the renewed planning of the “Urban Planning Act”, both the construction and movement of public facilities and utilities showed the direction of developing jurisdictions at all levels, therefore, there has also been a wide expectation of the inhibition of the declining inclination of downtown areas. On the one hand, the current condition is that the facilities that invite a lot of customers in the suburbs is not limited to commercial facilities, and has been expanded to public utilities. With the aging of medical facilities, cases transferring to the suburbs with certain road access and low price have gradually increased. Besides, the insufficiency or uneven distribution of doctors v.s. medical facilities is also a major problem. Accompanying these problems, medical facilities that cease to diagnose, treat or close are on the rise in Diagnosis Department. Furthermore, with the progression of aging, there have been greater medical needs. It is foreseeable that issues such as insufficiency or uneven distribution of doctors are deeper. Medical institutions such as hospitals and clinics are indispensable in perfect life. But in recent years, there is a tendency of reduced hospitals. Lack of doctors has become an especially severe problem in local and urban hospitals. To live in comfort and with great ease, medical facilities in hospitals or clinics play a critical role. But due to problems

such as uneven distribution in regions and of Departments of Diagnosis and Treatment, the number of places where medical services can't be fully enjoyed keeps increasing. It becomes more necessary to carefully study the site selection of medical facilities in intensive cities.

Medical institutions, such as hospitals and clinics, are necessary for our daily lives and play a key role in ensuring peace of mind. Understanding the importance of medical facilities as social infrastructure and daily life service has been integral to Japan's new medical systems, such as the Community-Based Integrated Care System. However, a recent reduction in the number of hospitals and uneven distribution of regional service and medical treatment departments has led to a number of areas having adequate medical services but cannot be enjoyed. In addition, the possibility of a medical institution becoming a function-induction facility has attracted widespread attention. This has obviously been reflected in the urban planning policy development formulated by the Japanese government in recent years. The Law on Improvement and Vitalization in City Center (enacted in 1998) aimed to promote the integration of multiple urban functions, such as education facilities, culture facilities, medical facilities, and social welfare facilities. Medical collaborations centering on clinics have been established, such as Local Medical Cooperation System, which promotes medical function sharing and specialization according to the local medical institution's own facilities function, scale, characteristics, and local healthcare needs. Smooth collaborations between medical institutions and clinics, clinics and hospitals, medical institutions and hospitals, hospitals and hospitals, and other medical institutions are expected. This system makes it possible for medical patients to receive continuous and appropriate medical care in each area by utilizing the functions of each medical institution effectively and promptly. Furthermore, since the late 1990s, the Ministry of Health and Welfare took measures to promote the functional differentiation of one institution from another. Future medical plans aim to improve the efficiency of the medical delivery system through the functional conversion and reorganization of medical institutions.

1.2 Literature Review

The location layout of modern hospitals is crucial for optimally allocating medical resources in the region. Reasonably optimize location selection can effectively save costs, ensure the rational distribution of medical resources among urban residents, and promote the balanced development of medical and health systems. The double target classification planning was used to solve the issue of hospital location selection in literature^[4]; The coverage model and the P-median model was used to solve the hospital location issue in literature^[5]; The location selection decision qualitative analysis factors were used in the literature^{[6][7]}. The above studies use deterministic models to describe the number of patient visits with fixed values. However, in practice, due to the randomness of morbidity and seasonal reasons, the number of patient visits has high randomness. Therefore, taking the randomness of hospital location selection into account is particularly critical to location selection decision^{[8][9]}.

On the other hand, accessibility of medical treatment has attracted much attention from scholars as an important indicator. Accessibility refers to the ease with which one point spatially reaches from another point.^[10] Accessibility of medical treatment evaluates the ease with which residents receive hospital health services at their location. Many scholars at home and abroad have studied the accessibility of medical treatment. The evaluation methods include the supply ratio method^[11], the distance method^{[12][13][14][15]}, the statistical indicator method^[16], the buffer analysis method, and the potential model^{[15][17]}, and two-step mobile search method^{[18][19][20]}. The two-step mobile search method allocates limited medical resources according to the potential population^[21], taking the supply and demand situation and distance factors into account. Compared with other methods, the two-step mobile search method is more in line with the actual situation. However, most of the previous studies have calculated the accessibility based on the spatial network polarity, and they did not consider the difference in traffic modes, which affected the objectivity and authenticity of the results.

1.3 Research Purpose

Cities in Japan have continued to expand through the period of rapid growth, and policy development has been promoted in suburban residential areas. Thus, cavitation phenomena in central urban areas has become noticeable in various places. The idea of compact city is proposed. The concept emphasizes that urban activities should be located closer together to ensure better access to services and facilities via public transport, walking, and cycling, and more efficient utility and infrastructure provision. The suburbanization of large scale facilities has expanded not only to commercial facilities but also to public infrastructure. Among them, medical facilities are increasingly moving to a suburb with cheap land prices due to the accessibility of main road. The need to consider the location of medical facilities in the future compact city is increasing.

This study is done with the following research objectives:

- 1) This paper analyzes the current distribution of various clinics in Fukuoka City from the perspective of the aggregation of point distribution.
- 2) For each medical and therapeutic subject, this paper establishes the current status and evaluation model for the existing medical facilities. Taking the medical facilities in Fukuoka as an example, this paper quantifies and visualizes the distribution of medical resources in various regions, and analyzes the problems existing in the distribution of existing medical resources.
- 3) This paper explores the status of hospital layout evaluation and layout optimization and establishes an influencing factors database.
- 4) This paper further explores the hospital layout optimization location model and takes Fukuoka City as an example to collect case verification, which provides a scientific basis for future hospital layout optimization decisions.

1.4 Dissertation Structure

This paper will explore the above-mentioned issues and perform a theoretical analysis and quantification on each issue. The specific chapters are detailed as follows:(Figure 1)

Chapter 1 explores the status faced by Japanese society under the crisis of population decline caused by the low birth rate in Japan, the increasingly urban intention and re-construction, as well as the increasingly aging phenomenon, the absent elderly care, and medical issues. Attention is also paid to the rapid development of the city, the shifting of the residents to suburbs areas, the intensification of urban hollowing, and the accompanying facts such as medical facilities are transferred to the suburbs, and the hospitals are closed down. Finally, it summarizes the importance of medical facilities landing and its relationship with the population in terms of supply and demand as a service facility to explore academic expectations in the policy orientation and research fields.

Chapter 2 avoids the traditional thinking ways, it does not take the hospital as the object, but separates each diagnosis and treatment subject, taking the subject as the unit. Firstly, the current distribution situation of various clinics in Fukuoka City was analyzed from the aggregation of point distribution. Then, the relationship between the spatial distribution of hospitals and clinics under each medical subject was explored.

Chapter 3 takes the population distribution elements into consideration on the basis of the second chapter, adopts the 2SFCA method, analyzes from the provider to the receiver of the service, obtains the enrichment for each subject under each block and conducts a visual study. Two-step floating catchment area with the distance-decay function is applied to examine the relative proportion of the service supply range and the population demand of each medical department, and give a "relative ratio of supply and demand " index. On the basis of grasping the relationship between supply and demand of existing medical resources, this paper constructs the evaluation system of supply and

demand pressure to provide the reference value for the establishment and location of future clinics.

Chapter 4 further improves 2SFCA and applies it to patient volume calculations for medical services to support subsequent patient analysis. we developed a model that estimates the number of patients for each diagnostic group and considers the location and attributes of each hospital. We then conducted a case study of 52 general hospitals located in Fukuoka City. We were able to grasp the supply and demand balance for each region. In other words, the future relocation of medical facilities should consider the arrangement of general hospitals and specialized hospitals, including the location of the hospital and the distance between the hospitals, as well as the supply and demand balance for each diagnostic group. In addition, the relocation of future medical facilities should examine the arrangement of general hospitals and special hospitals, including the location of each hospital and the distance between hospitals, in addition to the supply and demand balance for each diagnostic group. Moreover, the 2SFCA model developed in this study will be a useful tool for developing hospital facilities in the future, in accordance with the reorganization of cities due to changes in future population distribution and traffic planning.

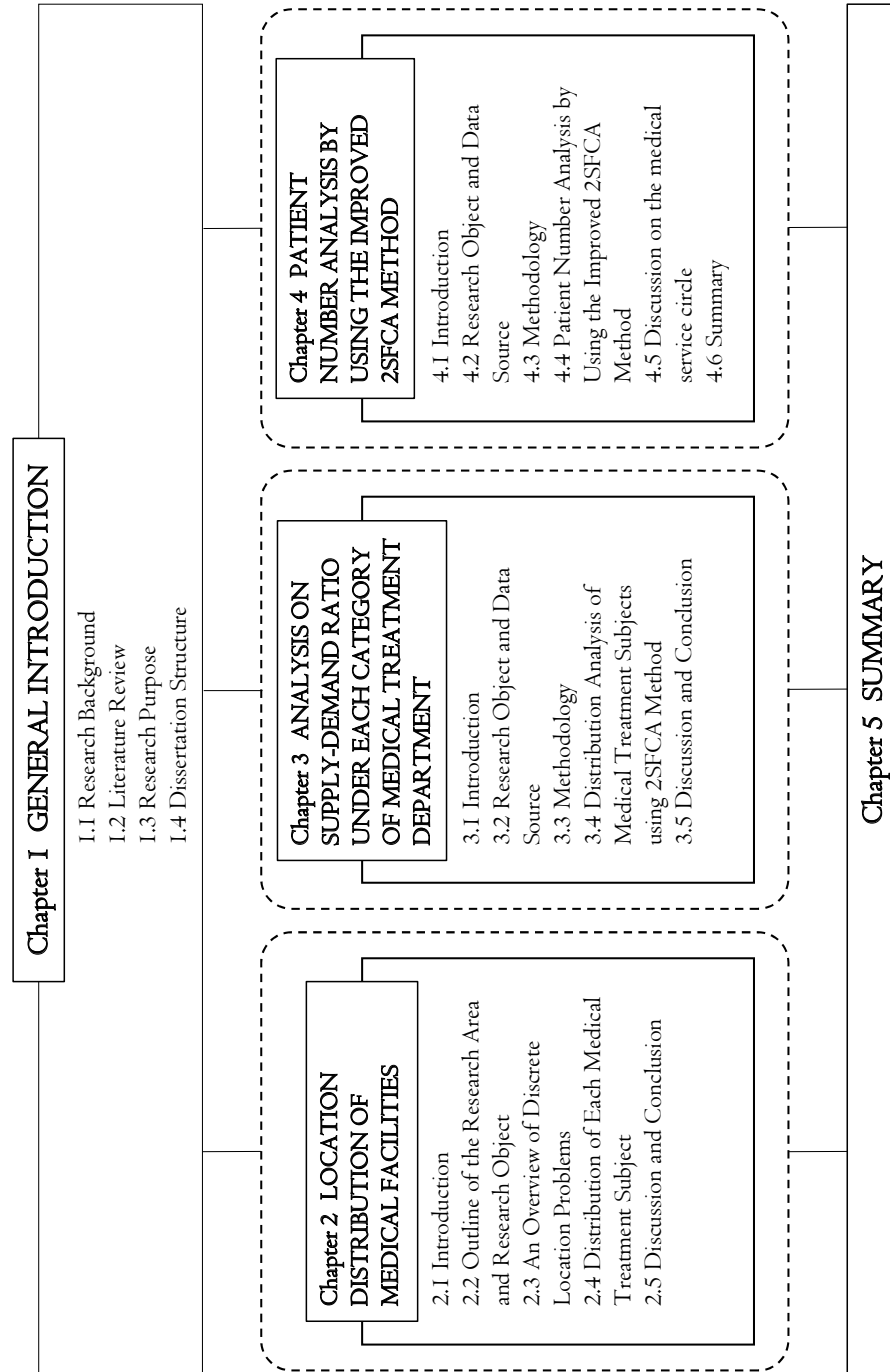


Figure 1 Dissertation Structure

References

- [1] Cabinet Office: https://www8.cao.go.jp/shoushi/shoushika/whitepaper/measures/w-2017/29webgaiyoh/html/gb1_s1-1.html
- [2] National Institute of Population and Social Security Research: <http://www.ipss.go.jp/>
- [3] Ministry of Land, Infrastructure, Transport and Tourism: <http://www.mlit.go.jp/index.html>
- [4] Mitropoulos P., Mitropoulos I., Giannikos I., et al: A Bi-objective model for the location planning of hospitals and health centers, *Health Care and Management Science*, pp.171-179, 2006.9
- [5] Brandeau M., Sanfort F., Pierskallas W. P.: *Operations research and health care: A handbook of methods and applications*, United States: Springer Publication, 2004
- [6] CHEN Qing-feng, LU Jian-xia, LIU Min: Application of a non-symmetrical AHP method to location selection for logistics centers, *Industrial Engineering*, Vol.8, No.1, pp.75-78, 2005
- [7] LIU Xiao-feng, CHEN Tong, LIU Jin-ming, et al: The ANP-based evaluation model and application of the site selection of logistics center, *Industrial Engineering*, Vol.10, No.5, pp.136-140, 2007
- [8] Melin A., Granath J. A.: Patient focused healthcare: An important concept for provision and management of space and services to the healthcare sector, *Facilities*, Vol.22, No.11, pp.284-289, 2004
- [9] ZONG Hong-jun, ZHANG Shi-xia: Thoughts on location of hospitals for infectious diseases, *Chinese Journal of Current Hospital Administration*, Vol.1, No.2, pp.64-65, 2003
- [10] Johnston R J.: *The dictionary of human geography*. CHAI Y. W., CAI Y. L., GU C. L., et al, Trans. Beijing: the Commercial Press, 2004
- [11] CHE Lian-hong: Review on the measures and application of spatial accessibility to health care, *The Chinese Health Service Management*, Vol.2, pp.88-91, 2013
- [12] Love D, Lindquist P.: The geographical accessibility of hospitals to the aged: geographic information systems analysis within Illinois, *Health Services Research*, Vol.29, No.6, pp.629-651, 1995
- [13] Roserobixby L.: Spatial access to health care in Costa Rica and its equity: a GIS-based study, *Social Science & Medicine*, Vol.58, No.7, pp.1271-1284, 2004
- [14] WANG Yuan-fei: GIS and Voronoi Polygon based public health care accessibility analysis, *Geomatics & Spatial Information Technology*, Vol.29, No.3, 2006.6
- [15] ZHENG Chao-hong: Analysis of spatial accessibility to medical institutions in county-level city based on GIS: a case study of Shishi, Fujian, *Topical Geography*,

Vol.31, No.6, pp.598-603, 2011.11

- [16] WU Jian-jun, KONG Yun-fen, LI Bin: The spatial accessibility analysis of rural medical facilities based on GIS: a case study of Lankao county, Henan province, *Human Geography*, Vol.23, No.5, pp 37-41, 2008.10
- [17] SONG Zheng-na, CHEN Wen, CHEN Qian-jin, ZHANG Lei: Measurement of spatial accessibility to health care facilities and defining health professional shortage areas based on improved potential model – a case study of Rudong County in Jiangsu province, *Scientia Geographica Sinica*, Vol.30, No.20, pp.213-219, 2010.4
- [18] WANG F H, LUO W.: Assessing spatial and nonspatial factors for healthcare access: Towards an integrated approach to defining health professional shortage areas, *Health and Place*, Vol.11, No.2, pp.131-146, 2005
- [19] LIU Zhao, GUO Su-qiang, JIN Hui-hua, XIE Zhe, WU Xian, ZHU Xiao-dong: Application of the GIS-based two-step floating catchment area method in measurement of spatial accessibility to hospitals in Beijing, *Science of Surveying and Mapping*, Vol.32, No.1, pp.61-63, 2007.3
- [20] TAO Zhuo-lin, CHENG Yang, DAI Te-qi: Measuring spatial accessibility to residential care facilities in Beijing, *Progress in Geography*, Vol.33, No.5, pp.616-624, 2014.5
- [21] SONG Zheng-na, CHEN Wen: Measuring spatial accessibility to health care facilities based on potential model, *Progress in Geography*, Vol.28, No.6, pp.848-854, 2019.11

Chapter 2

LOCATION DISTRIBUTION OF MEDICAL FACILITIES

Chapter 2

LOCATION DISTRIBUTION OF MEDICAL FACILITIES

2.1 Introduction

2.1.1 Research background

Cities in Japan have continued to expand through the period of rapid growth, and policy development has been promoted in suburban residential areas. Thus, cavitation phenomena in central urban areas has become noticeable in various places. The idea of a compact city is proposed. The concept emphasizes that urban activities should be located closer together to ensure better access to services and facilities via public transport, walking, and cycling, and more efficient utility and infrastructure provision. The suburbanization of large scale facilities has expanded not only to commercial facilities but also to public infrastructure. Among them, medical facilities are increasingly moving to a suburb with cheap land prices due to the accessibility of the main road. The need to consider the location of medical facilities in the future compact city is increasing. Medical institutions such as hospitals and clinics are indispensable for our lives. However, hospitals have been decreasing in recent years, and doctor shortage has become a serious problem especially in local cities. Medical facilities such as hospitals and clinics play an important role in living everyday life with peace of mind. However, there are problems such as uneven distribution in the region and uneven distribution of medical departments, and an increasing number of regions cannot receive sufficient medical services. There is a growing need to consider the location of medical facilities in future compact cities.

On the other hand, It is expected that medical institutions and clinics, clinics and hospitals, medical institutions and hospitals, hospitals and hospitals, and the other medical institutions work together smoothly. It is a system that

makes it possible for the medical patient to receive continuous and appropriate medical care in each area by utilizing the functions of each medical institution effectively and promptly. Furthermore, from the late 90s, the Ministry of Health and Welfare has laid out measures to promote functional differentiation one after another. In future medical plans, the efficiency of the medical delivery system will be highly valued through functional conversion and reorganization of medical institutions with distributed, excessive and uneven distribution.

2.1.2 Literature review

In medical environment, incorrect facility location decision has a serious impact on the communities. From this perspective, facility location modeling for medical facilities is more critical than similar modeling for other areas. In problems of locating health-care facility, various objectives have been considered. At first, access to health-care facilities is thought as a crucial issue and a major concern for government planning ^[1]. And the research focuses on the definitions and the measurements of access to medical care ^[2]; then, improving the access to health-care facilities is set as one objective in the planning of health-care facility ^{[3][4][5]}. Later, improving the equity of access to health-care has been concerned ^[6] and then prompted research on the reasonable allocation of health-care facilities ^[7]. Apart from improving the access and the equity of access, reducing the cost metrics^[8], increasing flexibility in service location selection, and the number of people within an acceptable travel distance of at least one facility^[9] are getting more and more concerned, which have been thought as objectives in solving location-allocation problems. Obviously, various objectives have been considered in solving the problem of locating health-care facilities.

Perhaps for Japanese city, the comprehensive location-allocation study in the field of medical facilities was presented by ICHIKAWA Mihoko^[10]. In this study, through the analysis of the location selection of medical facilities (including relocation and new-build) in provincial city in recent 20 years, the location selection pattern of medical facilities in provincial city recent years was clarified. In addition, ISHII Norimitsu's research ^[11] is about the differences of hospital location condition among different areas based on the number of hospital and

clinic in each area. Most of prior research focus on the facilities but there is no research with a view to each subject.

2.1.3 Research purpose and chapter structure

Based on the above background, in this study, from the viewpoint of probability distribution of nearest neighbor distance, focusing on the distribution of medical subjects for medical facilities in Fukuoka City, we aim to compare and examine the medical facilities of each subject, and to grasp the location of medical facilities quantitatively from various angles. The purpose of this research is to analyze the existing distribution of medical facilities, explore the relationship between hospital and clinic, and find out how they influence each other from a location analysis perspective.

In chapter 2.2 The selection and outline of the research object are explained. First of all, we describe the medical environment in Fukuoka City and summarize the changes in the number of hospitals and clinics in recent years. Finally, we explain how to select the subjects to be further studied.

In chapter 2.3, a G-function method, a K-function method, and a mutual K-function method that is an extension of the K-function method will be described. Also, the characteristics of each method are discussed.

In Chapter 2.4, the G-function method is applied to the subjects selected in Chapter 2.3 for each subject and analyzed. A simulation by the mutual K-function method is performed, and the location relationship between the hospital and the clinical subject in the same clinical subject will be considered.

Chapter 2.5 summarizes the results of this chapter.

2.2 Outline of the Research Area and Research Object

2.2.1 Medical environment in Fukuoka

The Fukuoka City, the capital city of Fukuoka Prefecture on the northern shore of the island of Kyushu in Japan, is chosen as a study area. (Figure 2-1) This



Figure 2-1 Basic Profile of Fukuoka City

research studies the spatial distribution characteristic of medical facilities using the data of Fukuoka at August 2016.^[12] Subjects in the study cover totally 151 medical departments in 115 hospitals and 1526 clinics, carried out by the Fukuoka City government. We attempt to analyze the types of basic discrete location focus-ing on each medical department.

Medical facilities in this research refer to hospitals and clinics, in which dental clinics is also included. Specifically, hospitals in this research refer to the health care institutions providing patient treatment with specialized medical

and nursing staff and medical equipment, and holding the number of sickbeds more than 20, while clinics are medical facilities that is primarily focused on the care of outpatients with no sickbed or the number of sickbeds is less than 19. And dental clinics are clinics that provides oral health services with a team of dentists. The information on medical facilities used in this research, which includes the name, location, the number of the sickbed, and the type of sickbed (only for hospital), is from the List of Medical facilities posting on the homepage of Fukuoka city. And the latitude and longitude information of medical facilities are obtained by using Geocoding and Mapping provided by KTGIS.NET^[13].

Extracting 115 hospitals, 1526 clinics and 1013 dental clinics located in Fukuoka as samples of this research. And classifying these medical facilities by their properties, including the type, scale, opening year, the number of a clinical department and the number of sickbeds. Creating a cross table based on the result of classification (Table. 2-1). As is shown in the table, among all the 2539 clinics, in which dental clinics are also included, about 50 percent (1259/2359) of clinics have the number of the clinical department is ranged from 2 to 3.

In addition, hospitals with more than 4 clinical departments account for about 72 percent (83/115) of all the sample hospitals. Besides, in terms of the number of the sickbed, all the clinics hold no more than the number of 50, while 66 percent (73/115) of hospitals have more than the number of 100. In the consideration of the opening year, 73 hospitals opened 30 years ago, which accounts for 67 percent of all the sample hospitals. Furthermore, as for clinics, most of them were opened between the year of 2006 and 2016, the number of which takes up 49 percent (747) of all the clinics, and followed successively by the number of clinics opened between the year of 1996 and 2005, the year of 1986 and 1996, and the year before 1985, and the percentages of which are 29% (445), 16% (244), and 6% (90) respectively. Different from hospitals, the number of newly established clinics in recent years has an increasing tendency, with which the dental clinic is the same.

2.2.2 Transition of medical facilities

According to the Medical Facilities Research conducted by the Ministry of

Table 2-1 A cross tabulation of medical facilities

Facility attributes		No.	11	12	13	31	32	33	41	42	43	44	51	52	53
Project	Hospital	11	115												
	Clinic	12	0	1526											
	Dental Clinic	13	0	0	1013										
Scale (m ²)	~2000	21	12	-	-										
	2001~5000	22	36	-	-										
	5001~	23	67	-	-										
No. of subjects	1	31	7	479	260	746									
	2~3	32	25	753	542	0	1320								
	4~	33	83	294	211	0	0	588							
Opening year	2006~2016	41	10	747	413	305	587	278	1170						
	1996~2005	42	16	445	285	200	389	157	0	746					
	1986~1995	43	16	244	212	136	256	80	0	0	472				
	~1985	44	73	90	103	105	88	73	0	0	0	266			
No. of sickbeds	1 ~ 50	51	20	1526	1013	740	1310	518	1162	736	460	201	2559		
	51 ~100	52	19	0	0	3	4	12	2	4	2	11	0	19	
	101~	53	76	0	0	3	15	58	6	6	10	54	0	0	76

Health, labor and welfare, ^[14] changes of the number of hospital in Fukuoka from 1996 to 2014 is shown as Figure 1. In light of figure 1, the fact that the number of the hospital is decreasing from the year of 1999 becomes clear. Compared with the year 1996, the number of the hospital according to the statistics in October 2014 has a decrease of 12. In addition, while the number of regular hospital keeps decreasing, the number of mental hospital stays in 12.

Then, as with the change of the number of hospitals(Figure2-2), the change of number of the clinical department is shown in Figure2-3. Although the growth rate keeps decreasing, the number of clinical departments increases steadily. Moreover, the fact that only clinics with no sickbed keep increasing, and clinics with sickbeds keeps decreasing can be known. The reason for the increase in no-bed clinics can be referred to as the tendency that clinics with beds became no-bed, and doctors used to work in the hospital opened their own clinics. Besides, compared with the high investment barrier of the hospital, it is possible to set up a clinic with relatively low investment in the beginning, for that large medical equipment which is expensive is not necessary.

2.2.3 Extraction of clinical departments

Because of the Healthcare system reform, the categories of clinical department increased. This research picks up 151 clinical departments from all the medical facilities in Fukuoka. And based on the explanation of these clinical departments released by the Ministry of Health, labor and welfare, all the 151 clinical departments can be classified into 28 categories. In terms of these categories, medical facilities are picked up respectively. (Figure 2-4) As a result, the number of medical facility with dentistry is 1046, which is the most, followed by the number of facilities with the internal department or pediatrics, both of which account for 10 percent of all, while facilities with nephrology or cardiovascular surgery are the least, both of which occupies about 1 percent of all.

2.3 An Overview of Discrete Location Problems

2.3.1 A cumulative frequency distribution function

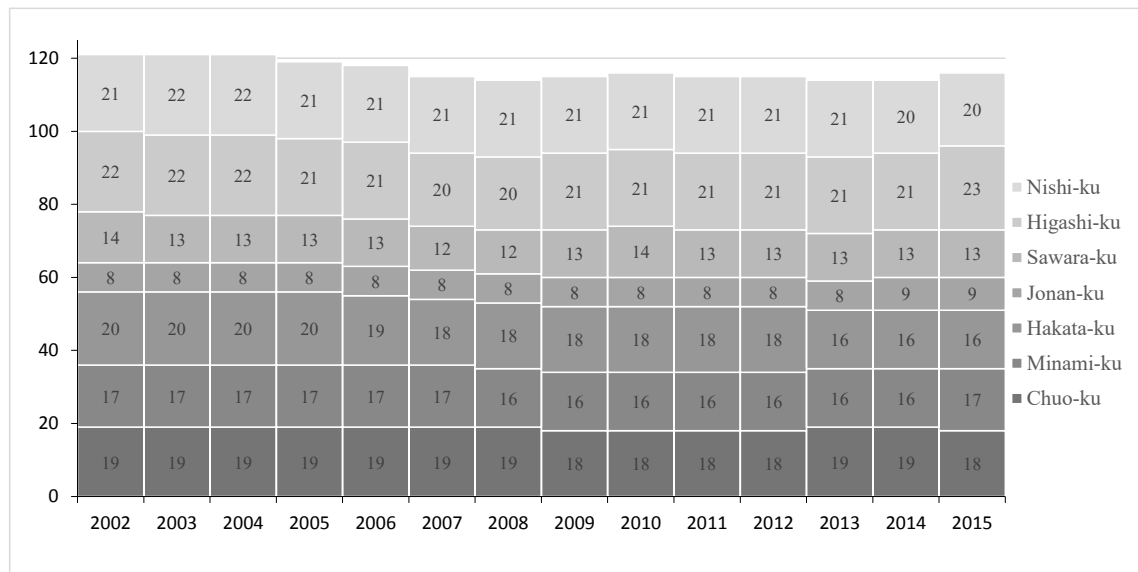


Figure 2-2 The transition of hospital

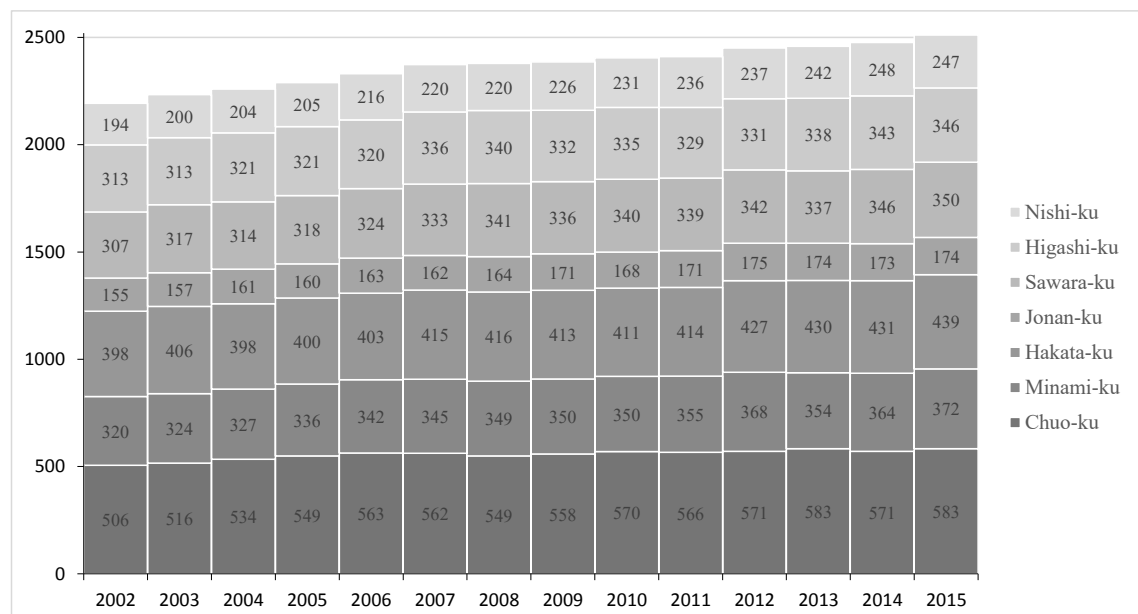


Figure 2-3 The transition of clinic

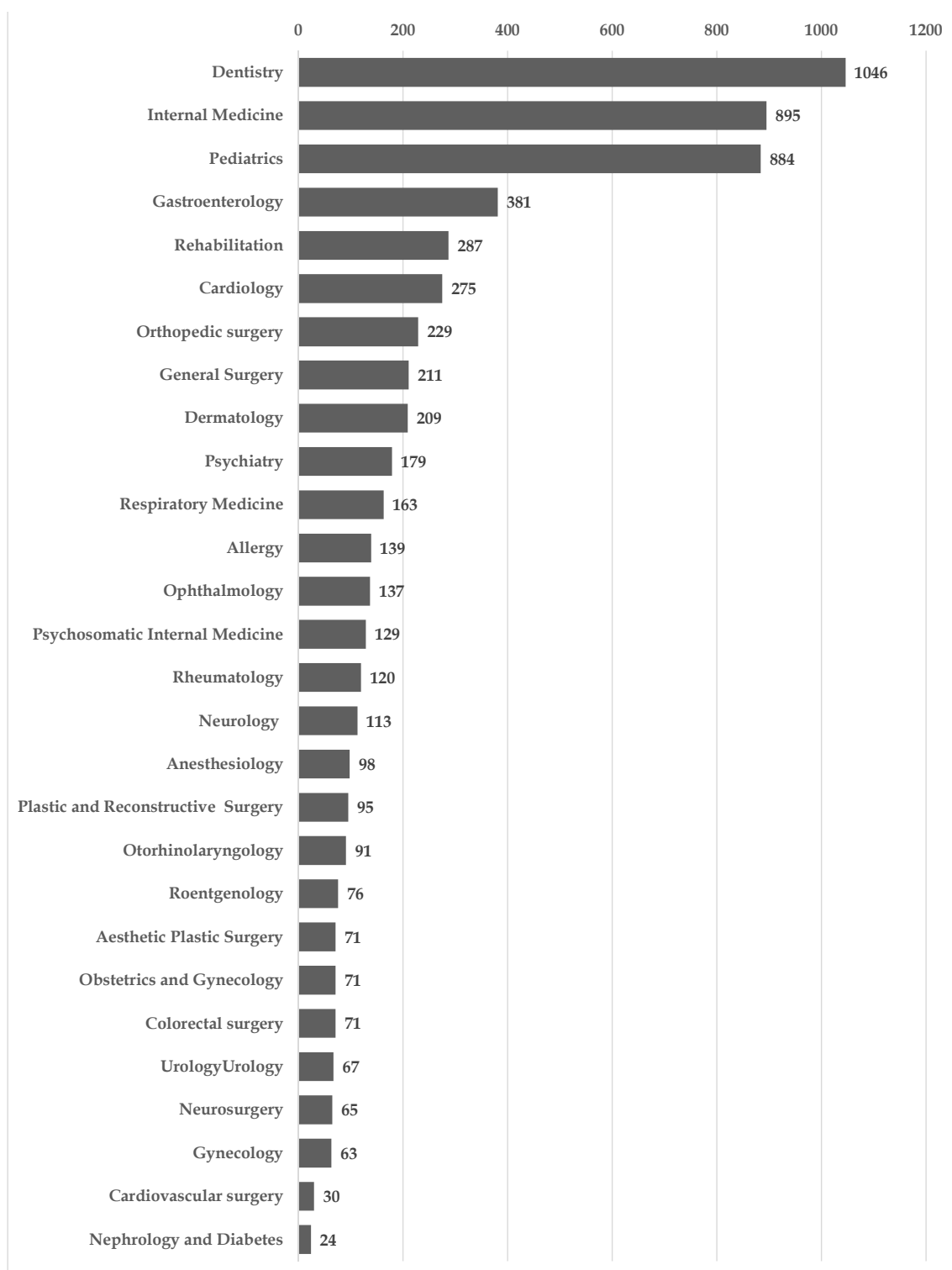


Figure 2-4 Extraction of medical treatment subject

1) Nearest neighbor distance

Nearest neighbor distance is the distance to each feature closest to each feature. As shown in Figure 2-5, the nearest neighbor of point 1 is point 4, but the nearest neighbor distance is 3.31. Based on the Euclidean distance, it is possible to calculate the nearest point and the distance between them for each point in the entire target region. Here, the nearest neighbor distance of the point S_i is represented by $d_{min}(S_i)$.

2) Analysis Method based on nearest neighbor distance analysis

The average nearest neighbor distance analysis method is a method of calculating the nearest neighbor distance index based on the average distance between each feature and the nearest feature, and classifying from the viewpoint of the distribution of points "distributed" and "dense". The average nearest neighbor distance is defined as:

$$r = \frac{1}{n} \sum_{i=1}^n d_i \quad (2-1)$$

When the point distribution follows a Poisson distribution, the expected value and standard deviation of the nearest neighbor distance are given by the following equations.

$$E(r) = \frac{1}{2\sqrt{p}} \quad (2-2)$$

$$\sigma(r) = \frac{0.26136}{\sqrt{p}} \quad (2-3)$$

Where p is the average density of the point distribution ($p = n / S$; S is the area of the target area) Also, the ratio of r and $E(r)$ is called the nearest neighbor measure R .

Intensive Distribution, $R < 1$,

Average Distribution: $R = 1$,

Distributed: $R > 1$

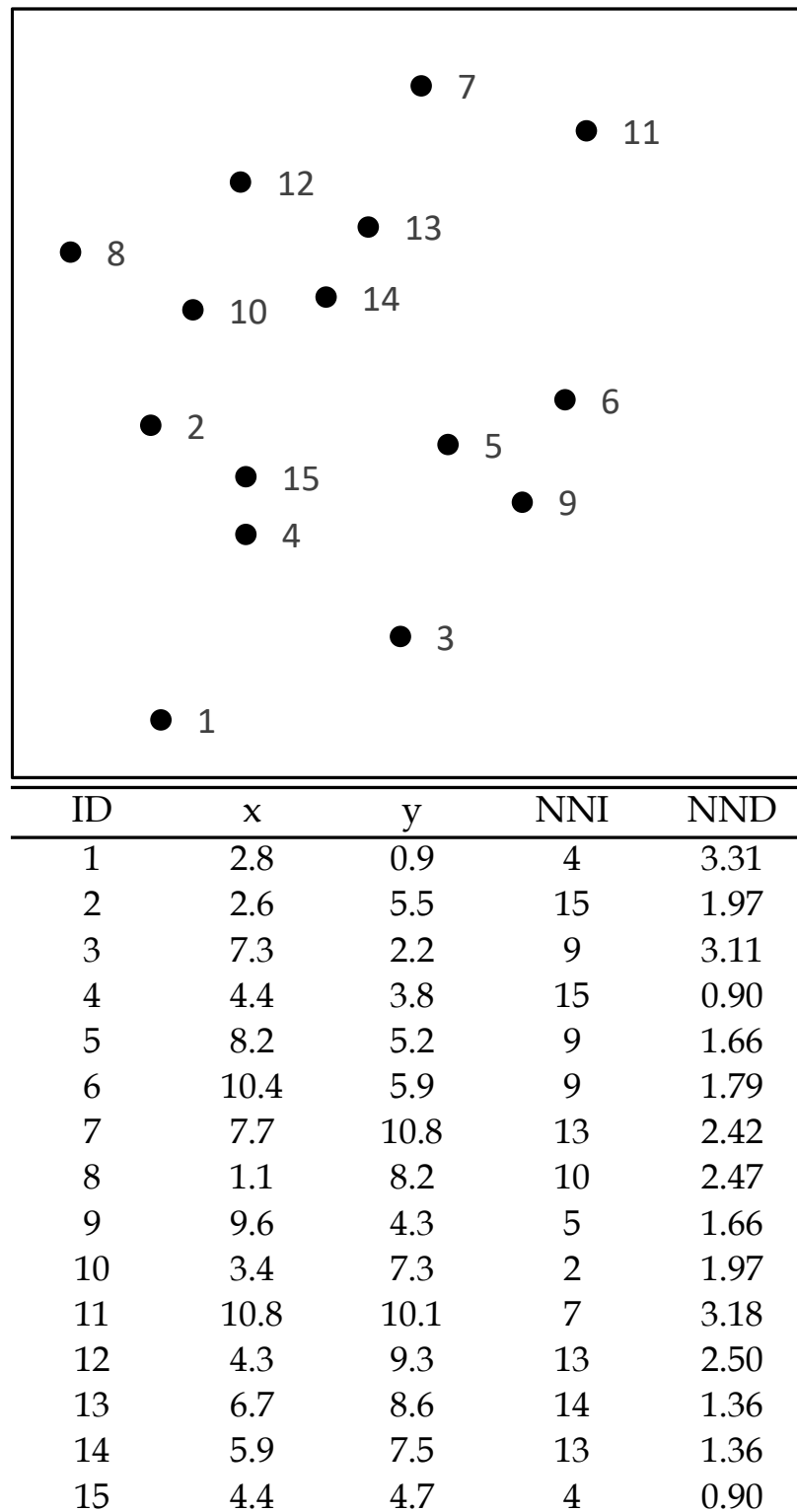


Figure 2-5 Nearest neighbor and nearest neighbor distance

3) G-function method

The average nearest neighbor distance analysis method described in the previous section analyzes the basic pattern of point distribution based on the average nearest neighbor distance. However, since all the information is included only by the average value, it is greatly affected by the area value. ([Analysis range] Changing the parameter value a little may change the result greatly).

In this way, analysis is performed using the average nearest neighbor distance of the point distribution, whereas the G-function method analyzes by focusing on the distribution of the nearest neighbor distance. The G function is a cumulative distribution function defined as follows.

$$G(d) = \frac{\#(d_{\min}(s_i) \leq d)}{n} \quad (2-4)$$

Where $\#(d_{\min}(s_i) \leq d)$ is the number of points whose nearest neighbor distance is less than or equal to d. And $\frac{\#(d_{\min}(s_i) \leq d)}{n}$ is the percentage of points where the nearest neighbor distance is less than or equal to d.

4) The procedure of G function method

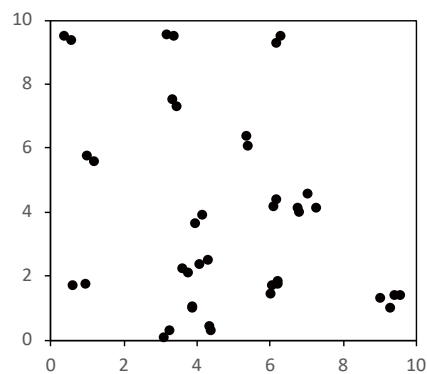
First, calculate the nearest neighbor distance from each point to the nearest point. From this, n nearest neighbor distances are obtained.

Next, arrange them in ascending order of the values of the nearest neighbor distances, divide them into fixed reference distances, and find the percentage of the total number of points included in each reference distance.

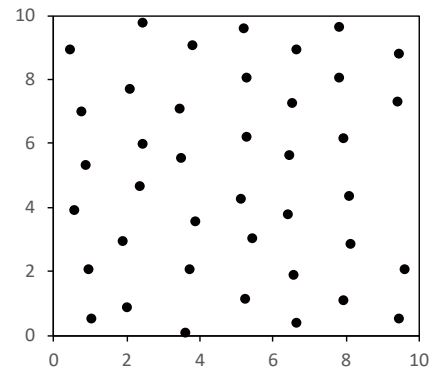
Finally, draw a G curve and typify the distribution of points compared to a random distribution curve.

As shown in Fig. 2-6, Since the curve a has a steep slope when the value of d is small, it can be seen that there are many points having a shortest nearest neighbor distance, and the distribution of points is considered to be “dense”.

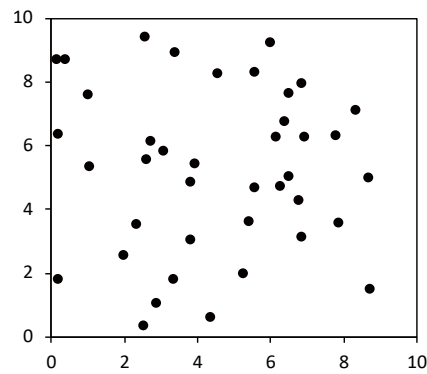
The curve c is considered to be a “distributed” distribution because there is



(a) Dense distribution



(c) Average Dstribution



(b) Random Distribution

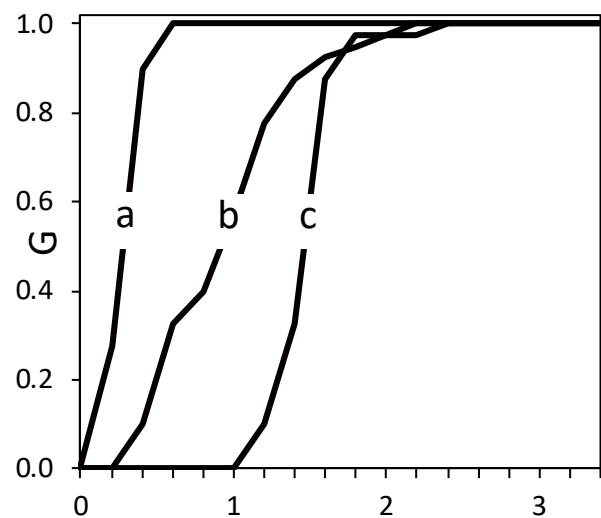


Figure 2-6 Image of G funtion curve

almost no increase when the value of d is small, and then the elongation rate increases and the nearest neighbor distance is long. The curve b indicates a “random type” distribution.

In this chapter, we develop a Visual Basic for Applications programs based on Microsoft Excel. When we input the data of longitude and latitude, it measures the distance between each feature and its nearest neighbor and then builds a cumulative frequency distribution function (G Function).

Also, we can simulate a hypothetical random distribution with the same

number of features covering the same total area and output the cumulative frequency distribution function of a random situation. According to the starting point, gradient, inflection point and other characters of the function image, the distribution of each medical department can be described and classified in terms of the level of clustering and dispersion.

2.3.2 Ripley's K(d) function

The G-function method, which focuses on the distribution of the nearest neighbor distance, analyzes using a part of the information of the point distribution, whereas the K-function method analyzes using the detailed position information of the point distribution. Specifically, a K-function is a statistic defined as follows:

$$K(d) = \frac{E[\#S \in C(s_i, d)]}{\rho} \quad (2-5)$$

while $E[]$ is operation symbol of the expected value calculation.

$\#S \in C(s_i, d)$ is the number of points contained in a circle with a radius d drawn around an arbitrarily selected point, and ρ is the point density obtained from the entire target area. That is, the K-function represents the ratio of the point density in the local spatial range (circle) of the radius d to the point density obtained from the entire target area.

Furthermore, it is expected to discover the mutual relationship of each feature. Different from G function, the one-dimensional function with only one independent variable, we choose Multi-Distance Spatial Cluster Analysis (Ripley's K Function) to make further analysis. ^{[15]-[18]}Ripley's K Function is the average density of points at each distance, divided by the average density of points in the entire area.

Using Ripley's K function you can determine whether points have a random, dispersed or clustered distribution pattern at a certain scale. When the observed K value is larger than the expected K value for a particular distance, the distribution is more clustered than a random distribution at that distance (scale of analysis). When the observed K value is smaller than the expected K, the distribution is more dispersed than a random distribution at that distance.

When the observed K value is larger than the Higher Confidence Envelop value, spatial clustering for that distance is statistically significant. When the observed K value is smaller than the Lower Confidence Envelop value, spatial dispersion for that distance is statistically significant.

2.3.3 Mutual-K(d) function

Furthermore, it is expected to discover the mutual relationship of each feature. Different from G function, the one-dimensional function with only one independent variable, we choose Multi-Distance Spatial Cluster Analysis (Ripley's K Function) to make further analysis. Ripley's K Function is the average density of points at each distance, divided by the average density of points in the entire area. In addition, it is believed to be considerably significant to expand to a Mutual-K Function, that can be applied to determine whether different types of features, or the values associated with features, exhibit statistically significant clustering or dispersion over a range of distances.

Unlike the ordinary nearest neighbor distance method, the mutual nearest neighbor distance method has two statistical methods for testing spatial clustering of point distributions. This is because there are two ways of treating point distributions, which is closely related to what the similarity between two distributions suggests: one distribution is a cause for the other distribution or two distributions have the same cause.

There are two sets of points A and B in a region S.

The mutual K – function of A judging from B is defined as follows.

$$K_{AB'}(d) = \frac{E[\#S_A \in C(s_{B_i}, d)]}{n_B \rho_A} \quad (2-6)$$

Meanwhile, the mutual K – function of B judging from A is defined as follows.

$$K_{A'B}(d) = \frac{E[\#S_B \in C(s_{A_i}, d)]}{n_A \rho_B} \quad (2-7)$$

Then the mutual nearest neighbor distance is given by the weighted mean between and :

$$K_{AB}(d) = \frac{n_B K_{AB'}(d) + n_A K_{A'B}(d)}{n_A + n_B} \quad (2-8)$$

The mutual nearest neighbor distance is small when two distributions are spatially clustered with each other. If they are separated, it shows a large value.

In order to make the results more visually, in this paper, we choose Mutual L(d)-function, which is the standardization of mutual K(d)-function.

$$L_{AB}(d) = \sqrt{\frac{K_{AB}(d)}{\pi}} - d \quad (2-9)$$

2.4 Distribution of Each Medical Treatment Subject

2.4.1 Application of G(d) function

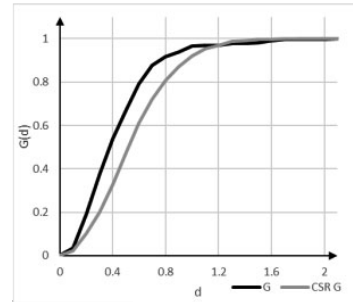
We picked up 151 subjects from all medical facilities in Fukuoka city and summarized them into 28 categories. the G-function method was applied for each category. (Appendix) After comparing each G-function curve and CSR-G-curve, it was possible to divide 28 kinds into three groups. Here, we take up the typical subjects in each group and perform an illustration of the characteristic of the curve. (Figure 2-7.)

Typically intensive type: (Neurology, Psychosomatic Internal Medicine, Urology, Plastic and Reconstructive Surgery, Aesthetic Plastic Surgery, Dermatology, Psychiatry)

The value of G-function increases sharply in a small range at first, then become slowly. Compared with other groups, G-curve's growth rate of this group is greater, for which the medical departments in this group can be considered highly intensively distributing.

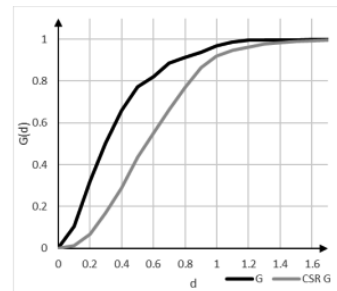
Intensive type: (Internal Medicine, Cardiology, Gastroenterology, Respiratory Medicine, Nephrology and Diabetes, General Surgery, Orthopedic surgery, Gynecology, Obstetrics and Gynecology, Pediatrics, Ophthalmology, Colorectal surgery, Anesthesiology, Roentgenology, Rheumatology, Allergy, Dentistry)

(1) Typically intensive type : Neurology, Psychosomatic Internal Medicine, Urology, Plastic and Reconstructive Surgery, Aesthetic Plastic Surgery, Dermatology, Psychiatry



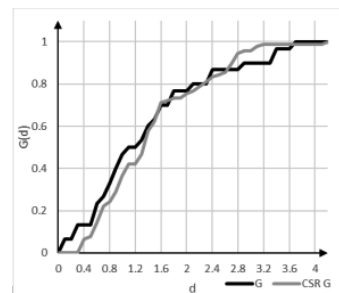
Example : Aesthetic Plastic Surgery

(2) Intensive type: Internal Medicine, Cardiology, Gastroenterology, Respiratory Medicine, Nephrology and Diabetes, General Surgery, Orthopaedic Surgery, Gynecology, Obstetrics and Gynecology, Pediatrics, Ophthalmology, Colorectal surgery, Anesthesiology, Roentgenology, Rheumatology, Allergy, Dentistry



Example : Internal Medicine

(3) Random type: Neurosurgery, Cardiovascular surgery, Otorhinolaryngology, Rehabilitation



Example : Cardiovascular Surgery

Figure 2-7 The feature of typical medical departments of each group

The value of G-Function is greater than the value of CSR G-curve, the intensive feature of this group is clear. However, compared with highly intensive group, the growth rate of G-curves in this group is smaller, thus this study distinguishes this group from the highly intensive group.

Random type: (Neurosurgery, Cardiovascular surgery, Otorhinolaryngology, Rehabilitation)

All the G-curves of this group almost coincide with CSR G-curve, for which the medical departments in this group can be considered distributing randomly.

2.4.2 Further subdivision

Through the analysis above, we can draw a general rule. For the curve, which can be observed as intensive type directly, the correlation coefficient is always lower than 0.9. And for the G function curve that can be observed directly as random distribution, the difference between the slope of the linear regression and the random distribution is not more than 10%, and the correlation coefficient is higher than 0.9.

Therefore, we confirm that the use of the slope and the correlation coefficient as the evaluation of the distribution in terms of degree is essentially the same as the G function image judgment. On the other hand, we can use the percentage difference of slope between G-function curve and random distribution, the calculation amount was used as the degree of aggregation. The following classification is made for the distribution of visually impossible, between high intensive type and random distribution:

a. Low level intensive(the percentage difference of slope between G-function curve and random distribution is lower than 10%)

Including: Internal Medicine, Respiratory Medicine, Gynecology, Obstetrics and Gynecology, Ophthalmology, Colorectal surgery, Roentgenology, Dentistry

b. Moderate level intensive (the percentage difference of slope between G-function curve and random distribution is between 10% and 20%)

Including: Cardiology, Gastroenterology, General Surgery, Orthopedic surgery, Pediatrics, Rheumatology

c. High level intensive (the percentage difference of slope between G-function curve and random distribution is higher than 20%, and the confidence level is over 0.9

Including: Nephrology and Diabetes, Anesthesiology, Allergy

In this way, we can divide 28 categories seemingly random aggregation into 5 types: random distribution, low level intensive distribution, medium level intensive distribution, high level intensive distribution and typical intensive distribution. (Table 2-2.) The degree of aggregation of these 5 categories increases in turn. Comparing these 5 kinds of subjects, we get the following rules:

For some subjects that professional and medical device requirements are not very high, regardless of the number of subjects, whether the distribution is widespread or not, show a random distribution or low level intensive aggregation. For example: Internal Medicine, Dentistry, Pediatrics hold a large amount, while, the number of Gynecology, Colorectal surgery, Ophthalmology is less.

For some professional and medical equipment demanding subjects, the distribution turn to be high level intensive or moderate level intensive. For example: Psychosomatic Internal Medicine, Nephrology and Diabetes, Anesthesiology etc.

For special subjects or unconventional subject whose target is special population, they always show typical intensive distribution. For example: Aesthetic Plastic Surgery, Psychiatry etc.

2.4.3 Relationship of distribution feature between hospitals and clinics

We applied mutual-K function to each subject and got the result about the relationship between hospital and clinic.

We can find various types of spatial patterns in the relationship between

Table 2-2 Further subdivision of each subject

Subject	Number	Slope	CSR Slope	Slope difference	Correlation coefficient	Classification
Internal Medicine	895	2.23	2.08	7%	0.94	L
Cardiology	275	1.33	1.19	12%	0.98	M
Gastroenterology	381	1.60	1.41	14%	0.95	M
Respiratory Medicine	163	0.96	0.92	4%	0.94	L
Neurology	113	0.62	0.71	-13%	0.90	T
Psychosomatic Internal Medicine	129	0.66	0.75	-11%	0.87	T
Nephrology and Diabetes	24	0.43	0.35	22%	0.96	H
General Surgery	211	1.21	1.02	18%	0.94	M
Neurosurgery	65	0.54	0.55	-1%	0.97	Random
Cardiovascular surgery	30	0.33	0.37	-11%	0.95	Random
Urology	67	0.55	0.65	-14%	0.85	T
Orthopaedic Surgery	229	1.28	1.10	16%	0.98	M
Plastic and Reconstructive Surgery	95	0.49	0.69	-30%	0.86	T
Aesthetic Plastic Surgery	71	0.31	0.62	-50%	0.51	T
Gynecology	63	0.61	0.56	9%	0.96	L
Obstetrics and Gynecology	71	0.62	0.60	3%	0.94	L
Pediatric	884	2.36	2.08	14%	0.95	M
Ophthalmology	137	0.82	0.85	-3%	0.90	L
Otorhinolaryngology	91	0.78	0.71	10%	0.98	Random
Dermatology	209	0.90	1.03	-12%	0.87	T
Colorectal surgery	71	0.65	0.66	-1%	0.94	L
Psychiatry	179	0.85	0.95	-11%	0.87	T
Anesthesiology	98	0.88	0.73	21%	0.96	H
Roentgenology	76	0.61	0.59	5%	0.96	L
Rheumatology	120	0.99	0.84	18%	0.99	M
Allergy	139	1.02	0.85	21%	0.97	H
Rehabilitation	287	1.26	1.17	7%	0.95	Random
Dentistry	1046	2.36	2.21	7%	0.94	L

L: Low level intensive M: Moderate level intensive H: High level intensive T: Typically intensive

two point distributions. In the real world, the most important pattern is the similarity between two distributions. If two distributions show similar patterns, it suggests that they are related with each other, either directly or indirectly.

Considering the property of L(d) curve, the distribution can be summarized as two types (Figure 2-8.) From the distribution image of the Neurosurgery, we can see the number of hospital and the number of Clinic are relatively close, but

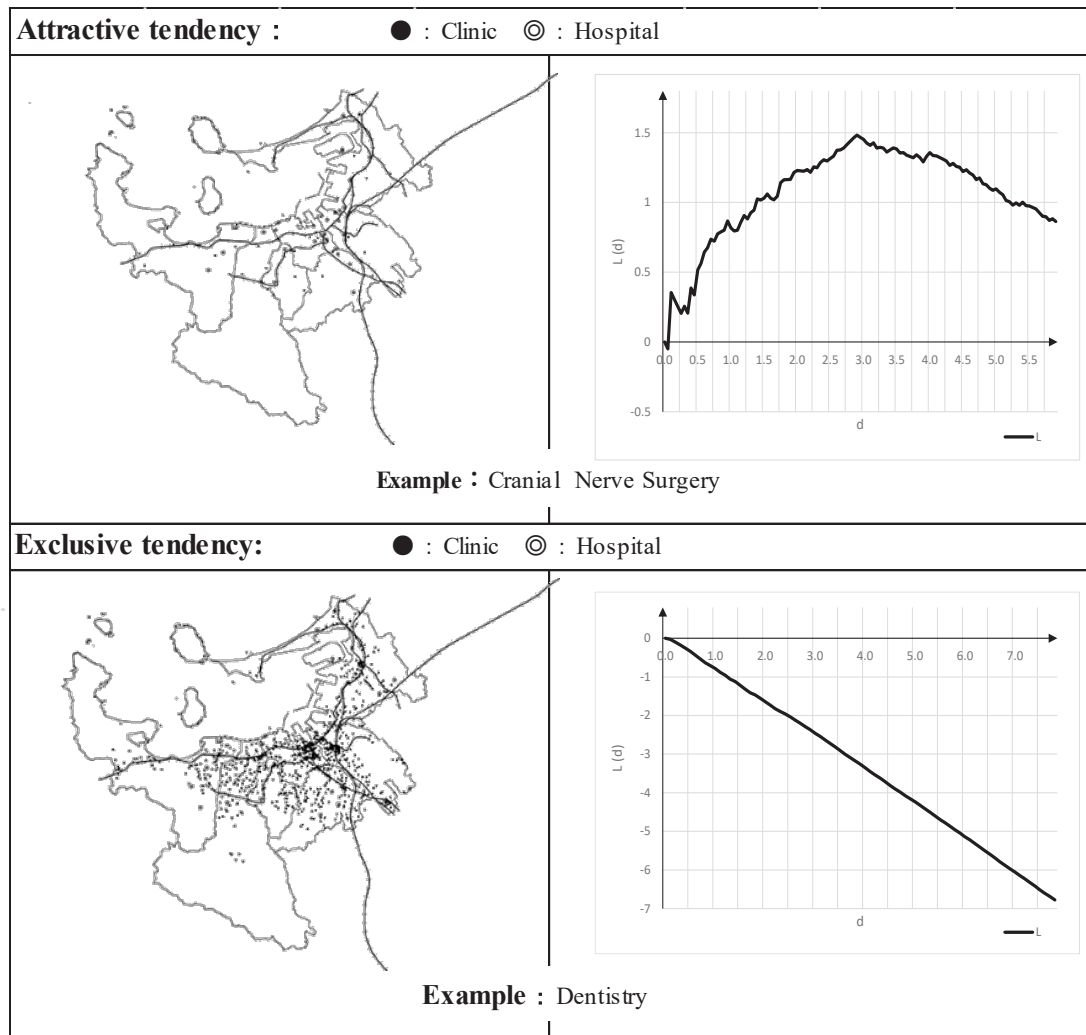


Figure 2-8 Analysis applying Mutual Ripley'K Function

significantly distribute to different area, the clinic distribution is more discrete, covering many areas not covered by hospitals. The corresponding L function, in the range of less than 0.2 km there is a particularly large fluctuation, that can be considered caused by too few samples. In the case of ignoring the fluctuation, the L function can be fitted to three straight lines. The range of 0-0.6 km, the slope value of the curve is large, rapid growth means hospital and clinic show obvious aggregation, which means attracting each other; the range of 0.6-2.8 km, the slope value is relatively small, the trend of attracting weakens. After 2.8km, the slope value is negative, the curve decreased slowly, illustrates that there is

a mutual exclusion effect between them, but the effect is not obvious, the whole trend overall still maintains the state of mutual attraction.

There is another example about Dentistry. From the distribution image of the dentistry, we can find that considering both the number and the coverage area, dental clinics is larger than hospitals. and clinics also gathered in the area avoiding the hospital. It can be seen from the image that there is an obvious repulsion between dental hospital and clinic. The L function also illustrates this point, the curve can be fitted to a line whose slope is negative, starting at the 0.1km from origin point. In the whole range, hospital and clinic show stable rejection.

Medical departments that require special technology and usually needs cooperation with big hospital, such as cardiovascular surgery and cranial nerve surgery. Medical departments that need treatment in the hospital, such as anesthesiology and Radiology.

2.5 Discussion and Conclusion

In this chapter, we made effort to do quantitative analysis about the existing distribution of medical facilities, explore the relationship between hospital and clinic, and find out how they influence each other from a location analysis perspective. The Fukuoka City, the capital city of Fukuoka Prefecture on the northern shore of the island of Kyushu in Japan, is chosen as a study area. Subjects in the study cover totally 151 medical departments in 115 hospitals and 1526 clinics. We attempt to analyze the types of basic discrete location focusing on each medical department.

We developed a Visual Basic for Applications programs based on the longitude and latitude, it measures the distance between each feature and its nearest neighbor, and then builds a cumulative frequency distribution function (G Function). According to the result of G function, 28 categories are divided into three groups, and by further analysis based on the aggregation degree

defined by the difference of slope, the distribution of each medical department can be described and classified in terms of the level of clustering and dispersion, five classifications are proposed.

Furthermore, it is considerably significant to discover the mutual relationship of each subject. We choose Multi-Distance Spatial Cluster Analysis (Ripley's K Function) and expand it to a Mutual-K Function to find out the relationship between hospital and clinic for each subject.

References

- [1] Landa-Torres, I., Manjarres, D., Salcedo-Sanz, S., Del Ser, J., & Gil-Lopez, S.: Amultiobjective grouping Harmony Search algorithmfor the optimal distribution of 24-hour medical emergency units, *Expert Systems with Applications*, Vol.40, No.6, pp.2343 – 2349, 2013
- [2] Aday, L. A., & Andersen, R.: A framework for the study of access to medical care, *Health Services Research*, Vol.9, No.3, pp.208, 1974
- [3] Langford, M., & Higgs, G.: Measuring potential access to primary healthcare services: The influence of alternative spatial representations of population, *The Professional Geographer*, Vol.58, No.3, pp.294 – 306, 2006
- [4] Murawski, L., & Church, R. L.: Improving accessibility to rural health services: The maximal covering network improvement problem, *Socio-Economic Planning Sciences*, Vol.43, No.2, pp.102 – 110, 2009
- [5] Gu,W.,Wang, X., &McGregor, S. E.: Optimization of preventive health care facility locations, *International Journal of Health Geographics*, Vol.9, No.1, 17, 2010
- [6] Ngui, A. N., & Apparicio, P.: Optimizing the two-step floating catchment area method for measuring spatial accessibility to medical clinics in Montreal, *BMC Health Services Research*, Vol.11, No.1, pp.166, 2011
- [7] Wang, F., McLafferty, S., Escamilla, V., & Luo, L.: Late-stage breast cancer diagnosis and health care access in Illinois, *The Professional Geographer*, Vol.60, No.1, pp.54 – 69, 2008
- [8] Bretthauer, K. M., & Cote, M. J.: A model for planning resource requirements in health care organizations, *Decision Sciences*, Vol.29, No.1, pp.243, 1998
- [9] Shariff, S. R., Moin, N. H., & Omar, M: Location allocation modeling for healthcare, 2012
- [10] ICHIKAWA Mihoko, et al: The Location Trend of Medical Facilities and Planning Control in Local Cities, *Journal of the City Planning Institute of Japan*, Vol.41, No.3, pp.803-808, 2006.10
- [11] ISHII Norimitsu: Current Situation and Problems of the Hospital Location in Depopulation Time, *Operations research as a management science research* Vol.57, No.3, pp.119-123, 2012.3
- [12] Fukuoka city homepage: Fukuoka Prefecture regional medical treatment plan. <http://www.pref.fukuoka.lg.jp/contents/hoken-iryo-keikaku.html>
- [13] KTGIS.NET: <http://ktgis.net/gcode/>
- [14] Ministry of Health Labor and Welfare: Medical facilities investigation. <http://www.mhlw.go.jp/toukei/list/79-1a.html>

- [15] Wilschut, L.I., Laudisoit, A., Hughes, N.K., Addink, E.A., de Jong, S.M., Heesterbeek, J.A.P., Reijniers, J., Eagle, S., Dubyanskiy, V.M., Begon, M.: Spatial distribution patterns of plague hosts: point pattern analysis of the burrows of great gerbils in Kazakhstan, *Journal of Biogeography*. Vol.42, No.7, pp.1281 – 1292, 2015
- [16] Bartlett, M.S.: The spectral analysis of twodimensional point processes, *Biometrika* Vol.51, pp.299 – 311, 1964
- [17] Cressie, N.A.C.: *Statistics for Spatial Data*, Wiley, New York, 1991
- [18] Moser, E.B.: The analysis of mapped spatial point patterns, in *Proceedings of the 12th Annual SAS Users Group International Conference*, Vol.12, pp. 1141 – 1145, 1987

Chapter 3

ANALYSIS ON SUPPLY-DEMAND RATIO UNDER EACH CATEGORY OF MEDICAL TREATMENT DEPARTMENT

Chapter 3

ANALYSIS ON SUPPLY-DEMAND RATIO UNDER EACH CATEGORY OF MEDICAL TREATMENT DEPARTMENT

3.1 Introduction

3.1.1 Research background

Public service facilities play a vital role in meeting the growing material and cultural needs of people and improving the quality of life in an all-round way. The rational allocation of public service facilities is an important goal for planning and layout. However, the contradiction between the growing demand for public services and the short supply of public services in urban areas is becoming more prominent. Intensification of metropolitan problems such as urban hollowing, the adequacy of public facilities services and the balanced proportion are getting more attention.

Medical facilities are an important part for ensuring the normal and orderly operation of urban functions...However, there is a shortage of medical facilities, and the irrational distribution of medical resources caused by the irrationality of the layout of medical institutions are affecting the quality of medical services provision. This is supported by the statistics from Japan's Ministry of Health, Labor and Welfare^[1], that indicate the number of general hospitals have declined year by year, in contrast, the number of new clinics has increased. The distribution of medical facilities influences the entire health care system that is expected to maximize the coverage of the service and minimize the travel needs of the patient, the role of clinics, as a support for the entire health care system is highly valued. With this criterion it is worthy to investigate whether the rational allocation of clinics can share the treatment pressure of general hospitals to a certain extent.

3.1.2 Literature review

The medical facility is an important part of public service that impacts people's lives and safety. Residential distance from the public medical facilities and the degree of service level of medical institutions directly relates to the level of medical treatment opportunities for patients. There is a considerable literature on the measurement and modeling of medical facilities service provision. Researchers have reviewed different parts of the literature of medical facilities location from various perspectives^{[2]-[10]}. This literature can be summarized under two broad headings: the covering-based problems and median-based problem. Covering-based problems assume that demand locations need to be within a specific coverage distance (or time) from facilities, which serve them, in order to be covered by the service, or satisfactorily served. Median-based problems locate facilities at candidate points so as to minimize the weighted average distance costs between demand points and the facilities to which they are assigned. The earliest location-allocation study in the field of medical facilities (HCFs) was presented by Gould and Lienbach. In this study, the problem of locating hospitals and determining their capacities was considered as a p-median problem in the western part of Guatemala.

The research of public service facilities has attracted much attention and many scholars have introduced methods and mathematical models into the layout and planning of public service facilities. Among them, two-step floating catchment area (2SFCA) is an analysis method designed to investigate facility accessibility through the analysis of supply and demand ratio facility^{[11][12][13]}^[14]. In the aforementioned studies, medical facilities are usually examined as a whole and do not take into account the diversity of medical facilities, the complexity, the differences between the various subjects, nor do they provide a more detailed, reasonable, specific Supply and demand analysis. In this paper, medical departments are divided into nine categories, each of them is considered as a unit for analysis and comparison.

3.1.3 Research purpose

In this chapter, Two-step floating catchment area (2SFCA) with the distance-

decay function is applied to examine the relative proportion of the service supply range and the population demand of each medical department, and give a "relative ratio of supply and demand " index. On the basis of grasping the relationship between supply and demand of existing medical resources, this paper constructs the evaluation system of supply and demand pressure to provide the reference value for the establishment and location of future clinics.

3.2 Research Object and Data Source

3.2.1 Study area

Fukuoka City is the capital city of Fukuoka Prefecture on the northern shore of the island of Kyushu in Japan, and chosen as the study area. Fukuoka has a population of more than 1.5 million and is the most populated city and political, economic and transportation center in Kyushu. It is also the most populous city, west of Osaka. The Fukuoka metropolitan area comprise a large number of government agencies and enterprise branches, and is Japan's fifth largest urban metropolitan area. Fukuoka has seven wards (ku): Higashi-ku, Hakata-ku, Chuo-ku, Minami-ku, Jonan-ku, and Sawara-ku, Nishi-ku. In this paper, since the facilities located in Shika island, Nokono island, Genkai island are not included as research subjects because of special location. The distribution of medical facilities and population in these seven wards of Fukuoka city is shown in Table3-1. Medical departments in the study cover totally 151 medical departments in 115 hospitals, 1526 clinics and 1013 dental clinics, carried out by the Fukuoka City government at August 2016^[15].

Medical facilities in this research refers to general hospitals and clinics, and dental clinics are included. Specifically, hospitals in this research refer to the medical institutions providing patient treatment with specialized medical and nursing staff and medical equipment, and holding the number of sickbeds more than 20. Clinics are medical facilities that are primarily focused on the care of outpatients with no sickbed or the number of sickbed is less than 19. Dental clinics are clinics provides oral health services with a team of dentists.

In this research, we selected 151 clinical departments from all the medical

Table 3-1 The distribution of medical facilities in seven wards of Fukuoka city

District	Hospital	Clinic	Population
Higashi-ku	22	207	302,300
Hakata-ku	17	265	212,899
Chuo-ku	17	370	186,391
Minami-ku	17	221	253,618
Jonan-ku	9	105	129,310
Sawara-ku	13	201	216,452
Nishi-ku	20	157	205,616

facilities in Fukuoka. According to the Ministry of Health, labor and welfare, all the 151 clinical departments can be classified into nine categories: Internal Medicine, General Surgery, Pediatrics, Obstetrics and Gynecology, Psychiatry, Ophthalmology, Dentistry, Otorhinolaryngology, and Dermatology. In terms of these categories, medical facilities are picked up respectively. (Table3-2). Internal Medicine includes different departments such as Respiratory Medicine, and Cardiology. General Surgery covers different types of surgeries such Orthopedic surgery and Colorectal surgery. Here, we have compiled the facility information for each clinical subject, and then we will examine it as a unit. Since most facilities have more than one subject, the sum of hospitals and clinics does not match the total number mentioned before.

Table 3-2 Categories of medical departments

	Hospital	Clinic
Internal Medicine	105 (10%)	939 (90%)
General Surgery	64 (13%)	432 (87%)
Obstetrics and Gynecology	19 (19%)	83 (81%)
Pediatric	20 (2%)	864 (98%)
Ophthalmology	26 (19%)	111 (81%)
Otorhinolaryngology	18 (20%)	73 (80%)
Dermatology	28 (13%)	181 (87%)
Psychiatry	39 (22%)	140 (78%)
Dentistry	20 (2%)	1026 (98%)

3.2.2 Data source

The initial data chosen for modeling were drawn from a number of sources. The key data of medical facilities includes the name, location, the number of sickbed. The type of sickbed (only for the hospital) is gathered from the List of Medical facilities posted on the homepage of Fukuoka city. Additional data including latitude and longitude of medical facilities are obtained by using Google Map. We acquired a third set of data that included neighborhood-based demographics specific to the gender distinction and age class population^[16]. We, considered the differences in the frequency and needs of people for different ages, and assigned weights to the population. We used the statistics of treatment rate conducted by Japan's Ministry of Health, Labor and Welfare^[17]. The data provided the overall treatment rate in Japan in 2016 and the treatment rate of people of different ages. (the number of patients per 100,000 people)

3.3 Methodology

3.3.1 2SFCA Method

The proportional relationship between the supply side (medical facilities in this paper) and the demand side (population in this paper) was analyzed using the two-step floating catchment (2SFCA) method. 2SFCA is an important method of research on spatial accessibility to public services, and has been widely applied in studies on the spatial layout of public service facilities^[18]. The method computes the ratio of suppliers to residents within a service area centered at a supplier's location and sums up the ratios for residents living in areas where different providers' services overlap. (Figure3-1) The procedure is as follows:

Step 1. For each medical facility location j , search all population locations (k)^{*1)} within a threshold distance d_0 from location j (catchment area j), and compute the facility-to-population ratio R_j , within the catchment area:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_0\}} P_k} \quad (3-1)$$

where P_k is the population of tract k whose centroid falls within the catchment (that is, $d_{kj} \leq d_0$), S_j is the number of medical facilities at location j , and d_{kj} is the travel time between k and j .

Step 2. For each population location i , search all medical facility locations (j) within the threshold travel time d_0 from location i (catchment area i), and sum up the facility -to-population ratios, R_j , at these locations:

$$A_i^F = \sum_{j \in \{d_{ij} \leq d_0\}} R_j = \sum_{j \in \{d_{ij} \leq d_0\}} \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_0\}} P_k} \quad (3-2)$$

where A_i^F represents the accessibility at resident location i based on the two-step FCA method, R_j is the facility-to-population ratio at physician location j whose centroid falls within the catchment centered at i (that is, $d_{ij} \leq d_0$), and d_{ij} is the distance between i and j . A larger value of A_i^F indicates a better accessibility at a location.

The first step corresponds to the assigning of an initial ratio to each service area centered at physician locations, and the second step corresponds to summing up the initial ratios in the overlapped service areas (where residents

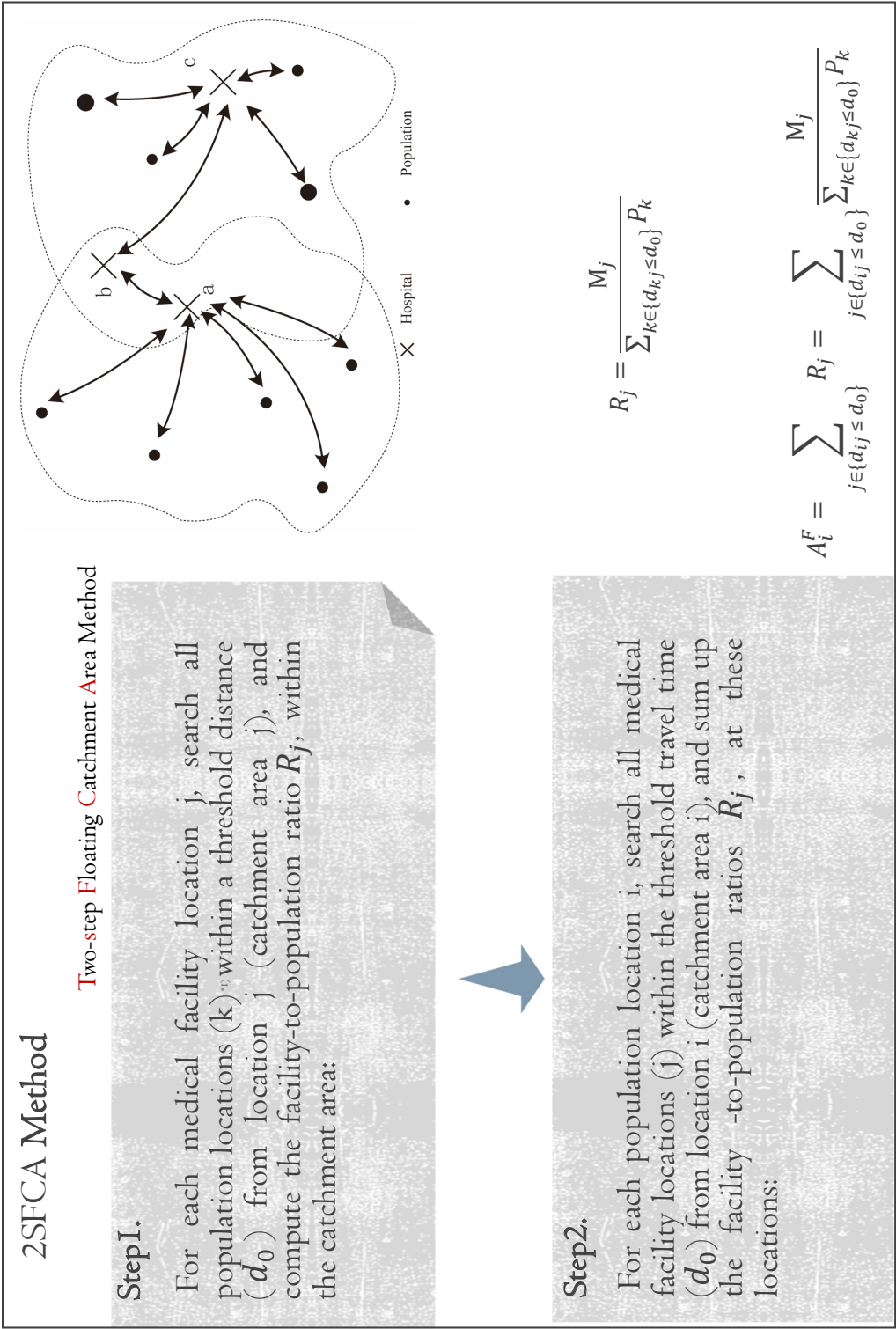


Figure 3-1 Concept of 2SFCA Method

have access to multiple physician locations). In implementation, a matrix of travel times between any pair of facility location and population location (d_{ij} or d_{kj}) is computed once and accessed twice.

During the procedure, we meet two challenges:

1) Weight of the population data

As previously mentioned, according to the statistics that shows the rate of treatment on the gender distinction and age class, we assign a weight to the population.

For each age class, we use the number of patients per 100,000 in statistics as a basis for weighted integration of population. The ratio of the local treatment rate and the average treatment rate is defined as the weighting coefficient to give a weight to the population of the age class and reintegrate the total population of each district. (Table3-3) For the seven medical departments, except Pediatrics, Obstetrics and Gynecology, the age of different populations on the medical facilities of different needs, according to the age of each treatment rate and the ratio of the overall rate of treatment to determine the age weighting coefficient. In this way, the number of people with a low treatment rate has been reduced, while the number of people with a high treatment rate has been expanded.

2) Determining threshold distance

To determine the threshold distance, we first calculate the distance matrix of each population point to every facility point, and then calculate the minimum value of each row. Finally, these maximum and minimum values were used as the threshold distance. This ensures that the target will not be empty within the catchment area.

3.3.2 Distance-decay function

In the model, a facility nearby is considered more influential than a remote one, and thus weighted higher. The most common distance attenuation functions can be classified as Figure3-2.

A simple gravity model to illustrate the concept is proposed the following

Table 3-3 Weight of the population data

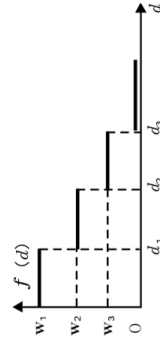
Age	Patients per 100,000 people	Treatment Rate	Weight Coefficient
0~4	7,109	0.07109	1.06
5~9	4,514	0.04514	0.67
10~14	2,741	0.02741	0.41
15~19	2,054	0.02054	0.31
20~24	2,405	0.02405	0.36
25~29	2,957	0.02957	0.44
30~34	3,382	0.03382	0.50
35~39	3,584	0.03584	0.53
40~44	3,712	0.03712	0.55
45~49	4,254	0.04254	0.63
50~54	5,255	0.05255	0.78
55~59	6,133	0.06133	0.91
60~64	7,578	0.07578	1.13
65~69	9,659	0.09659	1.43
70~74	12,598	0.12598	1.87
75~79	15,032	0.15032	2.23
80~84	16,485	0.16485	2.45
85~89	16,951	0.16951	2.52
90~	17,486	0.17486	2.60
Overall	6,734	0.06734	1.00

Refine 2SFCA Method ①

Distance decay function

Enhanced 2SFCA

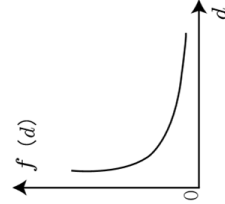
$$f(d_{ij}) = \begin{cases} W_1, & d_{ij} \in D_1 \\ \dots, \dots & \\ W_r, & d_{ij} \in D_r \end{cases}$$



Luo W, Qi Y. 2009. An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians[J]. Health & Place, 15(4): 1100-1107.

Gravity 2SFCA

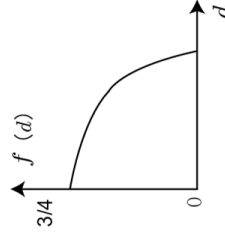
$$f(d_{ij}) = d_{ij}^{-\beta}, \quad d_{ij} \leq d_0$$



[Tao Z L, Cheng Y, Dai T Q. 2014. Measuring spatial accessibility to residential care facilities in Beijing[J]. Progress in Geography, 33(5): 616-624.]

Kernel Density 2SFCA

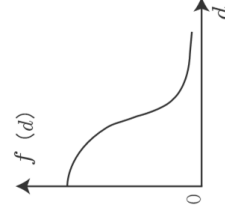
$$f(d_{ij}) = \frac{3}{4} \left[1 - \left(\frac{d_{ij}}{d_0} \right)^2 \right], \quad d_{ij} \leq d_0$$



Dai D J. 2011. Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene[J]. Landscape and Urban Planning, 102(4): 234-244.

Gaussian 2SFCA

$$f(d_{ij}) = \frac{e^{-1/2 \times (d_{ij}/d_0)^2} - e^{-1/2}}{1 - e^{-1/2}}, \quad d_{ij} \leq d_0$$



[Wei Y, Xin C L, Gao R, et al. 2014. Evaluation of green space accessibility of Shenyang using Gaussian based 2-step floating catchment area method[J]. Progress in Geography, 33(4): 479-487.]

Figure 3-2 Distance decay function

model for accessibility (A_i^H) at location i :

$$A_i^H = \sum_{j=1}^n S_j d_{ij}^{-\beta} \quad (3-3)$$

where S_j is the number of facilities at location j , d_{ij} is the travel time between population location i and facilities location j , β is the travel-friction coefficient and n is the total number of facility locations.

The gravity-based accessibility measure at location i can be written as:

$$A_i^G = \sum_{j=1}^n \frac{S_j d_{ij}^{-\beta}}{V_j} \quad (3-4)$$

where S_j is the number of facilities at location j , d_{ij} is the travel time between population location i and facilities location j , β is the travel-friction coefficient and n is the total number of facility locations.

Where

$$V_j = \sum_{i=1}^n P_i d_{ij}^{-\beta} \quad (3-5)$$

For resistance coefficient β , it is possible to choose a different value for a different application, which extends the scope of application of the model, and also improve the accuracy of the measurement, but on the other hand, how to choose the value of β has become a problem. Researchers tend to think that β can have different mathematical expressions (such as linear, exponential and other forms), and it is dependent on the type of service and crowd characteristics. Comprehensive research has been done, and scholars generally use linear expression of β .

Regarding the value of β , Peeters^[19] summed up the Love, Berens, Brimberg and other scholars' point of view, and found that the values are mainly in [0.9, 2.29]. These authors consider that the value of β in [1.5, 2] made less impact on results. Tao Haiyan^[20] used a potential model on a research of public health services accessibility spatial distribution of Zhuhai, Guangzhou and applied β value of 1. Wang Yuanfei^[21] and others used Huff model to study the service area of General Hospital in Shanghai Pudong and applied two cases $\beta = 1$, $\beta = 2$, respectively. By comparing the research, we consider the results are more reasonable when $\beta = 2$. In view of the above, the actual operation of β is usually

a linear expression, the value of more concentrated in the [1, 2].

A_i^G is the gravity-based index of accessibility, where n and m are the total numbers of facility and population locations, respectively. It may be considered as the ratio of supply to demand, both of which are weighted by the negative power of travel times.

3.3.3 Analysis procedure

In this study, we use Geographic Information System (GIS) to analyses supply-demand pressure. The process is shown in the (Fig3-3). Here, we take Internal Medicine as an example to show the procedure.

First, we used 'feature to point' tool in GIS neighborhood-based map to generate the population centroid position. We identified 1138 people population centroid points, the ID, address and latitude and longitude coordinates as shown in (Fig3-3a)., We picked up 1054 medical facilities that has the department of Internal Medicine (Fig3-3b). According to the population centroid and the latitude and longitude coordinates of the medical facilities, the distance matrix of each population centroid position to every medical facility was calculated by the 'point distance' tool (Fig3-3c). Second, the threshold distance was determined by the maximum value of the minimum value of each row. For hospitals and clinics, we took a different graded radius (9312km, 6688km). We weighted the population according to the treatment rate. Third, we calculated the supply and demand ratio of each population point based on the two-step floating catchment area method theory (Fig3-3d), Finally, we joined the index attribute table to the population point attribute table based on the Object ID field, the visualization on the map through the depth of the color was achieved.

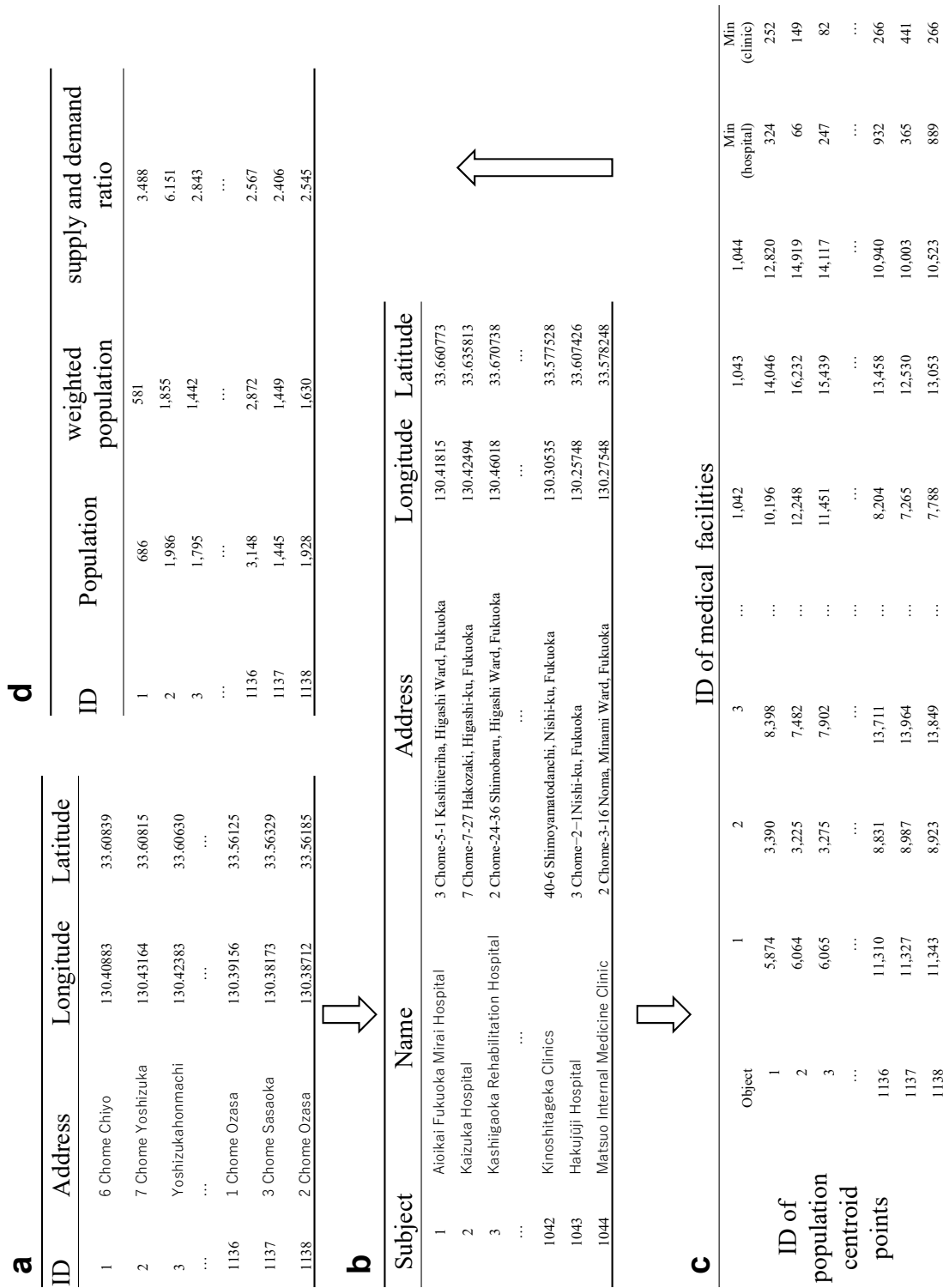


Figure 3-3 Procedure of 2SFCA method in GIS

3.4 Distribution Analysis of Medical Treatment Subjects using 2SFCA Method

3.4.1 The results of supply and demand ratio

The results of supply and demand ratio for each category can be summarized as Figure3-4.

The distributions of supply and demand ratio of Otorhinolaryngology, Dermatology and General Surgery are similar and the simplest, and the area with high supply and demand ratio is concentrated in Chuo-ku and decrease in the peripheral areas. In a small area of Nishi-ku, the supply and demand ratio of General Surgery is high, however it is more balanced in other areas.

The distributions of supply and demand ratio of Obstetrics, Gynecology, and Ophthalmology are similar, and residents in Chuo-ku receive more medical services for Ophthalmology, Gynecology, and Ophthalmology, decreasing to the periphery. In parts of Chuo-ku and Hakata-ku, supply and demand ratio is significantly higher than other regions. The Sawara-ku is the largest among the seven wards in Fukuoka city. The supply and demand ratio was high in the areas close to Chuo-ku, while it is low in the remote areas and distribution of medical facilities is extremely uneven. In Higashi-ku, Nishi-ku, Minami-ku and Jonan-ku, although there are some areas of high supply and demand ratio (red highlights), but the overall relatively balanced.

Internal Medicine and Psychiatry are similar. The difference from the above two is: the areas with high supply and demand ratio are not only around Chuo-ku, but also some areas in Nishi-ku and Jonan-ku away from Chuo-ku.

For Dentistry and pediatrics, the distribution shows that supply and demand ratio is almost balanced in the Higash-ku and it's relatively high in 2-3 areas in Nishi-ku.

In general, the distribution of supply and demand ratio of each department is basically ratio is concentrated in Chuo-ku and decreasing to the periphery. In Higashi-ku, Nishi-ku and Sawara-ku away from Chuo-ku, the supply and demand ratio is generally low.

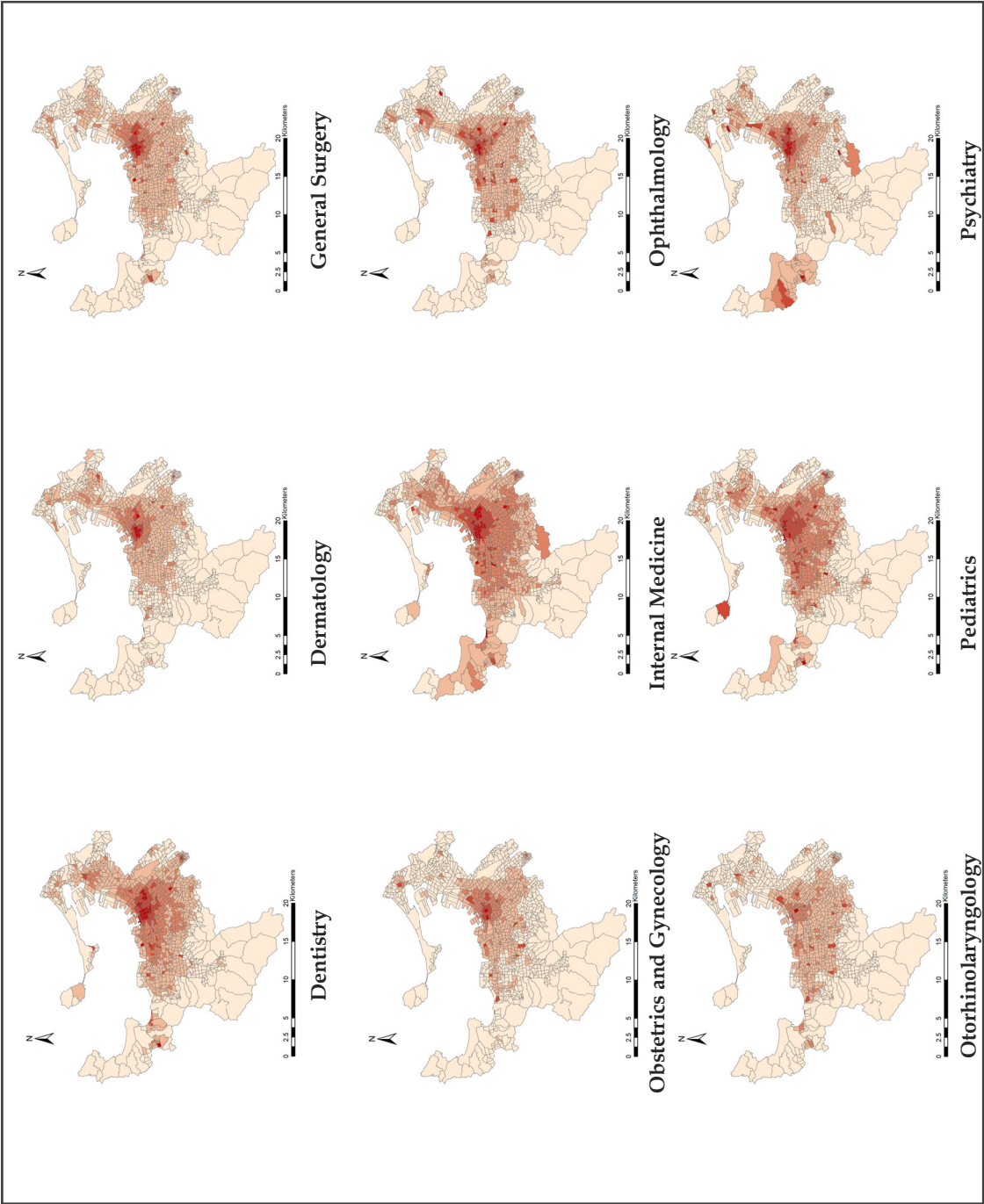


Figure 3-4 The visualization of the supply and demand ratio of each category

3.4.2 Distribution of supply and demand ratio

Fig.3-5 shows the distribution of population in Fukuoka city. The population of Sawara-ku and Nishi-ku is too small. And there are a small number of densely populated areas in Nishi-ku. Besides, in other areas, the population distribution is relatively balanced.

Then we compared the distribution of supply and demand ratio between all seven areas of Fukuoka, on each medical department. The result of the Internal Medicine analysis is shown in the Fig3-6-a.

From the boxplot, it can be intuitively seen that the medical resources of Chuo-ku is significantly higher than other areas, and the distribution is not balanced. The overall supply and demand ratio in the Hakata-ku is slightly higher than others, with a few areas significantly higher. And there are still more than half of the population points that shows no significant difference between other 5 areas, the distribution is very unbalanced. The distribution in the Higashi-ku, Nishi-ku, Minami-ku and Jonan-ku is relatively balanced, with the Minami-ku and Jonan-ku slightly higher, the Higashi-ku and Nishi-ku are slightly lower. The distribution of the Sawara-ku is unbalanced and most of districts are low.

To compare the supply-demand pressure of each medical department among the districts, we introduce the average supply and demand ratio as the judgment standard. And compare the average value of each districts with that of whole Fukuoka. As can be seen from the Fig3-6, the result of Internal Medicine also applies to other departments.

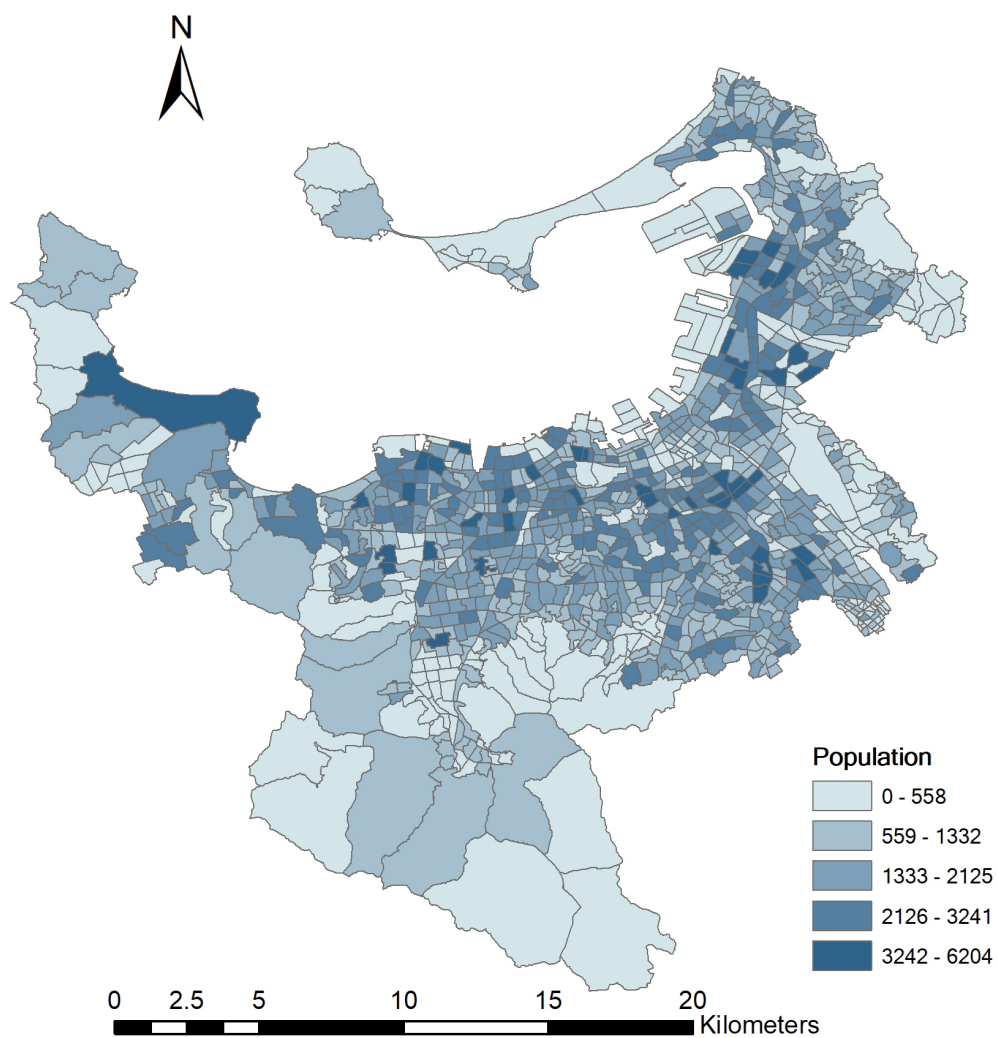


Figure 3-5 Distribution of population of Fukuoka city

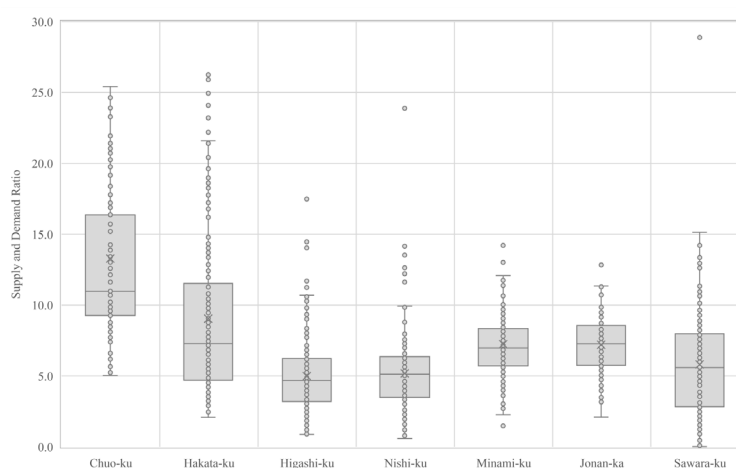


Figure 3-6-a The supply-demand ratio of Dentistry in seven wards

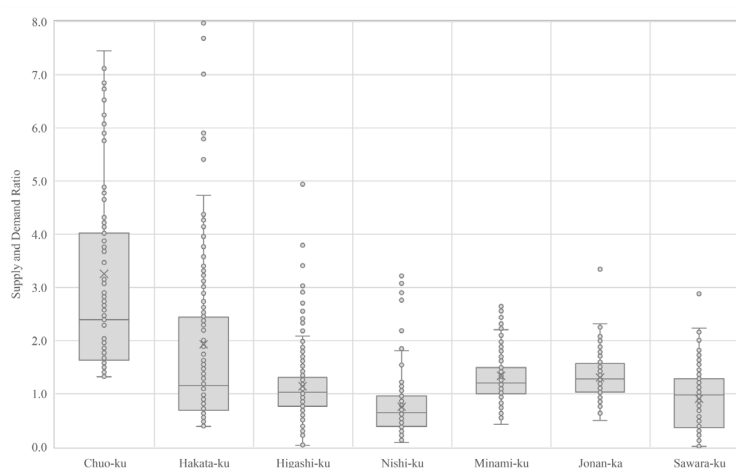


Figure 3-6-b The supply-demand ratio of Dermatology in seven wards

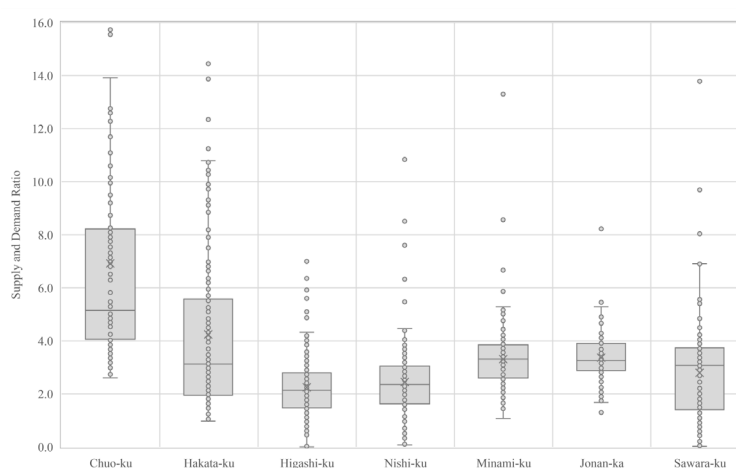


Figure 3-6-c The supply-demand ratio of General Surgery in seven wards

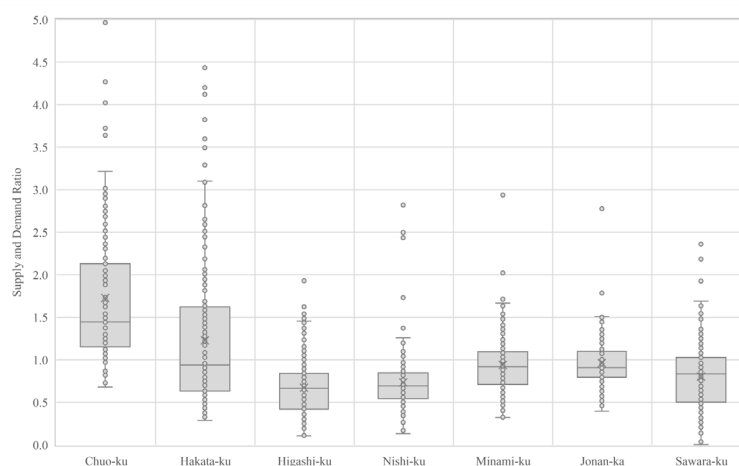


Figure 3-6-d The supply-demand ratio of Internal Medicine in seven wards

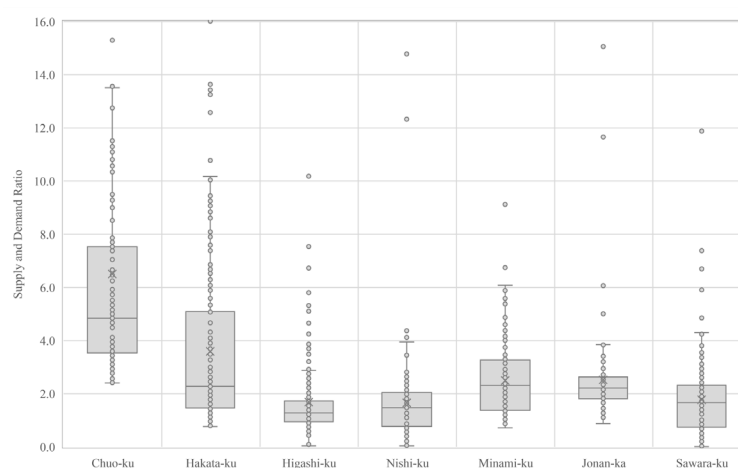


Figure 3-6-e The supply-demand ratio of Obstetrics And Gynecology in seven wards

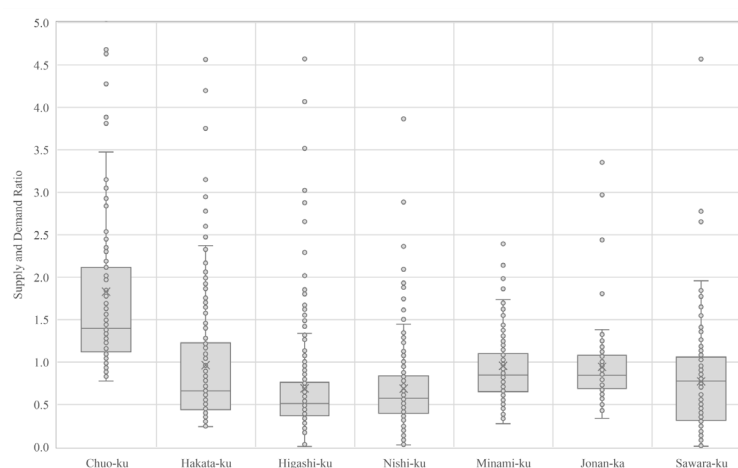


Figure 3-6-f The supply-demand ratio of Ophthalmology in seven wards

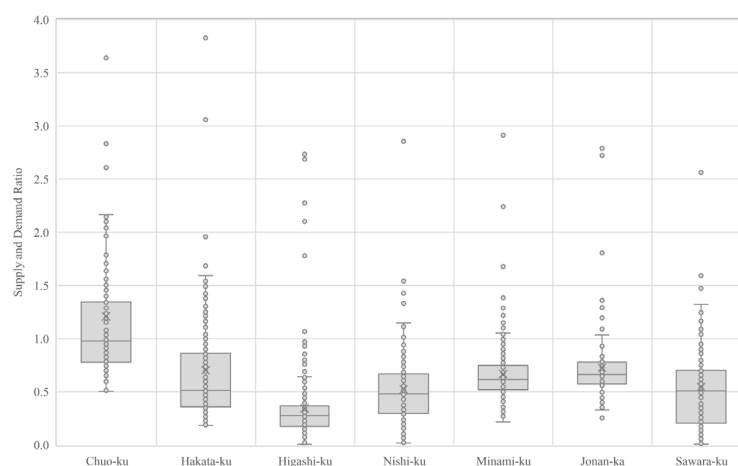


Figure 3-6-g The supply-demand ratio of Otorhinolaryngology in seven wards

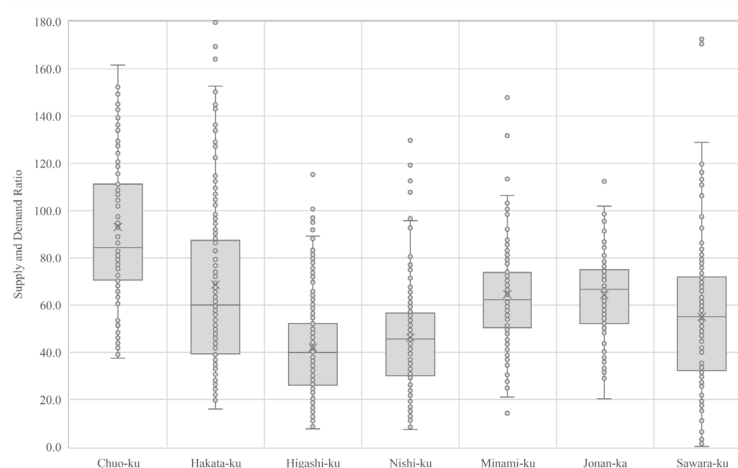


Figure 3-6-h The supply-demand ratio of Pediatrics in seven wards

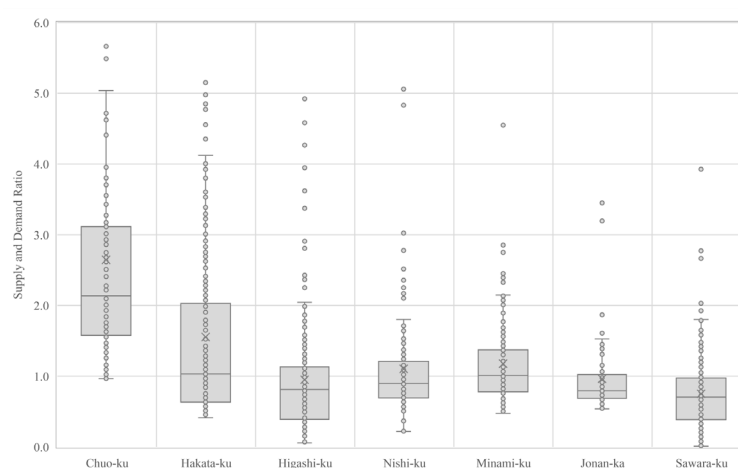


Figure 3-6-i The supply-demand ratio of Psychiatry in seven wards

3.5 Discussion and Conclusion

In this study, the distribution of medical services against population distribution was estimated by supply and demand ratio defined by 2SFCA method. The areas with and without the adequate number of medical services were determined by GIS.

We established, the residents in Chuo-ku and part of Hakata-ku are available to receive more medical services on all department than others. The supply and demand ratio of half of them is more 50% than the average value of whole city; In Higashi-ku, Hakata-ku and most of the Sawara-ku, supply and demand ratio is lower than the city's average level; It's not balanced in Chuo-ku, Hakata-ku and Sawara-ku, and Hakata-ku is the most disparate.

As there is no data on the maximum number of service people, it's only available to calculate the relative supply and demand ratio used to compare the various areas of access to medical services, but not to make a quantitative analysis on the specific medical department. The research on how to measure the maximum number of service people of hospitals or clinics, will be much helpful for analyzing supply-demand on medical services.

References

- [1] Ministry of Health Labor and Welfare: Medical facilities investigation. <http://www.mhlw.go.jp/toukei/list/79-1a.html>
- [2] Ahmadi-Javid A., Seyedi, P. and Syam, S. S.: A survey of healthcare facility location. *Computers & Operations Research*, Vol.79, pp.223-263, 2017
- [3] Brotcorne L. Laporte G. and Semet F.: Ambulance location and relocation models. *Eur J Oper Res*, Vol.147, No.3, pp.451 – 63, 2003
- [4] Li X. Zhao Z. Zhu X. and Wyatt T.: Covering models and optimization techniques for emergency response facility location and planning: a review. *Math Methods Oper Res*, Vol.74, No.3, pp.281 – 310, 2011
- [5] Rais A. and Viana A.: Operations research in healthcare: a survey. *Int Trans Oper Res*, Vol.18, No.1, pp.1 – 31, 2011
- [6] Wang F.: Measurement, optimization, and impact of health care accessibility: a methodological review. *Ann Assoc Am Geogr*, Vol.102, No.5, pp.1104 – 12, 2012
- [7] Guti é rrez EV. And Vidal CJ.: Home health care logistics management problems: a critical review of models and methods. *Rev Fac Ing*, Vol.68, pp.160 – 75, 2013
- [8] Ingolfsson A.: EMS planning and management. In: Zaric GS, editor. *Operations Research and Health Care Policy*. New York: Springer, pp.105 – 28, 2013
- [9] G ü neş ED and Nickel S.: Location problems in healthcare. In: Laporte G, Nickel S, Saldanha da Gama F, editors. *Location science Cham*. Springer, pp.55-79, 2015
- [10] Gould PR. and Leinbach TR.: Approach to the geographic assignment of hospital services. *Tijdschr voor Econ En Soc Geogr*, Vol.57, No.5, pp.203 – 6, 1966
- [11] Luo J.: Integrating the Huff model and floating catchment area methods to analyze spatial access to healthcare services[J]. *Transactions in GIS*, Vol.18, No.3, pp.436-448, 2014
- [12] Luo W. and Qi Y.: An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians[J]. *Health & Place*, Vol.15, No.4, pp.1100-1107, 2009
- [13] Luo W. and Wang F H.: Measures of spatial accessibility to health care in a GIS environment, Synthesis and a case study in the Chicago region[J]. *Environment and Planning B: Planning and Design*, Vol.30, No.6, pp.865-884, 2003
- [14] Luo W, Whippo T: Variable catchment sizes for the two-step floating catchment area (2SFCA) method[J]. *Health & Place*, Vol.18, No.4, pp.789-795, 2012

- [15] Fukuoka city homepage: Fukuoka Prefecture regional medical treatment plan. <http://www.pref.fukuoka.lg.jp/contents/hoken-iryo-keikaku.html>
- [16] National Land Numerical Information download service: <http://nlftp.mlit.go.jp/ksj-e/index.html>
- [17] Summary of survey of patients in Heisei 26 years: <http://www.mhlw.go.jp/toukei/saikin/hw/kanja/14/dl/kanja.pdf>, 2014
- [18] Tao Z.: Research progress of the two-step floating catchment area method and extensions[J]. Progress In Geography, Vol.35, No.5, pp.589- 599, 2016
- [19] Peeters D. and Thomas I.: Distance predicting functions and applied location-allocation models[J]. Journal of Geographical Systems, Vol.2, pp.167-184, 2000
- [20] Tao, H. Y., Chen, X. X. and Li, X.: Research on spatial accessibility to health service: a case study in the Haizhu district of Guangzhou. Geomatics & Spatial Information Technology, 2007
- [21] Wang, Y. F. and Zhang, C.: GIS and gravity polygon based service area analysis of public facility: case study of hospitals in Pudong new area. Economic Geography, Vol.25, No.6, pp.800-803, 2005

Chapter 4

PATIENT NUMBER ANALYSIS BY USING THE IMPROVED 2SFCA METHOD

Chapter 4

PATIENT NUMBER ANALYSIS BY USING THE IMPROVED 2SFCA METHOD

4.1 Introduction

4.1.1 Research background

Understanding the relationship between the supply and demand of service facilities which can be applied to the estimation of the service circle is a critical issue in urban analysis. Although a number of comprehensive reviews have examined the catchment area of commercial facilities' sphere of influence, few have assessed the impact on medical services. Japan has become one of the countries with the longest lifespans, with more than 30 million people aged 65 and above. This number is estimated to reach 39 million in 2042, whereas the population ratio of people aged 75 years or above is expected to increase^[1]. Medical institutions, such as hospitals and clinics, are necessary for our daily lives and play a key role in ensuring peace of mind. Understanding the importance of medical facilities as social infrastructure and daily life service has been integral to Japan's new medical systems, such as the Community-Based Integrated Care System. However, a recent reduction in the number of hospitals and uneven distribution of regional service and medical treatment departments has led to a number of areas having adequate medical services but cannot be enjoyed^[2]. In addition, the possibility of a medical institution becoming a function-induction facility has attracted widespread attention. This has obviously been reflected in the urban planning policy development formulated by the Japanese government in recent years. The Law on Improvement and Vitalization in City Center (enacted in 1998) aimed to promote the integration of multiple urban functions, such as education facilities, culture facilities, medical facilities, and social welfare facilities. Healthcare collaborations centering on clinics have been established, such as Local Medical Cooperation System, which promotes medical function sharing and specialization according to the local

medical institution's own facilities function, scale, characteristics, and local healthcare needs. Smooth collaborations between medical institutions and clinics, clinics and hospitals, medical institutions and hospitals, hospitals and hospitals, and other medical institutions are expected. This system makes it possible for medical patients to receive continuous and appropriate medical care in each area by utilizing the functions of each medical institution effectively and promptly. Furthermore, since the late 1990s, the Ministry of Health and Welfare took measures to promote the functional differentiation of one institution from another. Future medical plans aim to improve the efficiency of the medical delivery system through the functional conversion and reorganization of medical institutions

4.1.2 Literature review

A medical facility is an important public service that impacts on people's daily lives, health, and safety. There is extensive literature on the measurement and modeling of the location of medical services which has focused on two broad categories: coverage-based problems and median-based problems^{[3]-[11]}. Coverage-based problems assume that demand locations need to be within a specific coverage distance (or time) from the facilities which serve them in order to be covered by the service or be served satisfactorily. Meanwhile, Median-based problems locate a facility at a candidate point to minimize the weighted average distance costs between demand points and the assigned facilities. The residential distance between public medical facilities and the services offered by medical institutions directly relates to potential patients' access to medical treatment. On the other hand, the relationship between the supply and demand of medical resources has attracted much attention. Both government and citizens wish to optimize the availability of medical resources through the equitable allocation of medical facilities. A number of researchers have studied the supply and demand status of public service facilities; for example, the two-step floating catchment area (2SFCA) method was first proposed by Radke et al. (2000)^[12] and further improved by Luo et al. (2003)^{[13]-[17]}. In addition, Ukai et al.^[19] proposed a new index representing the supply-demand gap, then discussed the features of the proposed index with numerical examples and explained the

calculation procedure. Meanwhile, Masuyama^[21] analyzed spatial accessibility to home care services in Hirosaki-shi and discussed the implication of the analysis. These previous research studies focused on hospitals rather than clinics or facility treatment specialties. Furthermore, the function sharing effect of clinics as relatively small medical facilities is rarely discussed. On the other hand, hospital coverage is regarded as a circle with a specified radius in general. While this model is applicable to a customer-based facility, such as a railway station, it might not be appropriate for hospitals. When determining hospital coverage, other factors, such as facility treatment specialties, age composition of the neighboring population, morbidity, and distances between potential patients and the facility, must be considered.

4.1.3 Research purpose

In this study, we developed a model that estimates the number of patients for each diagnostic group and considers the location and attributes of each hospital. We then conducted a case study of 52 general hospitals located in Fukuoka City. We were able to grasp the supply and demand balance for each region. In other words, the future relocation of medical facilities should consider the arrangement of general hospitals and specialized hospitals, including the location of the hospital and the distance between the hospitals, as well as the supply and demand balance for each diagnostic group. In addition, the relocation of future medical facilities should examine the arrangement of general hospitals and special hospitals, including the location of each hospital and the distance between hospitals, in addition to the supply and demand balance for each diagnostic group. Moreover, the 2SFCA model developed in this study will be a useful tool for developing hospital facilities in the future, in accordance with the reorganization of cities due to changes in future population distribution and traffic planning.

This chapter therefore aimed to address three points as present in Figure4-1.

- 1) It is desirable to utilize the limited medical resources effectively and distribute medical services appropriately, but the existing circumstances of each medical treatment subject is still not clear. Since the segmented information is

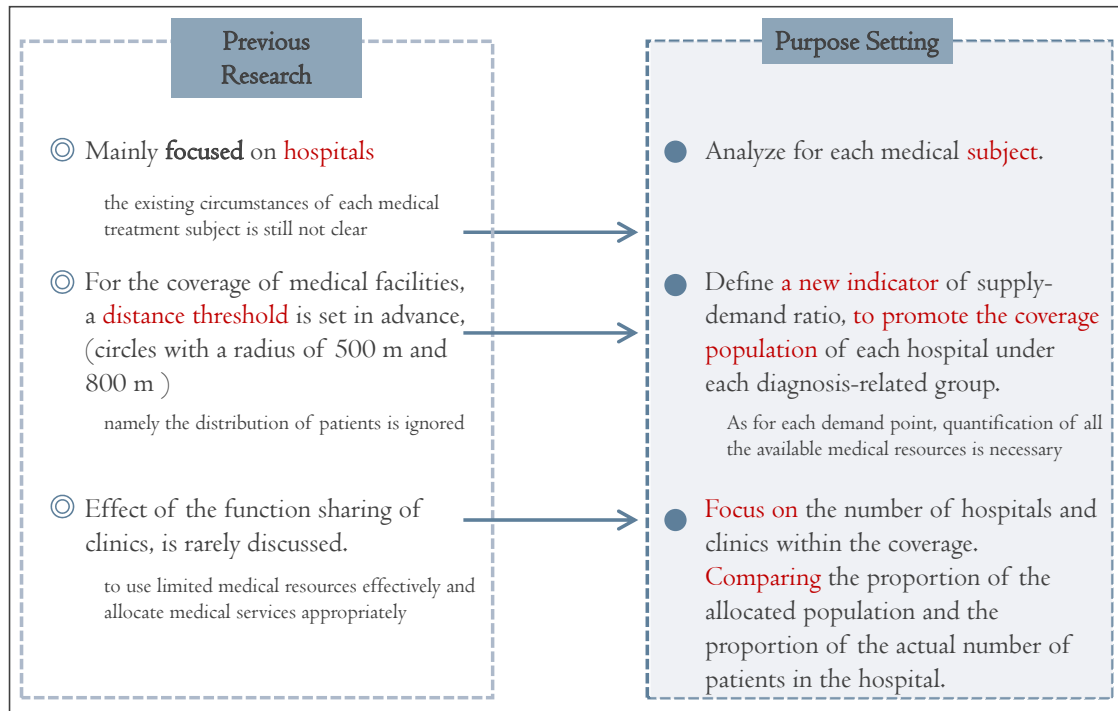


Figure 4-1 Purpose Setting of Chapter4

more important than the hospital as a whole, in this study, medical treatment subjects were analyzed to understand the supply and demand of each diagnosis-related group.

2) As for each demand point, quantification of all the available medical resources is necessary and it is feasible to modify the 2SFCA method and define a new indicator of supply-demand ratio, to promote the coverage population of each hospital under each diagnosis-related group.

3) Spatial quantitative analyses of the allocation situation under optimal balance of hospitals and the population is important, and individuals also concern about what the actual conditions is. It will be valuable that if we know the actual number of patients and compare both, then by focusing on the relationship between this value difference and the hospitals' attributes, the supply capacity of each subject in different hospitals can be summarized.

4.2 Research Object and Data Source

4.2.1 Outline and trend of DPC system

This chapter provides an overview of the selection of research subjects and the data collection procedure. First of all, we selected hospitals that did not have a competitive difference due to the differences in the cost of the treatment, that is, the patients stimulating demand did not need to consider different charges across supplier facilities when making their choice. The DPC system is a medical fee-based payment system based on a diagnosis-related group. It is an inclusive evaluation system of medical treatment fees for acute medical care introduced in 2003. Briefly, the traditional calculation method called fee-for-services payment was based on the number of medical examinations, injections, and drugs required, but under this new calculation method, medical expenses are classified into 18 diagnostic groups (from 1, 572 classifications) according to the name of the disease and patients' treatment requirements. The total medical fee is calculated by referring to the daily fixed medical expenses for each category (Figure4-2). The data from the Ministry of Health, Labor and Welfare reveals that in 2003, specialty function hospitals were introduced into the DPC system. After that, the number of hospitals participating began increasing year by year, and by July 2010, the number of DPC hospitals was about 1400. In Fukuoka City, as presented in Figure4-3, the number of hospitals participating in the DPC survey is increasing and has followed the same trend as the national increase throughout the country.

4.2.2 Research object and data source

The selected area was Fukuoka, the capital city of Fukuoka Prefecture on the northern shore of the island of Kyushu in Japan. Fukuoka has a population of more than 1.5 million and is the most populated city in Kyushu. It serves as the political, economic, and transportation center of Kyushu. This study investigated 151 medical departments in 115 hospitals, 1526 clinics, and 1013 dental clinics, in conjunction with the Fukuoka City government in August 2016. In this research, we selected the comprehensive DPC hospitals in Fukuoka. The distribution of a total of 52 general hospitals is presented in Figure4-4.

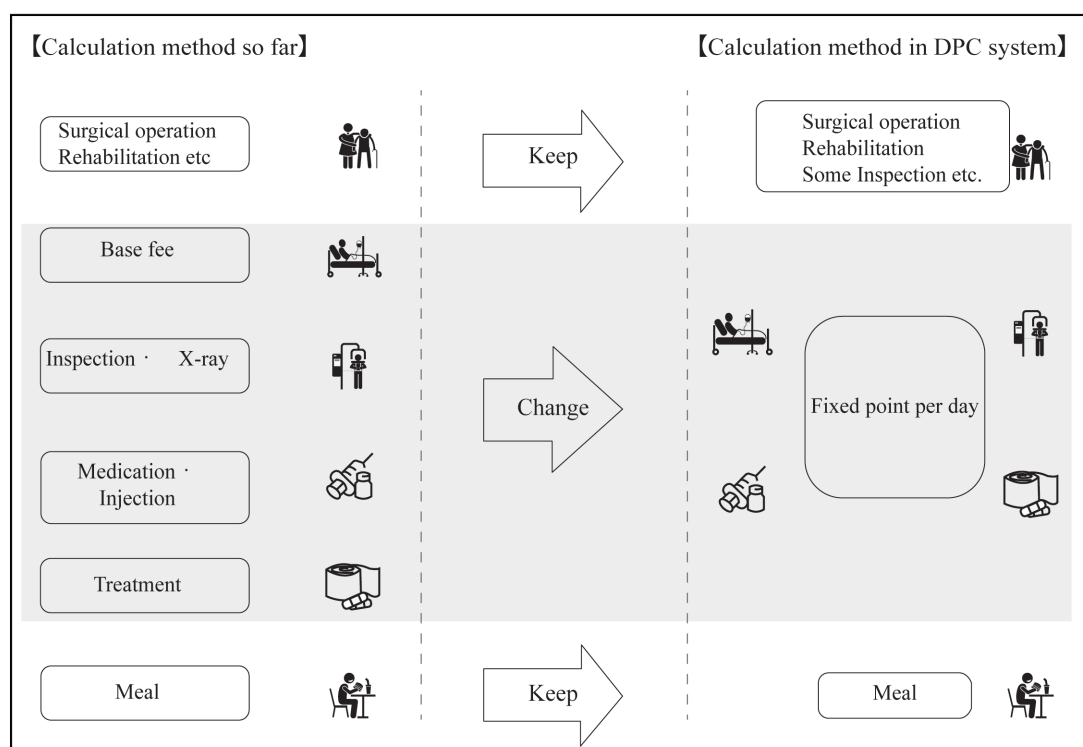


Figure 4-2 Outline of DPC system

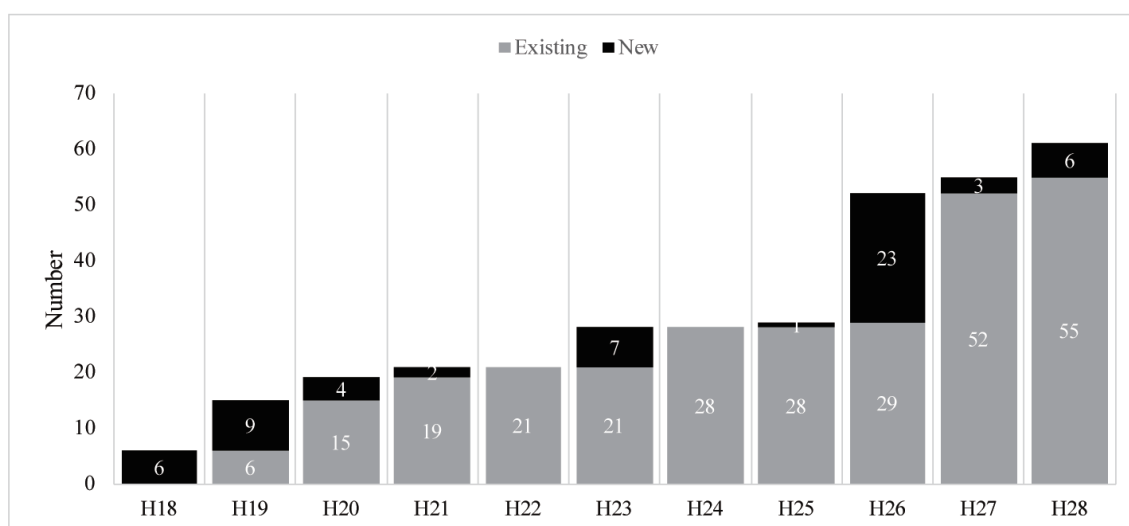


Figure 4-3 The trend of the hospitals introduced the DPC system

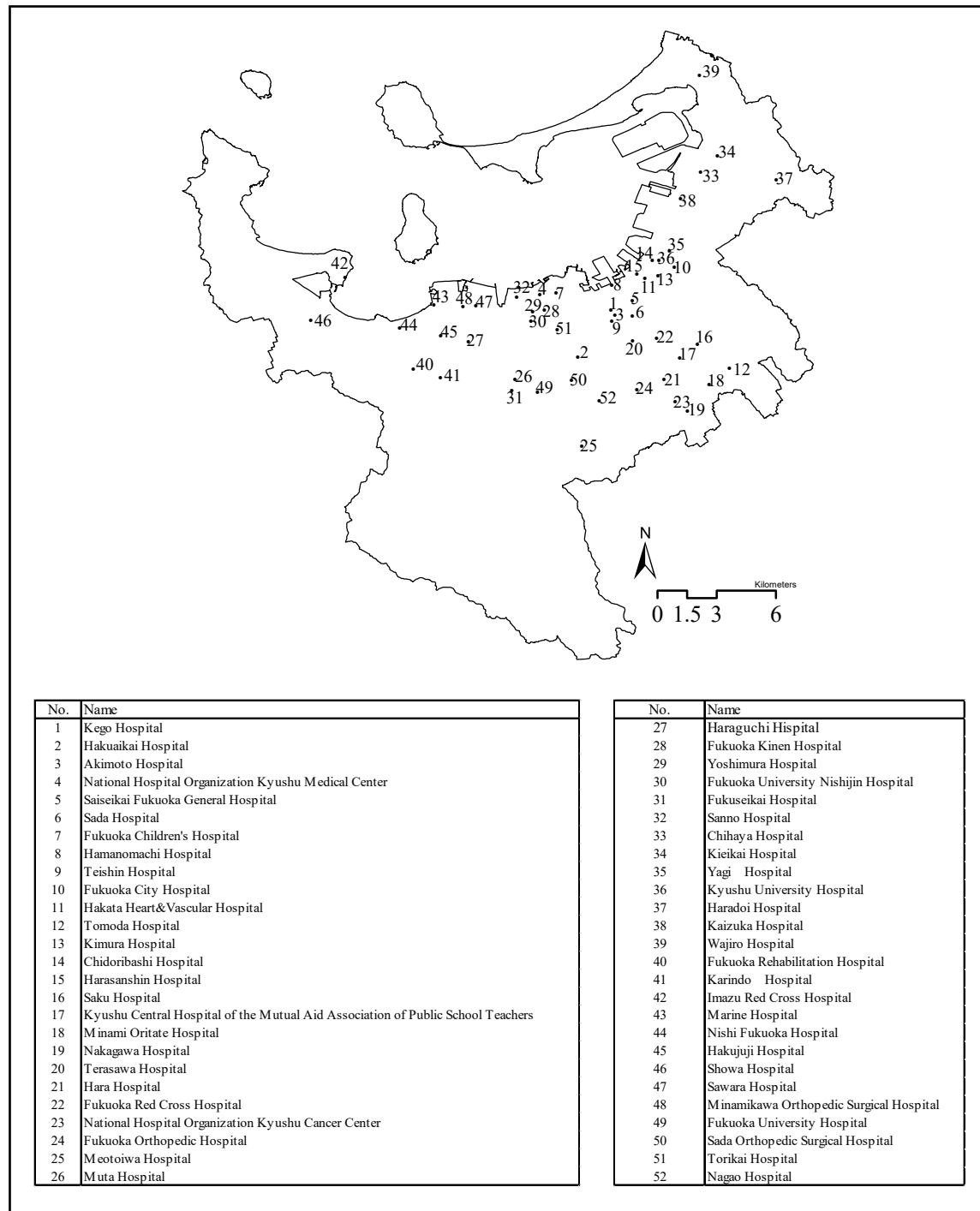


Figure 4-4 List of study area-Fukuoka city and research objects

One hundred 51 clinical departments from all the medical facilities in Fukuoka were also selected and classified into 18 categories according to the DPC system's diagnostic group classification principle (Table.4-1). The data chosen for modeling were drawn from several sources. The key data from medical facilities included the name, location, and type, which was gathered from the List of Medical facilities posted on the homepage of Fukuoka City^[12]. Additional data, including the detailed location information about medical facilities, were obtained using the National Land Numerical Information download service^[24]. A third set of data, including neighborhood-based demographics, such as gender and age of the population, was acquired. Differences in the frequency and needs of people of different ages were considered, and population weights were assigned. Morbidity rate statistics from Japan's Ministry of Health, Labor and Welfare were also applied. The data reporting the overall treatment rate in Japan in 2016 and the treatment rate of people of different ages (the number of patients per 100,000 people) was acquired. This data indicated patient treatment trends, with a gradual decrease from 0 to 20 years old and a gradual increase

Table 4-1 Diagnostic group classification principle of DPC system

ID	Diagnostic group classification
S_01	Nervous system disease
S_02	Ophthalmic disease
S_03	Otorhinolaryngologic disease
S_04	Respiratory disease
S_05	Cardiovascular disease
S_06	Disease related to Digestive system, liver · Biliary tract · pancreas
S_07	Musculoskeletal disease
S_08	Diseases related skin and subcutaneous tissues
S_09	Breast disease
S_10	Diseases related to endocrine nutrition metabolism
S_11	Renal · Urinary system and Male Reproductive diseases
S_12	Female Reproductive system disease and Postpartum disease · Abnormal pregnancy delivery
S_13	Diseases Related to blood, hematopoietic organ, immune organ
S_14	Neonatal disease, Congenital malformation
S_15	Childhood illness
S_16	Trauma · Burn · Addiction
S_17	Mental disease
S_18	Others

from 20 to 90 years old. The weight of the population of each age group in the total population was assigned according to the proportional difference between the patient rate of each age group and the overall rate, and then the population number of each population point was weighted according to age group.

4.3 Methodology

4.3.1 2SFCA method introduced Priority selection function

In the last chapter, the distribution result obtained according to the traditional 2SFCA method is only based on the distance between the population and facility as the main factor. In other words, the principle of distribution is to treat each population point as independent and irrelevant to each other. However, as a matter of fact, the patient's choice at any population point will also impact on other population points. People will give priority to large-scale hospitals that serve a large number of people (i.e., the number of theoretically assigned population by 2SFCA), but such choices drive these hospitals to operate in excess of capacity, thus making medical services unobtainable. In this situation, people would prefer hospitals that are not overloaded and can provide services (Figure4-5). Therefore, a priority function is introduced here to endow the population with intelligence. It is assumed that the population has the capacity to judge and speculate on the hospital's workload to lower pressure on overloaded hospitals and ensure a more equitable distribution of medical resources.

That is to say, so far, the theory has simply considered the effect of distance and assumed that people fully understand the distance to the surrounding medical facilities when making choices. Here, it is necessary to further assume that service users know the distance to the surrounding facilities and the population covered by the facilities, in order to estimate the facilities' load before making a choice. Since the choice of population in turn affects the number using facilities and services, making a circular calculation of this process to obtain stable results is reasonable and can be performed as follows:(Figure4-6)

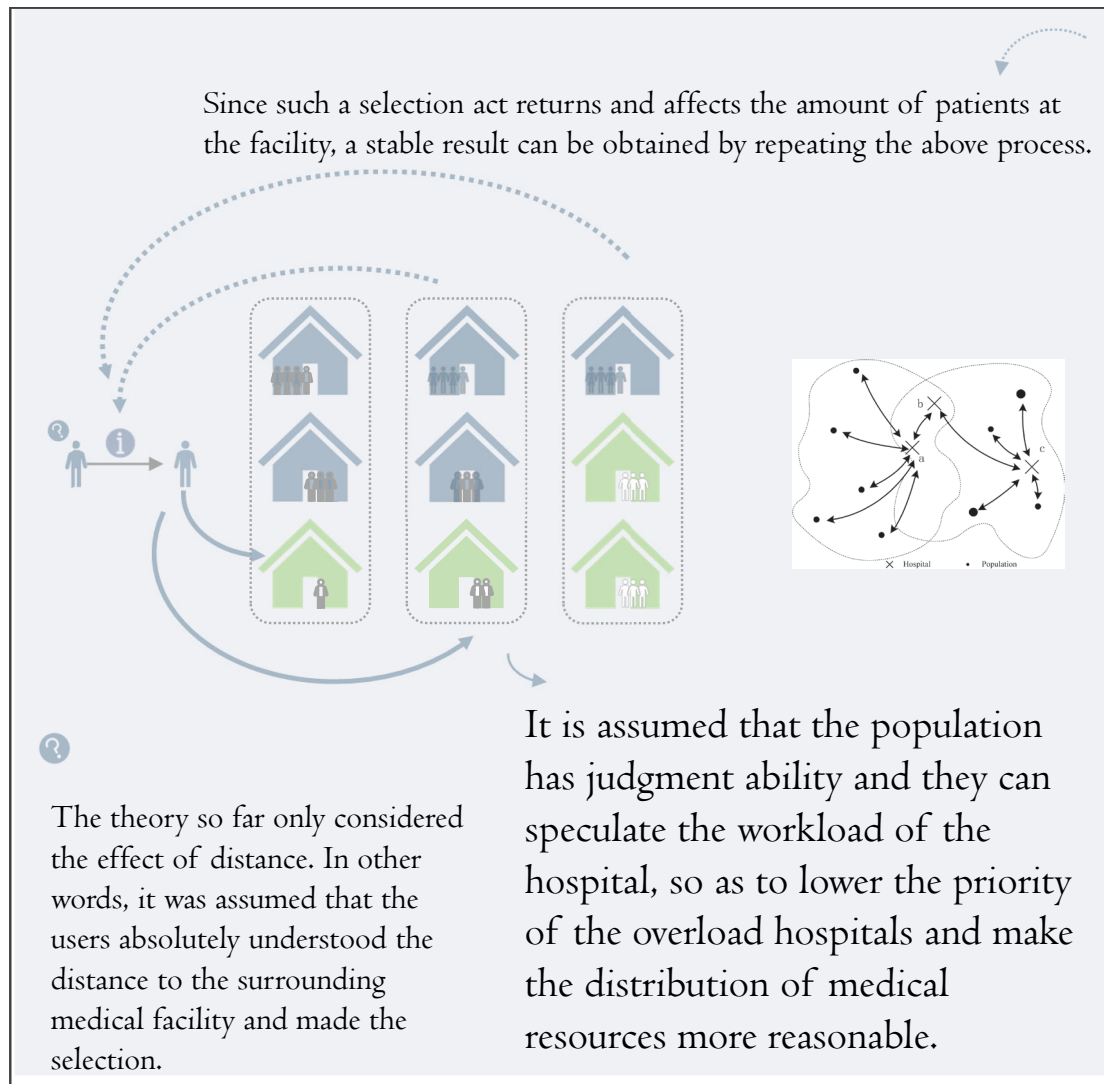


Figure 4-5 Diagram of Priority selection function

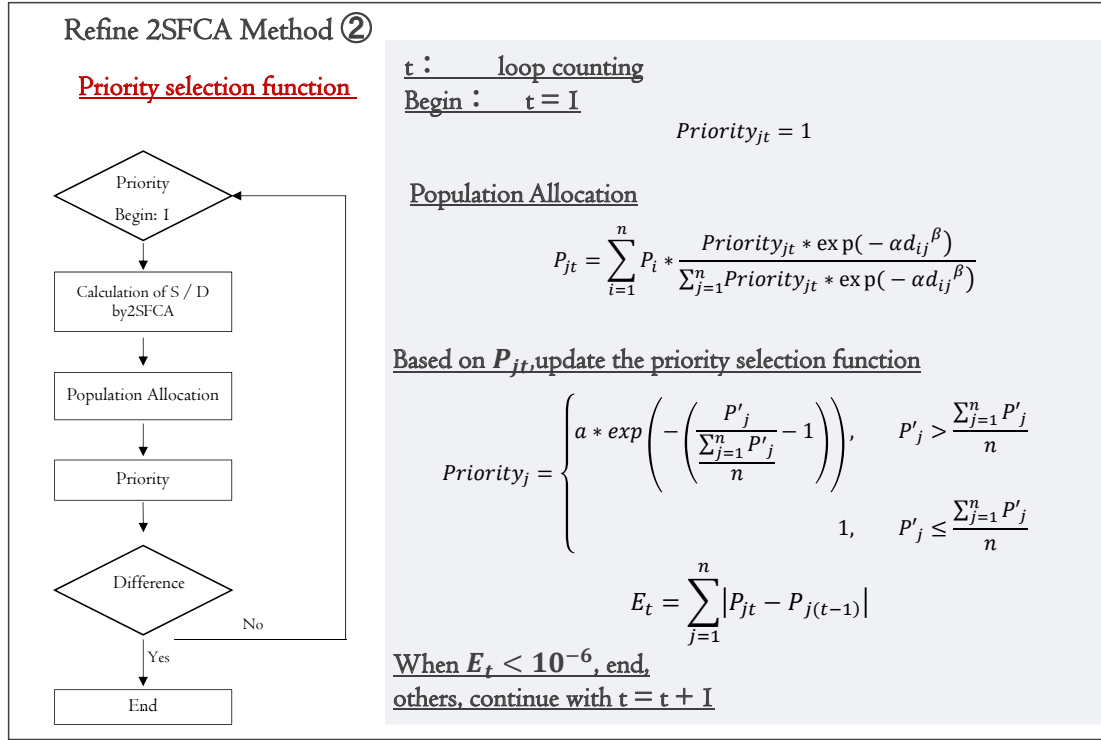


Figure 4-6 Procedure of Priority selection function

Suppose facilities j services for the population P'_j , the average is $\frac{\sum_{j=1}^n P'_j}{n}$, then relatively, the workload is: $\frac{P'_j}{\frac{\sum_{j=1}^n P'_j}{n}}$

The priority selection function can be set as:

$$Priority_j = \begin{cases} a * \exp\left(-\left(\frac{P'_j}{\frac{\sum_{j=1}^n P'_j}{n}} - 1\right)\right), & P'_j > \frac{\sum_{j=1}^n P'_j}{n} \\ 1, & P'_j < \frac{\sum_{j=1}^n P'_j}{n} \end{cases} \quad (4-1)$$

where a is the priority attenuation coefficient, and $a \leq 1$.

When the number of the population served is less than the average value, the function value is 1, that is, the effect of workload does not need to be considered; however, when the number of the population served is greater than the average,

it will be attenuated according to the deviation from the average. With the help of this priority selection function, the accessibility of each population point can be recalculated as follows:

$$A_i = \sum_{j=1}^n \text{Priority}_j * e^{xp(d_j^\beta)} \quad (4-2)$$

The number of people served by facility j at population point i is:

$$P_i * \frac{\text{Priority}_j * e^{xp(-ad_j^\beta)}}{\sum_{j=1}^n \text{Priority}_j * e^{xp(-ad_j^\beta)}} \quad (4-3)$$

Based on the number of the population served, the priority is recalculated. When the total difference with the previous priority is less than $10e-6$, it is judged to be stable.

Here, the selection of the priority attenuation coefficient needs to be specified, which will affect the final stability. If the parameter a is too small, the attenuation amplitude will be too small, resulting in a priority difference between each calculation, which will also be too small, so that the attenuation may enter a pseudo-stable situation. If a is too large, the attenuation will be too large, causing repeated selection which fails to enter a stable situation. For example, hospital A is an overloaded hospital, whereas hospital B is underloaded, so if B becomes the priority selection, then more patients choose B. However, as a result, B would be overloaded, whereas A would become underloaded, and yet when A was the priority selection, it was trapped in an endless loop and unable to attain a stable situation.

Given the two cases above, the optimal value of “ a ” should be the maximum value that enables it to enter a stable state. Here, we chose a decrease from 1 with an accuracy of 0.01. If the difference increases, we entered in the next round of value “ a ” until we selected the optimal value^{*2)}. On this basis, the 2SFCA method is optimized, and the theoretical allocation of patient numbers for each target hospital can be calculated.

4.3.2 The location environment

In this chapter, we take 52 hospitals participating in the DPC survey in Fukuoka as research objects. First of all, in order to grasp the current situation

of its location environment, we count the number of bus stations, railway stations and other public transit facilities, welfare facilities such as nursing home, such as supermarkets, shopping centers and other commercial facilities, Government agencies and other administrative facilities, the school education facilities around each hospital. The results of the collection of the quantity and performance level are shown in Table4-2.

4.4 Patient Number Analysis by Using the Improved 2SFCA Method

4.4.1 Value difference of patients

When studying transit facilities, supermarkets, and other public facilities, the “nearby principle” is a common principle. The density of the users and the distance between the users and facilities are the decisive factors affecting usage. The service specialties provided by a hospital indicates that there is likely to be a considerable difference between the theoretical allocation of patients determined by the method described above and the actual proportion of patients received. Actually, the existence of this difference and the extent of the difference indirectly reflect the existence of other factors affecting the hospital’s ability to attract patients. Therefore, first of all, the theoretical allocation of patients to each hospital was obtained in terms of each diagnostic group in accordance with the method described in the previous chapter. Then, comparing with the actual proportion of patients by referring to the patient volume data^[25] in the survey result of DPC system, we demonstrate the percentage data of individuals in the total in the two cases by the thermometer chart in Figure4-7. It is not difficult to see from the figure, for some hospitals, the real number of patients of almost all subjects is over the theoretical number, such as Kyushu University Hospital, National Hospital Organization Kyushu Cancer Center and so on. But for others, real number of most subjects is close to zero, such as Torikai Hospital and Haraguchi Hospital. The distribution of patients is extremely uneven. The absolute value difference between the two sides is demonstrated in the boxplot chart in Figure4-8. The black point is the

Table 4-2 The location environment of each hospital

Name of Hospital	Public transit facilities		Welfare facilities		Commercial facilities		Administrative facilities		Education facilities	
	Number	PL	Number	PL	Number	PL	Number	PL	Number	PL
Kego Hospital	89	(+138%)	22	(+25%)	156	(+132%)	4	(+110%)	51	(+18%)
Hakuaikai Hospital	29	(-22%)	21	(+19%)	54	(-20%)	2	(+5%)	60	(+39%)
Akimoto Hospital	78	(+109%)	27	(+53%)	142	(+111%)	4	(+110%)	53	(+23%)
National Hospital Organization Kyushu Medical Center	33	(-12%)	12	(-32%)	68	(+1%)	2	(+5%)	47	(+9%)
Saiseikai Fukuoka General Hospital	93	(+149%)	23	(+30%)	129	(+91%)	3	(+58%)	55	(+27%)
Sada Hospital	72	(+93%)	27	(+53%)	117	(+74%)	3	(+58%)	60	(+39%)
Fukuoka Children's Hospital	29	(-22%)	16	(-9%)	67	(-1%)	3	(+58%)	53	(+23%)
Hamanomachi Hospital	71	(+90%)	14	(-21%)	119	(+77%)	3	(+58%)	45	(+4%)
Fukuoka Teishin Hospital	54	(+44%)	25	(+42%)	125	(+86%)	4	(+110%)	56	(+30%)
Fukuoka City Hospital	49	(+31%)	25	(+42%)	98	(+45%)	3	(+58%)	33	(-24%)
Hakata Heart&Vascular Hospital	67	(+79%)	20	(+13%)	103	(+53%)	4	(+110%)	44	(+2%)
Tomoda Hospital	26	(-30%)	18	(+2%)	38	(-44%)	1	(-47%)	45	(+4%)
Kimura Hospital	64	(+71%)	25	(+42%)	113	(+68%)	4	(+110%)	38	(-12%)
Chidoribashi Hospital	58	(+55%)	18	(+2%)	98	(+45%)	4	(+110%)	34	(-21%)
Harasanshin Hospital	62	(+66%)	14	(-21%)	102	(+51%)	4	(+110%)	42	(-3%)
Saku Hospital	35	(-6%)	20	(+13%)	60	(-11%)	2	(+5%)	53	(+23%)
Kyushu Central Hospital of the Mutual Aid Association of Public School Teachers	36	(-4%)	28	(+59%)	82	(+22%)	2	(+5%)	54	(+25%)
Minami Oritate Hospital	23	(-38%)	20	(+13%)	49	(-27%)	1	(-47%)	53	(+23%)
Nakagawa Hospital	25	(-33%)	20	(+13%)	41	(-39%)	1	(-47%)	48	(+11%)
Terasawa Hospital	40	(+7%)	18	(+2%)	80	(+19%)	4	(+110%)	62	(+44%)
Hara Hospital	20	(-47%)	25	(+42%)	66	(-2%)	1	(-47%)	60	(+39%)
Fukuoka Red Cross Hospital	44	(+18%)	22	(+25%)	90	(+34%)	4	(+110%)	63	(+46%)
National Hospital Organization Kyushu Cancer Center	28	(-25%)	20	(+13%)	48	(-29%)	1	(-47%)	52	(+20%)
Fukuoka Orthopedic Hospital	24	(-36%)	17	(-4%)	49	(-27%)	1	(-47%)	56	(+30%)
Meotoiwa Hospital	2	(-95%)	2	(-89%)	14	(-79%)	0	(-100%)	17	(-61%)
Muta Hospital	26	(-30%)	17	(-4%)	56	(-17%)	2	(+5%)	48	(+11%)
Haraguchi Hospital	31	(-17%)	18	(+2%)	53	(-21%)	2	(+5%)	48	(+11%)
Fukuoka Kinen Hospital	42	(+12%)	14	(-21%)	83	(+23%)	2	(+5%)	57	(+32%)
Yoshimura Hospital	43	(+15%)	18	(+2%)	83	(+23%)	2	(+5%)	61	(+41%)
Fukuoka University Nishijin Hospital	38	(+2%)	20	(+13%)	83	(+23%)	2	(+5%)	60	(+39%)
Fukuseikai Hospital	24	(-36%)	13	(-26%)	46	(-32%)	0	(-100%)	43	(0%)
Sanno Hospital	29	(-22%)	8	(-55%)	70	(+4%)	3	(+58%)	54	(+25%)
Chihaya Hospital	39	(+4%)	29	(+64%)	62	(-8%)	0	(-100%)	40	(-7%)
Kieikai Hospital	37	(-1%)	19	(+8%)	54	(-20%)	0	(-100%)	36	(-17%)
Yagi Hospital	48	(+28%)	24	(+36%)	93	(+38%)	3	(+58%)	30	(-30%)
Kyushu University Hospital	55	(+47%)	21	(+19%)	104	(+54%)	4	(+110%)	36	(-17%)
Haradoi Hospital	28	(-25%)	10	(-43%)	17	(-75%)	0	(-100%)	17	(-61%)
Kaizuka Hospital	24	(-36%)	8	(-55%)	36	(-47%)	1	(-47%)	28	(-35%)
Fukuoka Wajiro Hospital	22	(-41%)	10	(-43%)	28	(-58%)	0	(-100%)	19	(-56%)
Fukuoka Rehabilitation Hospital	25	(-33%)	10	(-43%)	25	(-63%)	0	(-100%)	22	(-49%)
karindo Hospital	23	(-38%)	14	(-21%)	36	(-47%)	1	(-47%)	35	(-19%)
Imazu Red Cross Hospital	4	(-89%)	1	(-94%)	6	(-91%)	0	(-100%)	9	(-79%)
Marine Hospital	15	(-60%)	14	(-21%)	26	(-61%)	1	(-47%)	23	(-47%)
Nishi Fukuoka Hospital	13	(-65%)	8	(-55%)	25	(-63%)	1	(-47%)	18	(-58%)
Hakujuji Hospital	31	(-17%)	23	(+30%)	39	(-42%)	1	(-47%)	37	(-14%)
Showa Hospital	13	(-65%)	11	(-38%)	22	(-67%)	0	(-100%)	12	(-72%)
Sawara Hospital	34	(-9%)	12	(-32%)	49	(-27%)	2	(+5%)	43	(0%)
Minamikawa Orthopedic Surgical Hospital	28	(-25%)	20	(+13%)	55	(-18%)	2	(+5%)	35	(-19%)
Fukuoka University Hospital	27	(-28%)	8	(-55%)	43	(-36%)	1	(-47%)	45	(+4%)
Sada Orthopedic Surgical Hospital	34	(-9%)	26	(+47%)	58	(-14%)	1	(-47%)	48	(+11%)
Torikai Hospital	41	(+10%)	24	(+36%)	95	(+41%)	3	(+58%)	71	(+65%)
Nagao Hospital	19	(-49%)	19	(+8%)	49	(-27%)	0	(-100%)	35	(-19%)

*PL: Performance level: (+) above average, (-) below average

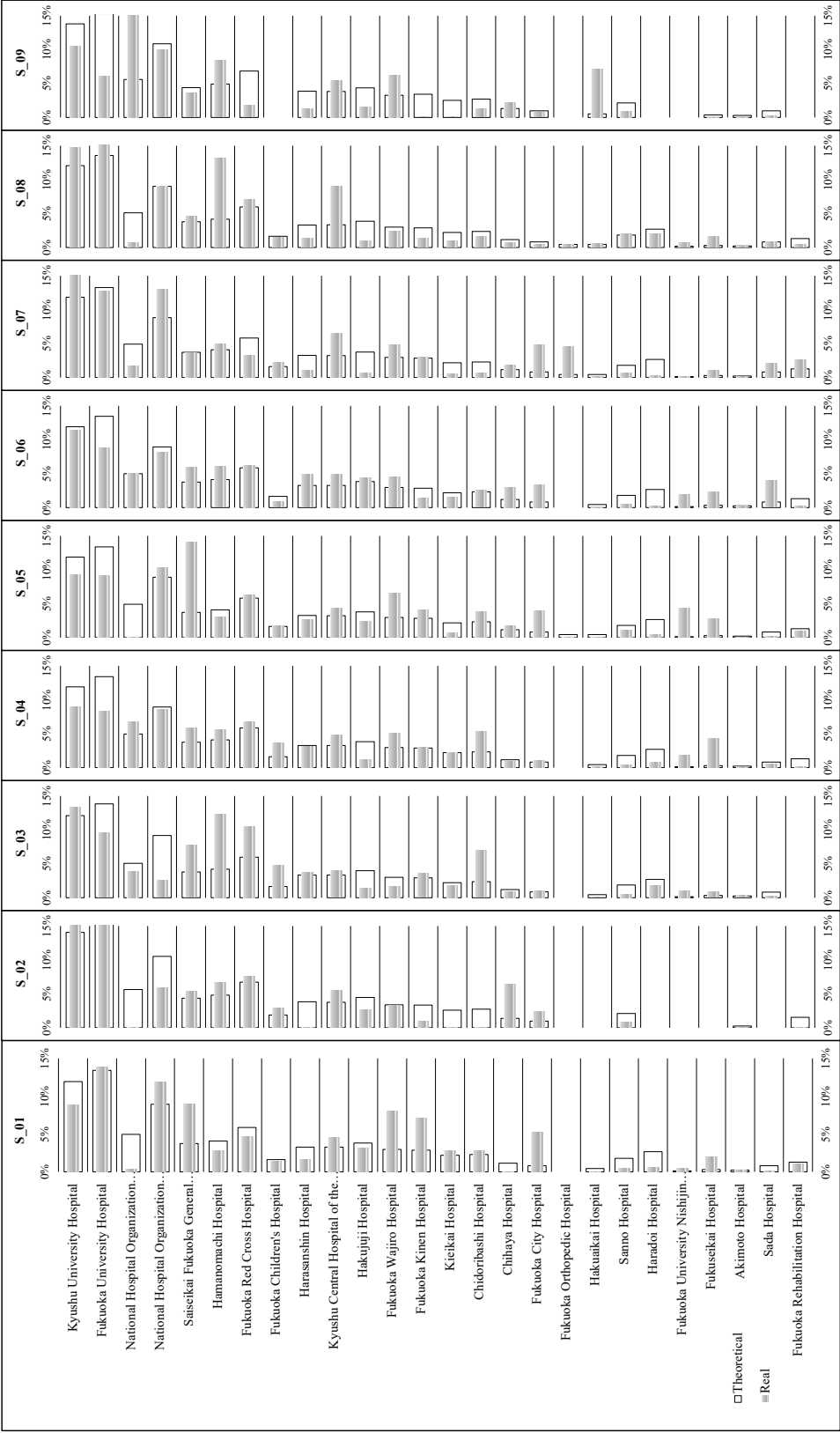


Figure 4-7-a Thermometer chart of value difference between theoretical served population and real number of patients-1

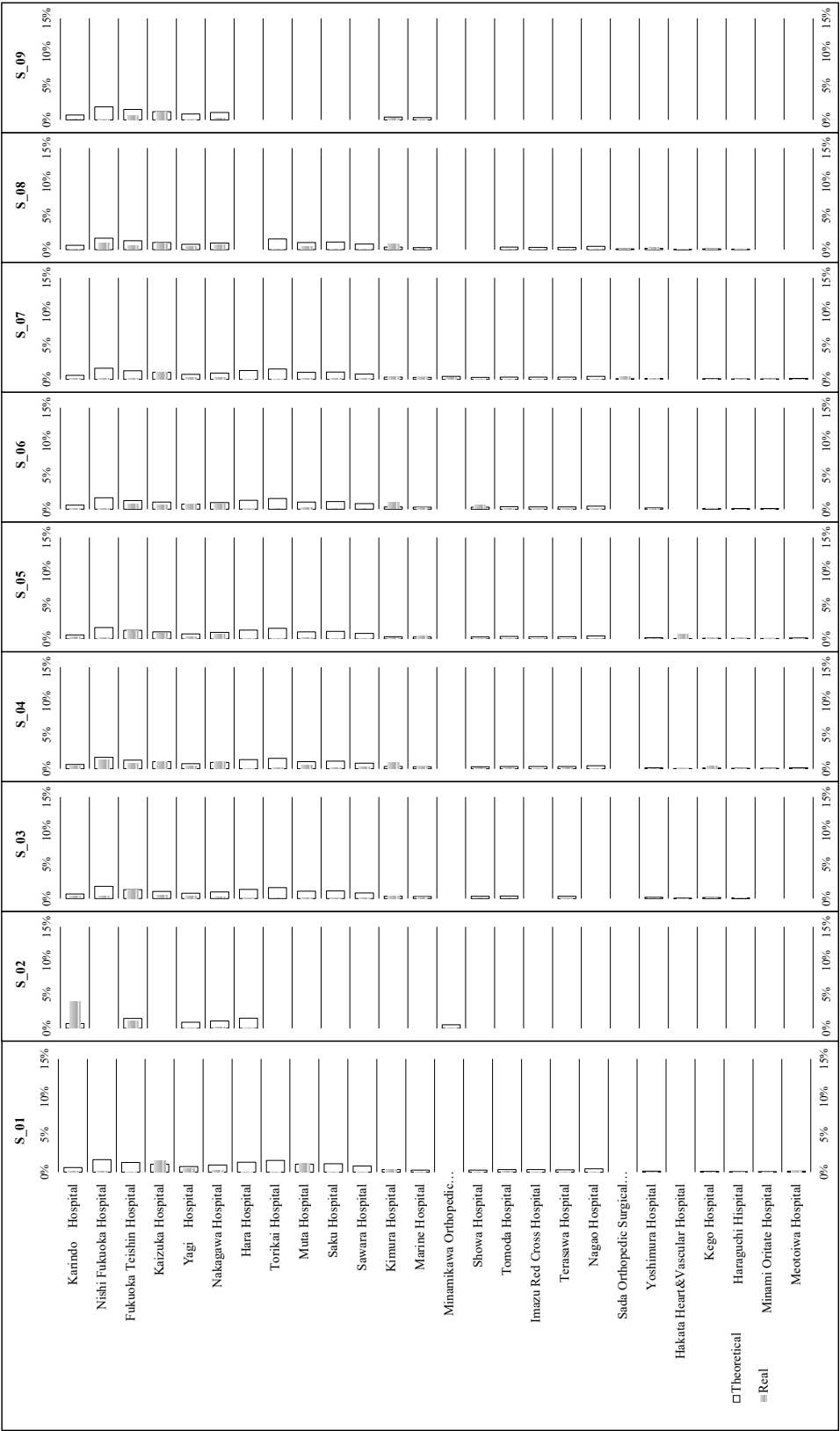


Figure 4-7-b Thermometer chart of value difference between theoretical served population and real number of patients-2

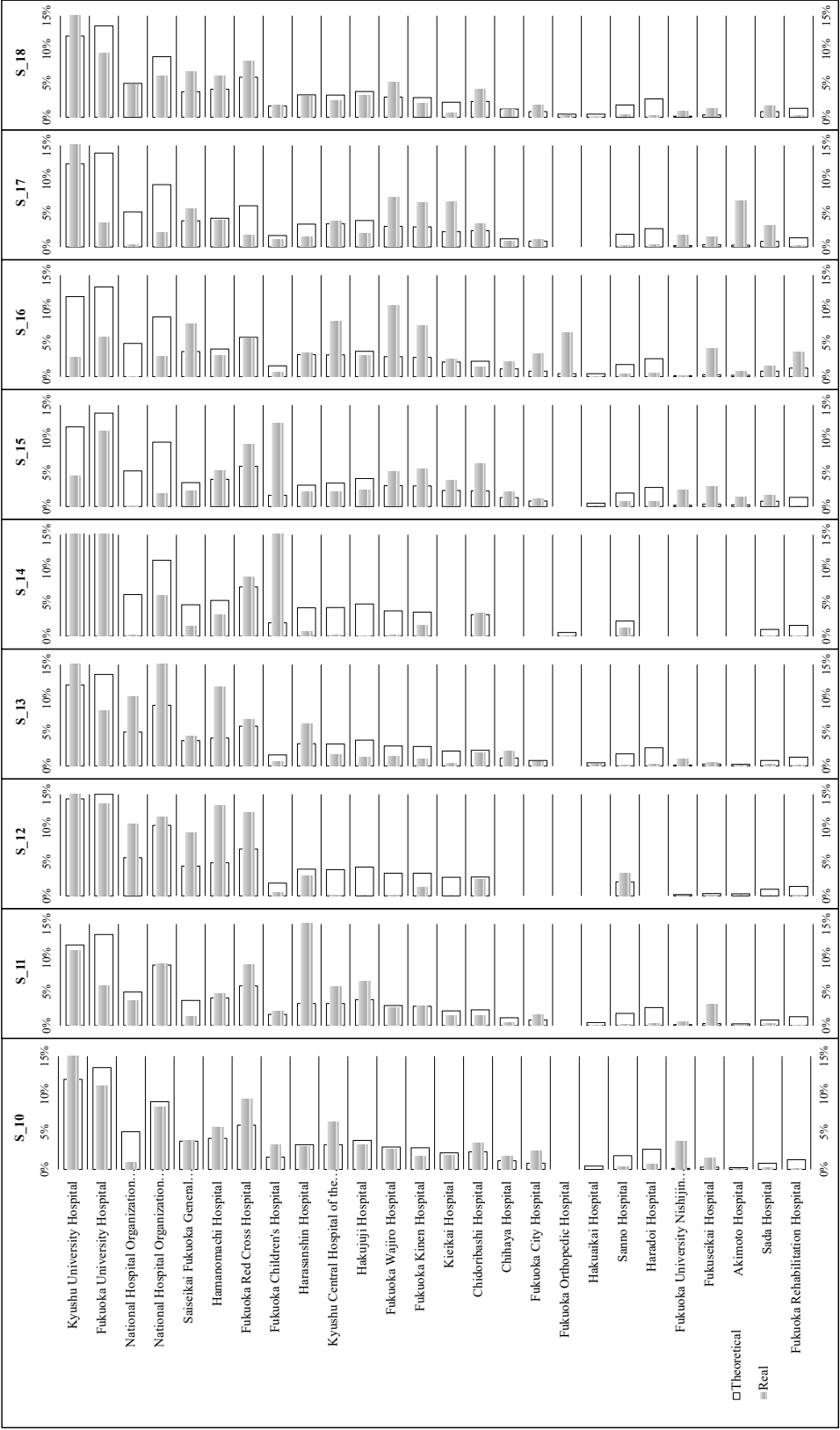


Figure 4-7-c Thermometer chart of value difference between theoretical served population and real number of patients-3

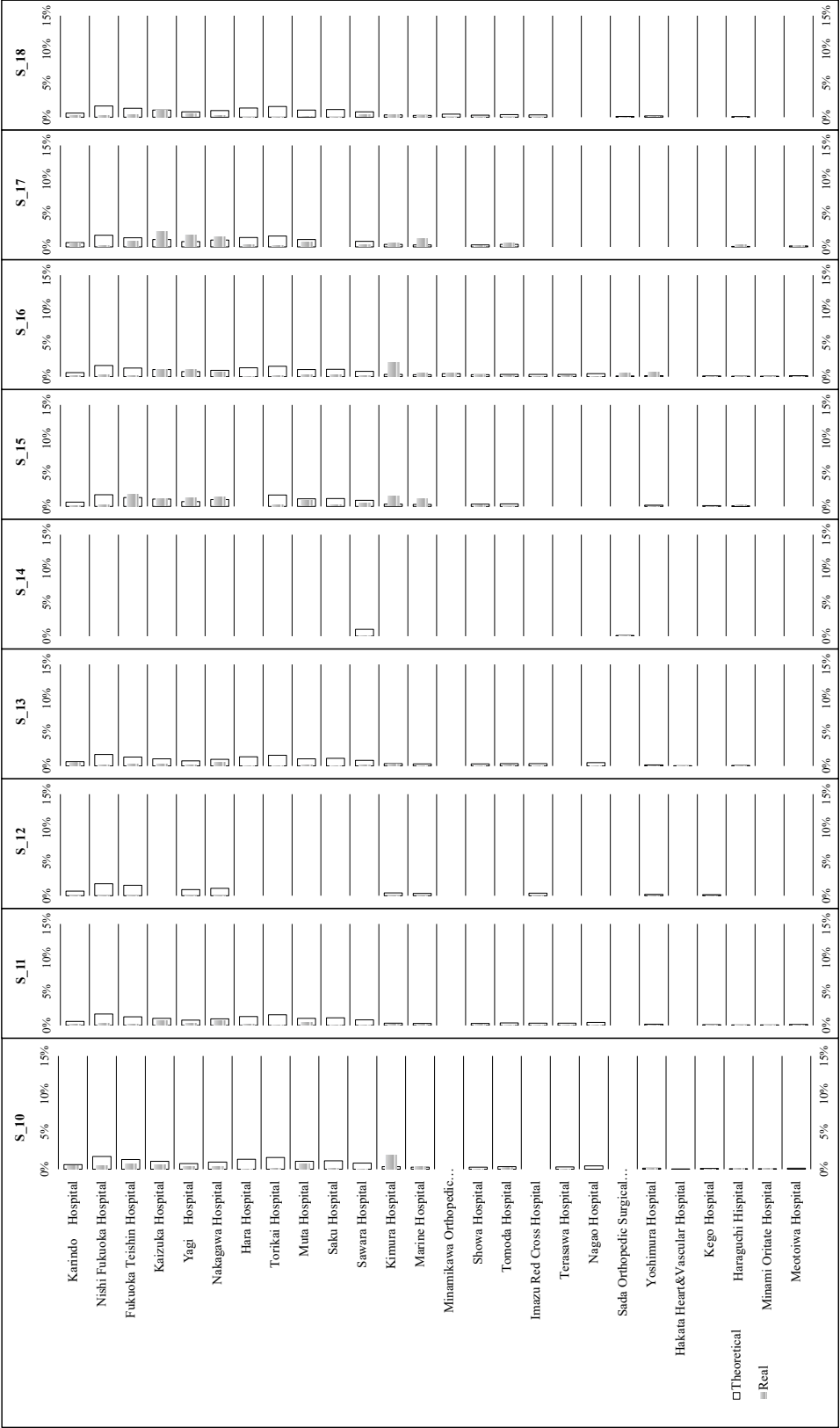


Figure 4-7-d Thermometer chart of value difference between theoretical served population and real number of patients-4

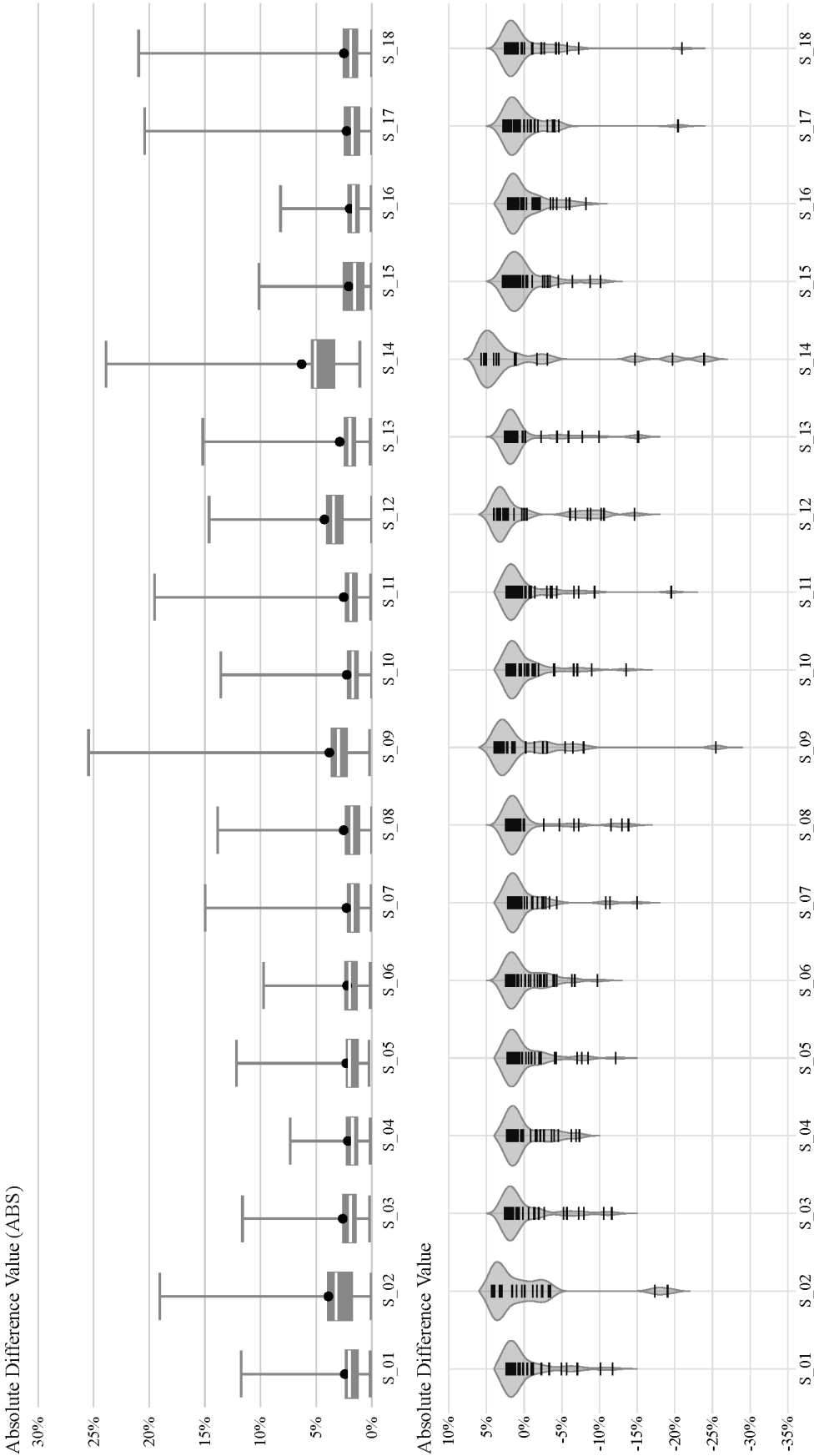


Figure 4-8 Absolute Value difference between theoretical served population and real number of patients

average value, the white line is the median, the gray box area is the confidence interval, and the gray horizontal lines are the minimum and maximum values. This theoretical model assumes that the supply quantities of the 52 hospitals are all the same, that is, the actual service capacity of each hospital is not expressed; therefore, there is a certain difference between the estimated value of patient allocation and the actual value. Typically, the estimated number of patients is much greater than the actual case when the service capacity used for estimation is larger than the actual value, and vice versa.

4.4.2 Analysis of the value differences

Next, the different relationships between the theoretical value and actual value and the attributes of the hospital, such as the number of opening years, number of medical treatment specialties, and number of sickbeds and hospital scales will also be discussed. Statistics were performed for 18 diagnostic groups using the hospital attribute dimensions listed above^{*3)}, as presented in Table 2. During the Durbin-Watson (DW) testing^{[30][31][32]}, if the residual value is greater than 2, the factors and the different values are independent, whereas if the residual value is less than 2, a positive correlation is considered; the closer the value to 0, the stronger the positive correlation. According to our results, the relationships between the different values of diagnostic groups and the number of sickbeds, scale, and years passed the DW testing. Significance testing indicated that the relationships between the different values of all diagnostic groups except S_09: breast disease and the other four factors were more credible, which indicates that these four factors directly affect the difference between theoretical and real values.

As can be observed in the Table4-3, all strong correlations between these four factors and different values were positive. That means, the more diagnostic groups treated, the more sickbeds, the larger the scale, and the more years the hospital has been opened, the larger the difference between the theoretical value and the actual value. Among these four factors, the number of sickbeds had a positive effect on all 18 types of disease and had a significant impact on 11 out of 18 diagnostic groups. There were five diagnostic groups with a significance level of 1% and six with 5% and five at 5% and six at 5%. On the

Table 4-3 Result of Regression analysis on the difference value

	S_01	S_02	S_03	S_04	S_05	S_06	S_07	S_08	S_09	S_10	S_11	S_12	S_13	S_14	S_15	S_16	S_17	S_18
Average of Difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Median of Difference	0.21%	0.44%	0.27%	0.09%	0.27%	0.14%	0.14%	0.27%	0.78%	0.21%	0.31%	0.38%	0.38%	1.28%	0.05%	0.04%	0.02%	0.29%
Maximum of Difference	4.53%	5.61%	6.63%	5.07%	4.84%	4.54%	3.15%	4.36%	9.11%	3.97%	7.56%	4.17%	5.31%	6.05%	7.51%	8.96%	10.27%	3.97%
Minimum of Difference	-5.30%	-8.02%	-8.19%	-4.04%	-10.33%	-3.21%	-4.81%	-9.07%	-23.78%	-3.63%	-18.11%	-8.52%	-7.99%	-26.49%	-10.72%	-7.59%	-10.21%	-10.85%
Constant	1.80%	0.20%	0.10%	0.10%	1.80%	0.10%	0.00%	0.00%	77.60%	0.00%	0.90%	8.60%	0.60%	2.40%	0.10%	0.30%	0.00%	0.10%
Num. of subjects	92.90% (-)	39.20% (+)	20.70% (+)	43.30% (+)	80.20% (-)	69.70% (+)	31.20% (-)	88.90% (-)	78.70% (+)	91.30% (-)	28.80% (+)	63.90% (-)	31.10% (-)	89.90% (+)	0.010** (+)	0.003** (+)	0.027* (+)	59.90% (-)
Num. of sickbeds	0.013* (+)	44.00% (+)	0.017* (+)	0.047* (+)	0.025* (+)	0.007** (+)	0.002** (+)	10.70% (+)	69.10% (+)	0.003** (+)	0.093** (+)	6.30% (+)	0.028* (+)	57.70% (+)	69.70% (+)	23.70% (+)	0.000** (+)	0.000* (+)
Scale	22.70% (-)	89.60% (+)	42.80% (-)	52.40% (+)	44.60% (+)	83.40% (+)	76.30% (+)	50.70% (+)	69.00% (+)	94.00% (+)	74.30% (-)	84.50% (+)	25.90% (+)	75.40% (+)	75.10% (-)	26.30% (-)	0.000** (+)	28.30% (-)
Opening years	27.40% (+)	78.60% (+)	37.90% (+)	74.20% (+)	64.40% (-)	73.20% (+)	23.20% (+)	0.042* (+)	68.50% (-)	31.90% (+)	66.50% (+)	96.40% (+)	59.10% (+)	17.60% (+)	14.90% (+)	90.90% (+)	91.90% (+)	97.10% (+)
Durbin-Watson	1.525	2.046	1.975	1.956	2.157	2.306	2.192	2.459	2.428	2.148	1.804	2.002	2.330	2.519	2.057	2.129	1.972	2.015
Significance	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.465	0.000	0.001	0.002	0.000	0.049	0.002	0.001	0.000	0.000

Note. * P-value is less than 0.05; ** P-value is less than 0.01

other hand, the number of medical treatment specialties had a positive impact on 10, 2 diagnostic groups with a significance level of 1%, and 1 with 5%, which is significantly more affected than the other two attributes.

The supply S_j so far only provides a reference to the proportion when distributed across the population, whereas the actual supply S_j has no practical significance. So, the relative scale of the hospital should be used instead of the supply capacity. The relative scale coefficient is calculated by multiplying the ratio of the number of sickbeds and the average number of sickbeds of all the investigated hospitals by the ratio of the number of diagnostic groups and the average number of hospitals. The main reason for obtaining the multiplication of these two ratios as the relative size coefficient is that the number of beds can be used as a reference to the number of patients admitted, whereas the number of departments can be used as a reference to the comprehensiveness of hospitals. These two different dimensions will have a dual effect here, as follows:

$$RS_j = \frac{n * bed_j}{\sum_{i=1}^n bed_j} * \frac{n * Subject_j}{\sum_{i=1}^n Subject_j} \quad (4-3)$$

RS_j indicates the relative scale coefficient of hospital j , bed_j indicates the number of beds of hospital j , and $Subject_j$ indicates the number of subjects of hospital j .

Figure4-9 indicates that the difference between the theoretical value and the actual value of most diagnostic groups is very small, and the mean and median of the absolute differences in values are around 1%. Also, it can be more clearly observed that for most diagnostic groups, the different value conforms to normal distribution with a mean of 0%, which explains that the supply and demand relationship of the overall medical resources in Fukuoka City is relatively balanced. It also indicates that the method proposed in this paper is valid for estimating the supply and demand relationship for each diagnostic group. At the same time, it is not difficult to see that some diagnostic groups have singularities, which makes the different value larger. Next, we will focus on the diagnostic groups with large variances by calculating the variance of the distribution of the different values under each diagnostic group. As presented in Figure4-9, the performance of the value difference can be roughly divided

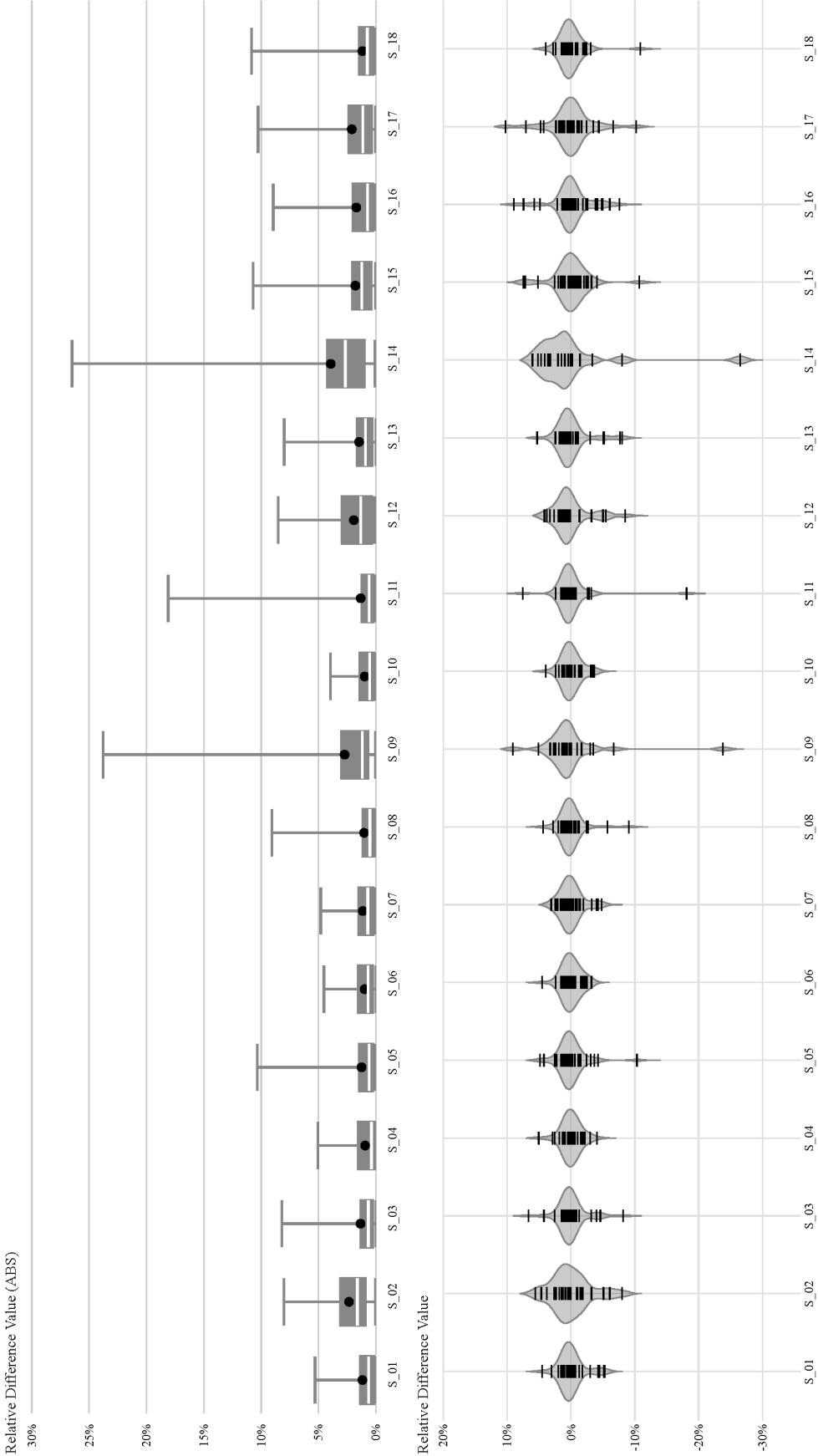


Figure 4-9 Relative Value difference between theoretical served population and real number of patients

into the following three situations:

Due to the existence of specialized hospitals for some diagnostic groups, they will bear a large number of patients with these diagnoses. That is to say, specialized hospitals affect the calculation of theoretical values present in this paper, which will cause a deviation in the theoretical allocation. For example, S_09: Breast disease; S_11: Renal Urinary system and Male Reproductive diseases; and S_14: Neonatal disease, Congenital malformation; and other subjects are very obvious. In Fukuoka City, there are specialized hospitals, such as cancer hospitals and children's hospitals, which are equivalent in size to ordinary general hospitals. However, in their respective specialties, the actual proportion of patients in these hospitals far exceeds that of ordinary general hospitals of the same size. The theoretical value calculated by the above method is significantly smaller than the actual value. To put it more concretely, for diagnostic group S_09, hospital No. 4 presents a difference of -23.8%. As a specialist cancer hospital, the popularity of breast cancer treatment in this hospital far exceeds that of other hospitals, and it admits about 30% of breast disease patients in Fukuoka City. In contrast, hospital No. 49 shows a difference of +9.1% in this diagnostic group. As the hospital with the second largest number of total patients, its comprehensiveness and scale allowed us to allocate a greater population when calculating theoretical values. However, the specialist department in hospital No. 49 is not that well known, and the actual proportion of patients is ranked sixth. For S_11: the difference in hospital No. 15, which is highly recognized for treatment specialties in kidney disease, kidney transplantation, and urology, is -18.1, yet the number of patients treated in this diagnostic group accounts for 21% in Fukuoka City. Conversely, for the same reason, the difference in hospital No. 49 was +7.6%.

For some other diagnostic groups, the theoretical values of comprehensive hospitals have been overestimated. For example, a trauma patient may prefer a general hospital rather than a large and comprehensive hospital. From the distribution of S_16: Trauma · Burn · Addiction in the figure, it can be observed that among hospitals with theoretical values higher than the actual values, all of the four hospitals with the largest deviation were comprehensive hospitals:

9% of hospital No. 36, 7.4% of hospital No. 49, 4.9% of hospital No. 23, and 5.7% of hospital No. 4. In Fukuoka City, although there is an orthopedic hospital (No. 24), the actual proportion of patients is only slightly higher than the theoretical value. Unlike characteristic 1 mentioned above, the difference between the theoretical and actual values of those four comprehensive hospitals is compensated by hospital No. 39, No. 24, and other general hospitals, but not any specialist hospital. That is to say, trauma, burn, and addiction patients are received more by general hospitals rather than by large and comprehensive hospitals.

The differences in S_02: Ophthalmic disease and S_14: Neonatal disease, Congenital malformation are discrete and do not coincide with the normal distribution. Fukuoka City currently has no specialized ophthalmology hospital. In addition, although S_14 is affected by the children's hospital, the distribution of the different values of other hospitals did not conform to the normal distribution. This difference indicates that diagnostic groups S_02 and S_14 make significantly different hospital choices than others.

4.5 Discussion on the medical service circle

4.5.1 Refinement of the definition of the medical service circle

According to the calculation of the distribution of the population served by each hospital, we can take the circle where 70% of the population is located as its core medical circle, then the medical circle radius of each hospital and each subject can be obtained. It's easy to know from this data that the average medical circle radius of each subject is about 4.8km, and the median is also about 4.8km. It can be determined that the medical circle radius conforms to the normal distribution centered at 4.8km. For the two subjects – “Female reproductive system disease and puerperal stage disease · abnormal pregnancy delivery” and “Diseases of blood, hematopoietic organ, immune the average service population of each hospital is more than that of other subjects, so the medical circle radius is larger than that of others, which is about 5.4km. In addition, the Imazu Red Cross Hospital is located at the edge of the peninsula. However, the setting of the

medical circle does not take into account the factors of the surrounding terrain. Due to its special geographical location, the radius obtained is much larger than that of other hospitals, and it's around 10km for all subjects. On the other hand, Fukuoka Wajiro Hospital has a large population and no other hospitals in the area. In such an environment, it has become the most important hospital in the area and the hospital mainly serves the area too. Therefore, the medical circle radius of each subject is less than 2km, making it the hospital with the smallest radius.

Comprehensive hospital is an important part for ensuring the normal and orderly operation of urban functions. However, this is supported by the statistics from Japan's Ministry of Health, Labor and Welfare, that indicate the number of general hospitals has declined year by year, in contrast, the number of new clinics has increased. The distribution of medical facilities influences the entire health care system that is expected to maximize the coverage of the service and minimize the travel needs of the patient, the role of clinics, as a support for the entire health care system is highly valued. With this criterion it is worthy to investigate whether the rational allocation of clinics can share the treatment pressure of general hospitals to a certain extent.

4.5.2 Distribution of 52 hospitals in 15 subjects

The scatter plot (Figure4-10) shows the distribution of the number of hospitals with more or less clinics surrounding according to the theoretical served population and the real number of patients. As can be summarized from the figure, hospitals with more clinics around are mainly concentrated in the following three regions: I, II and III:(Figure4-11)

- I: the number of theoretical served population is less than the average, while the real number of patients is more than the average;
- II: the number of theoretical served population is less than the average, while the real number of patients is also less than the average;
- III: the theoretical served population is more than the average, while the real number of patients is less than the average;

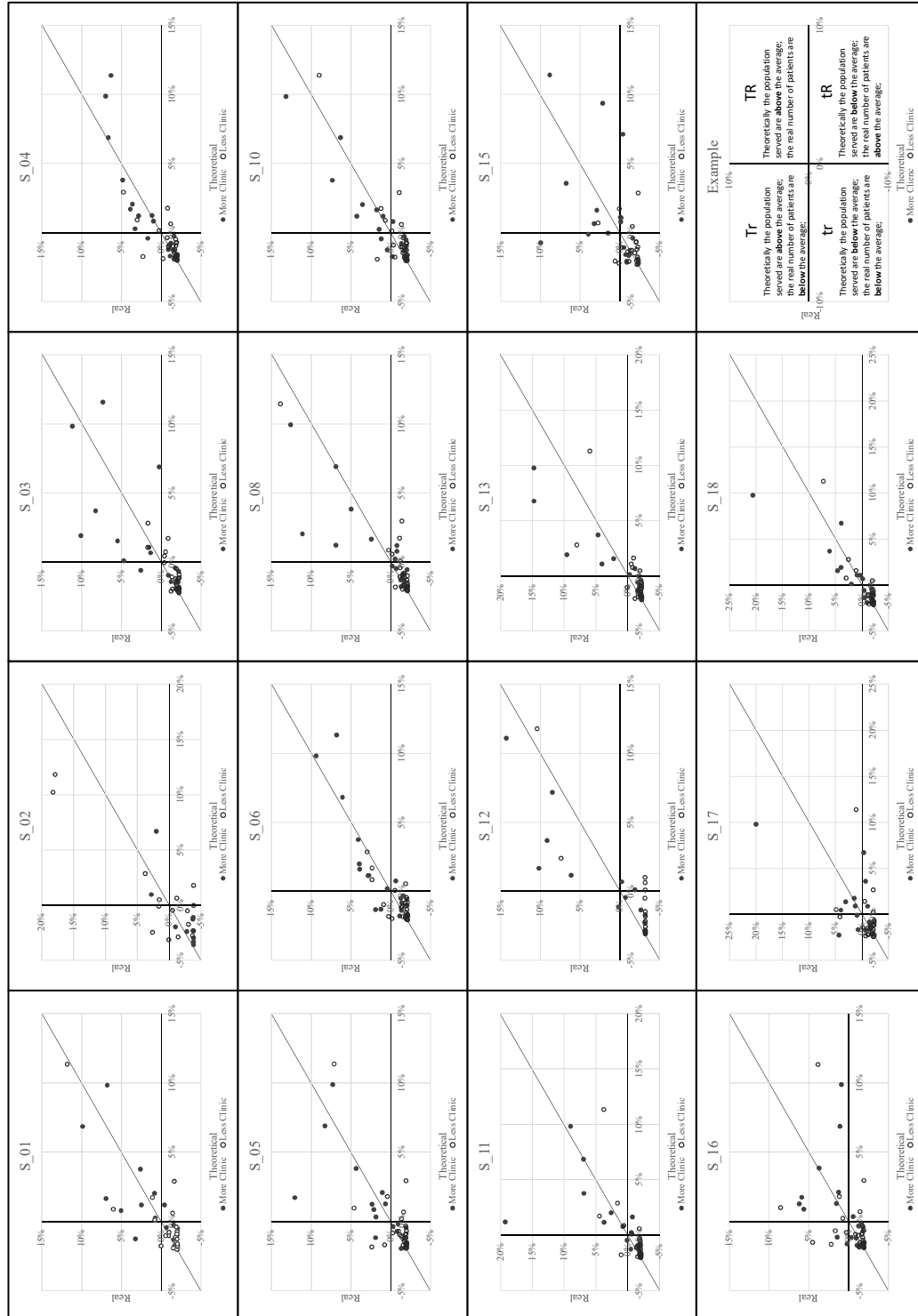


Figure 4-10 Scatter plot of the distribution of the hospitals with more or less clinics surrounding

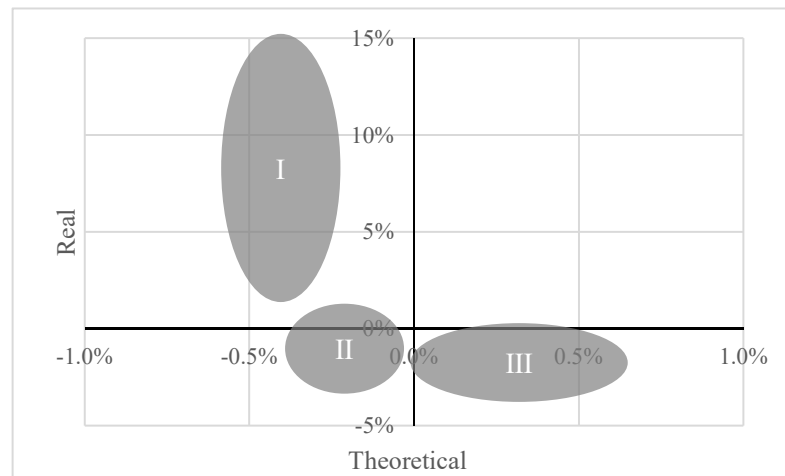


Figure 4-11-a Distribution feature of hospitals with more clinics surrounding

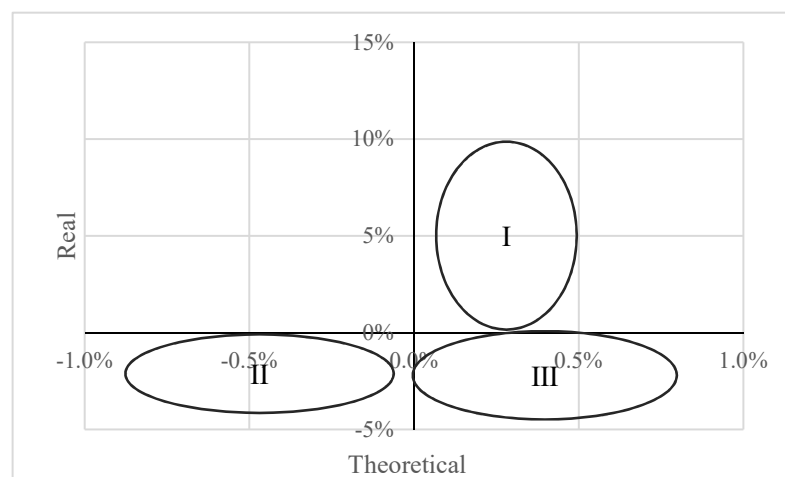


Figure 4-11-b Distribution feature of hospitals with less clinics surrounding

Meanwhile, hospitals with less clinics around located in the following areas:

- I: the number of theoretical served population is more than the average, while the real number of patients is more than the average;
- II: the number of theoretical served population is less than the average, while the real number of patients is also less than the average;
- III: the theoretical served population is more than the average, while the real number of patients is less than the average;

The difference in region I above indicates that the hospitals with less population served in theory will have more clinics around if the actual number of patients is more. But a hospital with a more population in theory will have fewer clinics if it actually receives more patients.

Therefore, it can be assumed that the hospitals with a large number of patients can be divided into the following two situations. If the hospitals are located in a region with a large population and the number of patients is large, the hospitals can basically meet the demand and the demand for clinics will decrease. If it is due to non-demographic factors such as the surrounding environment, these factors will also increase the demand for clinics.

4.5.3 Discussion of the potential functional substitution

In order to facilitate marking and analysis, we use the letter T/t to indicate the number of theoretical service population, the letter R/r to indicate the actual number of patients, and C/c to indicate the number of clinics. At the same time, uppercase letters indicate higher than average, lowercase letters indicate Below average. Then, the performance of 52 hospitals in this dimension is the combination of these six letters: a total of eight. As shown in Figure4-12.

Combined with the previous conclusions, in general, the number of clinics around hospitals that serve less people in theory but have more patients in practice will also be large (tRC), while the number of clinics around hospitals that serve more people in theory and also have a large number of patients in practice will be small (TRc). But there are exceptions in individual subject, such

Category	Description	S_01	S_02	S_03	S_04	S_05	S_06	S_08	S_10	S_11	S_12	S_13	S_15	S_16	S_17	S_18
TRC	Theoretically the population served are above the average; the real number of patients are above the average; the number of clinic around are above the average.															
TRc	Theoretically the population served are above the average; the real number of patients are above the average; the number of clinic around are below the average.															
TrC	Theoretically the population served are above the average; the real number of patients are below the average; the number of clinic around are above the average.															
Trc	Theoretically the population served are above the average; the real number of patients are below the average; the number of clinic around are below the average.															
tRC	Theoretically the population served are below the average; the real number of patients are above the average; the number of clinic around are above the average.															
trC	Theoretically the population served are below the average; the real number of patients are above the average; the number of clinic around are below the average.															
trc	Theoretically the population served are below the average; the real number of patients are below the average; the number of clinic around are above the average.															
trc	Theoretically the population served are below the average; the real number of patients are below the average; the number of clinic around are below the average.															
Total		48	26	44	49	50	47	47	48	48	31	45	42	51	40	45

Figure 4-12 Distribution of 52 hospitals in 15 subjects from the point of view of TRC type

as, Ophthalmic disease, Otolaryngology disorder disease, Diseases of skin and subcutaneous tissues, Female reproductive system disease and puerperal stage disease · abnormal pregnancy delivery and Mental illness. The number of TRc and TRC is similar or even the same, so it cannot be determined that there is a correlation between the hospital with less theoretical served population but more actual number of patients and the number of surrounding clinics.

In addition, by comparing the number of TrC and Trc, it can be seen that for most subjects, if the number of theoretical population allocation is large but the actual number of patients is small, the number of surrounding clinics is more inclined to be smaller than the average level. Of course, there are not obvious performance of the department, such as Digestive disease, liver · biliary tract · pancreatic disease, Diseases of skin and subcutaneous tissues, Diseases related to endocrine / nutrition / metabolism, Female reproductive system disease and puerperal stage disease · abnormal pregnancy delivery.

By comparing the number of trC and trc, it can be seen that most subjects have no significant difference in these two classifications.

Based on the above two points, it can be concluded that the actual number of patients in some hospitals is small, and there is no obvious correlation with the number of surrounding clinics, that is, there is no obvious substitution effect on the whole.

4.6 Summary

Public service facilities play a vital role in meeting people's growing material and cultural needs and improving the quality of life all-round. The rational allocation of public service facilities is an important planning and layout goal. However, the contradiction between the growing demand for public

services and the short supply of public services in urban areas is becoming more prominent. The intensification of metropolitan problems, such as urban hollowing, the adequacy of public service facilities, and the population balance, are getting more attention. Medical facilities are important for ensuring normal and orderly urban functioning. However, there is a shortage of medical facilities, and the irrational distribution of medical resources caused by the irrationality of the layout of medical institutions is affecting the quality of healthcare provision. Furthermore, in recent years, due to problems with facilities and management, medical services provision has become more restricted, and greater attention is being paid to the appropriate placement of hospitals and clinics.

In recent years, due to the challenge of facility surface and the management plane, it is noteworthy that it receives great restrictions on the improvement of medical function and attracts attention and it is desirable to proper placement of hospitals and clinics.

“Disease” in hospital and clinic cooperation is hospital, “Diagnosis” is the meaning of a clinic, that means the hospital and clinic cooperation are responsible for the roles, functions of the hospital and the clinic and cooperate with each other for the patient while providing more efficient and effective medical care. Currently, in Japan, it has been promoted the sharing of functions between medical institutions and disease diagnosis cooperation is also a policy aim of the country.

The conclusion of this study can be mainly summarized in the following points:

- 1) Refine the two-step floating catchment area method considering the distance attenuation. With the introduction of the priority function, calculate the theoretical service population of 52 target hospitals when the theoretical supply and demand relationship tends to average. And set 70% of the theoretical value as the medical service circle of the hospital, giving a new way to determine the medical circle.

- 2) By investigating the enrichment of transportation facilities and other public facilities around each hospital, a qualitative description of the site environment of the core medical circle of 52 hospitals is made, which is recorded as

convenient transportation type, welfare facility linkage-type, passenger gathering facility enrichment type, administrative organ concentration type, and education facility combination type. By comparing the difference between the theoretical service population obtained by the above methods and the actual number of patients received, and on the basis of the current situation of each hospital's ability to collect patients under each department, this paper explores whether the site environment and the enrichment of the surrounding facilities have an impact on it, as well as the impact size

3) Focusing on other clinics with the same diagnosis and subjects in the core medical circle of 52 hospitals, this paper first explored the possibility of potential functional substitution of clinics for medical triage by integrating the information of theoretical number of diagnosis and treatment, actual number of patients, and the enrichment degree of clinics.

4) In previous studies using the 2SFCA estimation model, only the distribution of population and distance were used as explanatory variables, resulting in a large difference between the estimated value and the actual value. Therefore, this study conducted a statistical analysis of the hospital attributes according to their number of beds and the number of medical treatment specialties, which are with their most significant attributes. Furthermore, by comparing the estimated value with the actual value, the accuracy of the estimated result was improved over the conventional model, and the features and the influence of medical treatment specialties were clarified by introducing the explanatory variable of hospital attributes. As a limitation of this research, it does not directly take into account the operational elements such as letters of introduction.

5) In this study, we developed a model that estimates the number of patients for each diagnostic group by considering the locations and attributes of hospitals. We then conducted a case study of 52 general hospitals located in Fukuoka City. We were able to grasp the supply and demand balance for each region. In other words, in the future relocation of medical facilities, the arrangement of general hospitals and specialized hospitals should be considered, not only in terms of hospital location and the distances between hospitals but also the supply and demand balance for each diagnostic

group. Moreover, the 2SFCA model developed in this study will be a useful tool for developing hospital facilities in the future, in accordance with the reorganization of city planning, changes in population distribution, and traffic planning.

References

- [1] Data source: Statistics Bureau of Japan: <https://www.stat.go.jp/data/jinsui/new.html> (accessed 2018.1)
- [2] ISHII Norimitsu: Current situation and problems of hospital location in the period of population decline [O]perations research as a management science [r]esearch, Vol.57, No.3, pp.119-123, 2012.3 (in Japanese)
- [3] 石井 儀光 : 人口減少期における病院立地の現状と課題 , オペレーションズ・リサーチ : 経営の科学 , 第 57 巻 , 第 3 号 pp.119-123, 2012.3
- [4] Ahmadi-Javid, A., Seyedi, P., and Syam, SS.: A survey of healthcare facility location, Computers & Operations Research, Vol.79, pp.223-263, 2017.3
- [5] Brotcorne, L. Laporte, G., and Semet, F.: Ambulance location and relocation models, Eur J Oper Res, Vol.147, No.3, pp.451 – 63, 2003.6
- [6] Li, X., Zhao, Z., Zhu, X., and Wyatt, T.: Covering models and optimization techniques for emergency response facility location and planning: a review, Math Methods Oper Res, Vol.74, No.3, pp.281 – 310, 2011.7
- [7] Rais A. and Viana A.: Operations research in healthcare: a survey. Int Trans Oper Res, Vol.18, No.1, pp.1 – 31, 2010.11
- [8] Wang, F.: Measurement, optimization, and impact of health care accessibility: a methodological review, Ann Assoc Am Geogr, Vol.102, No.5, pp.1104-12, 2012.3
- [9] Guti é rrez, E. V., and Vidal, C. J.: Home health care logistics management problems: a critical review of models and methods, Rev Fac Ing, Vol.68, No.3, pp.160 – 75, 2013
- [10] Ingolfsson, A.: EMS planning and management, In: Zaric GS, editor. Operations Research and Health Care Policy, New York: Springer, pp.105-28, 2013.3
- [11] Güneş, E. D., and Nickel, S.: Location problems in healthcare, In: Laporte G, Nickel S, Saldanha da Gama F, editors. Location science Cham, Springer, pp.55-79, 2015
- [12] Gould PR. and Leinbach TR.: Approach to the geographic assignment of hospital services, Tijdschr voor Econ En Soc Geogr, Vol.57, No.5, pp.203-206, 1966
- [13] Radke, J, Mu, L.: Spatial decomposition, modeling and mapping service regions to predict access to social programs, Geographic Information Sciences, Vol.6, pp. 105-112, 2000
- [14] Luo, W., and Wang, F. H.: Measures of spatial accessibility to health care in a GIS environment, Synthesis and a case study in the Chicago region[J], Environment and Planning B: Planning and Design, Vo.30, No.6, pp.865-884, 2003.12
- [15] Luo, J.: Integrating the Huff model and floating catchment area methods to analyze

- spatial access to healthcare services[J], Transactions in GIS, Vol.18, No.3, pp.436-448, 2014.6
- [16] Luo, W., and Qi, Y.: An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians[J], Health & Place, Vol.15, No.4, pp.1100-1107, 2009.12
 - [17] Luo, W., Whippo, T.: Variable catchment sizes for the two-step floating catchment area (2SFCA) method[J], Health & Place, Vol.18, No.4, pp.789-795, 2012.7
 - [18] Tao, Z.: Research progress of the two-step floating catchment area method and extensions[J], Progress In Geography, Vol.35, No.5, pp.589- 599, 2016
 - [19] Ukai, T., Sasaki, M.: A Proposal of New Indices Representing Spatial Demand-and-Supply Balance: A Case Study of Beds for Acute Phase Patients in Kanagawa, Vol.49, No.3, pp.987-992, 2014 (in Japanese)
 - [20] 鵜飼 孝盛, 佐々木 美裕.: 空間的な需給バランスを表す新しい指標の提案, 都市計画論文集, 第 49 巻, 第 3 号, pp.987-992, 2014
 - [21] Masuyama, A.: Measuring the spatial accessibility to home care services: A case study of Hirosaki-shi, Aomori, Vol.50 No.2. pp.210-220, 2015
 - [22] 増山 篤, 青森県弘前市における介護サービスへのアクセシビリティ計測の試み, 第 50 巻 第 2 号 pp.210-220, 2015
 - [23] Fukuoka Prefecture regional medical treatment plan. <http://www.pref.fukuoka.lg.jp/contents/hoken-iryo-keikaku.html> (accessed 2018.5)
 - [24] National Land Numerical Information download service: <http://nlftp.mlit.go.jp/ksj-e/index.html> (accessed 2018.5)
 - [25] Summary of survey of patients in Heisei 26 years (2014): <http://www.mhlw.go.jp/toukei/saikin/hw/kanja/14/dl/kanja.pdf>
 - [26] Peeters, D., and Thomas, I.: Distance predicting functions and applied location-allocation models[J]. Journal of Geographical Systems, 2, pp.167-184, 2000
 - [27] Tao, H. Y., Chen, X. X. and Li, X.: Research on spatial accessibility to health service: a case study in the Haizhu district of Guangzhou. Geomatics & Spatial Information Technology. 2007
 - [28] Wang, Y. F. and Zhang, C.: GIS and gravity polygon based service area analysis of public facility: case study of hospitals in Pudong new area. Economic Geography, Vol.25, No.6, pp.800-803, 2005
 - [29] Hospital Intelligence Agency: <https://hospia.jp>(accessed 2018.5)
 - [30] Durbin, J.; Watson, G. S.: "Testing for Serial Correlation in Least Squares Regression, I". Biometrika. Vol.37, No. 3/4, pp. 409-428, 1950
 - [31] Durbin, J.; Watson, G. S.: "Testing for Serial Correlation in Least Squares Regression, II". Biometrika. Vol.38, No.1/2, pp.159 – 179, 1951
 - [32] Durbin, J.; Watson, G. S.: "Testing for Serial Correlation in Least Squares Regression, III". Biometrika. Vol.58, No.1/2, pp.1 – 19, 1951
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Note

*1) Here we use the tool of feature-to-point in ArcGIS10.3 to extract the population centroid, and the tool of point distance to calculate the distance between the population centroid and the target hospital.

*2) We use the Visual Studio compiler to implement this algorithm in the environment of python 3.6.

*3) Statistical software SPSS is used to implement the operation of multiple linear regression.

Chapter 5

SUMMARY

Chapter 5

SUMMARY

Cities in Japan have continued to expand through the period of rapid growth, and policy development has been promoted in suburban residential areas. Thus, cavitation phenomena in central urban areas has become noticeable in various places. The idea of compact city is proposed. The concept emphasizes that urban activities should be located closer together to ensure better access to services and facilities via public transport, walking, and cycling, and more efficient utility and infrastructure provision. The suburbanization of large scale facilities has expanded not only to commercial facilities but also to public infrastructure. Among them, medical facilities are increasingly moving to a suburb with cheap land prices due to the accessibility of main road. The need to consider the location of medical facilities in the future compact city is increasing.

In recent years, due to the challenge of facility surface and the management plane, it is noteworthy that it receives great restrictions on the improvement of medical function and attracts attention and it is desirable to proper placement of hospitals and clinics.

“Disease” in hospital and clinic cooperation is hospital, “Diagnosis” is the meaning of a clinic, that means the hospital and clinic cooperation are responsible for the roles, functions of the hospital and the clinic and cooperate with each other for the patient while providing more efficient and effective medical care. Currently, in Japan, it has been promoted the sharing of functions between the medical institutions and disease diagnosis cooperation is also a policy aim of the country.

Public medical service system mainly attains the goal of improving residents' health by improving their medical facilities and eliminating space differences

in medical services. The result of the space allocation of medical facilities shall provide residents with due health services fairly. But most countries face the issue of wide gaps in the accessibility of health level and medical facilities between central cities and local cities, and the accessibility of medical facilities has become an issue of social equity. The premise of realizing fair allocation and the spatial accessibility of medical facilities is that planners shall adopt accurate and dependable ways of measurement to measure the differentiation in spatial accessibility, so as to accurately judge medically undeserved areas, redistribute medical resources and relieve the unequal allocation of medical resources. Inefficiency of medical resource allocation and unequal spatial distribution of medical resources due to inconsideration of the spatial position of medical facilities in traditional planning can be solved through accessibility analysis on space-based on GIA technology. This paper intends to take Fukuoka as example on the basis of GIS technology, and adopt spatial accessibility indicators to analyze the spatial distribution characteristics of its medical facilities, evaluate the spatial accessibility of the medical facilities of the city, so as to be of reference to the government's decision-making in seeking reasonable spatial layout of medical service.

The conclusion of this study, can be mainly summarized into the following points:

In chapter2, we made effort to do quantitative analysis about the existing distribution of medical facilities, explore the relationship between hospital and clinic, and find out how they influence each other from a location analysis perspective. The Fukuoka City, the capital city of Fukuoka Prefecture on the northern shore of the island of Kyushu in Japan, is chosen as a study area. Subjects in the study cover totally 151 medical departments in 115 hospitals and 1526 clinics. We at-tempt to analyze the types of basic discrete location focusing on each medical department.

We develop a Visual Basic for Applications programs based on the longitude and latitude, it measures the distance between each feature and its nearest neighbor, and then builds a cumulative frequency distribution function (G Function). According to the result of G function, 28 categories are divided into three groups, and by further analysis based on the aggregation degree defined

by the difference of slope, the distribution of each medical department can be described and classified in terms of the level of clustering and dispersion, five classifications are proposed.

Furthermore, it is considerably significant to discover the mutual relationship of each subject. We choose Multi-Distance Spatial Cluster Analysis (Ripley's K Function) and expand it to a Mutual-K Function to find out the relationship between hospital and clinic for each subject.

In chapter3, the distribution of medical services against population distribution was estimated by supply and demand ratio defined by 2SFCA method. The areas with and without the adequate number of medical services were determined by GIS.

We established, the residents in Chuo-ku and part of Hakata-ku are available to receive more medical services on all department than others. The supply and demand ratio of half of them is more 50% than the average value of whole city; In Higashi-ku, Hakata-ku and most of the Sawara-ku, supply and demand ratio is lower than the city's average level. It's not balanced in Chuo-ku, Hakata-ku and Sawara-ku, and Hakata-ku is the most disparate.

As there is no data on the maximum number of service people, it's only available to calculate the relative supply and demand ratio used to compare the various areas of access to medical services, but not to make a quantitative analysis on the specific medical department. The research on how to measure the maximum number of service people of hospitals or clinics, will be much helpful for analyzing supply-demand on medical services.

In previous studies using the 2SFCA estimation model, only the distribution of population and distance were used as explanatory variables, resulting in a large difference between the estimated value and the actual value. Therefore, chapter4 conducted a statistical analysis of the hospital attributes according to their number of beds and the number of medical treatment specialties, which are with their most significant attributes. Furthermore, by comparing the estimated value with the actual value, the accuracy of the estimated result was improved over the conventional model, and the features and the influence of medical treatment specialties were clarified by introducing the explanatory variable of

hospital attributes. As a limitation of this research, it does not directly take into account the operational elements such as letters of introduction.

Also, we developed a model that estimates the number of patients for each diagnostic group by considering the locations and attributes of hospitals. We then conducted a case study of 52 general hospitals located in Fukuoka City. We were able to grasp the supply and demand balance for each region. In other words, in the future relocation of medical facilities, the arrangement of general hospitals and specialized hospitals should be considered, not only in terms of hospital location and the distances between hospitals but also the supply and demand balance for each diagnostic group. Moreover, the 2SFCA model developed in this study will be a useful tool for developing hospital facilities in the future, in accordance with the reorganization of city planning, changes in population distribution, and traffic planning.

Finally, in chapter3, we refined the two-step floating catchment area method considering the distance attenuation. With the introduction of the priority function, calculate the theoretical service population of 52 target hospitals when the theoretical supply and demand relationship tends to average. And set 70% of the theoretical value as the medical service circle of the hospital, giving a new way to determine the medical circle.

By investigating the enrichment of transportation facilities and other public facilities around each hospital, a qualitative description of the site environment of the core medical circle of 52 hospitals is made, which is recorded as convenient transportation type, welfare facility linkage type, passenger gathering facility enrichment type, administrative organ concentration type, and education facility combination type. By comparing the difference between the theoretical service population obtained by the above methods and the actual number of patients received, and on the basis of the current situation of each hospital's ability to collect patients under each department, this paper explores whether the site environment and the enrichment of the surrounding facilities have an impact on it, as well as the impact size

Focusing on other clinics with the same diagnosis and subjects in the core medical circle of 52 hospitals, this paper first explored the possibility of

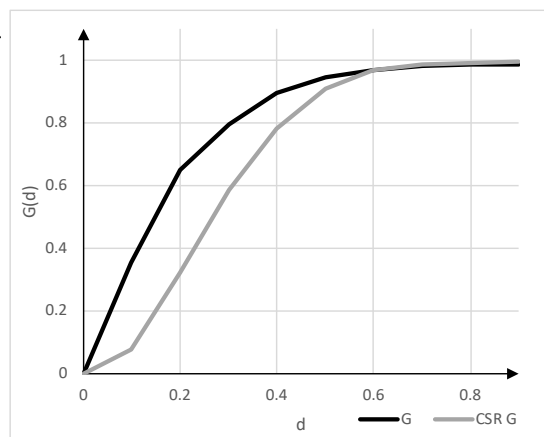
potential functional substitution of clinics for medical triage by integrating the information of theoretical number of diagnosis and treatment, actual number of patients, and the enrichment degree of clinics.

Appendix

G-curve and Mutual L-curve of each medical treatment categories



Distribution of Internal Medicine

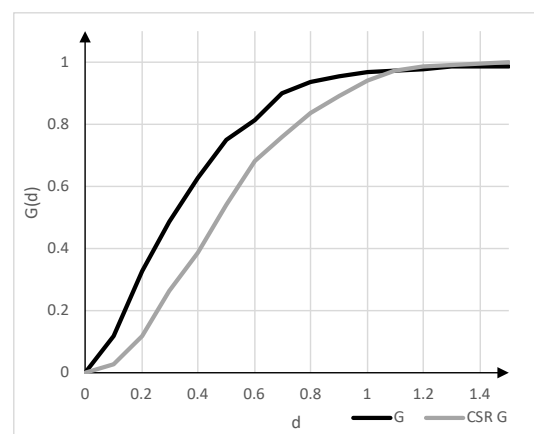


G-curve of Internal Medicine

There are 895 medical facilities in general internal medicine, which mainly treat common acute diseases such as fever, cough, abdominal pain and diarrhea, as well as long-term and persistent diseases such as loss of weight and appetite. They concentrated in the downtown, more than half of the facilities are located within 0.2km of the nearest facility, and almost all are in the areas less than 0.6 km from the nearest facility.



Distribution of Cardiology

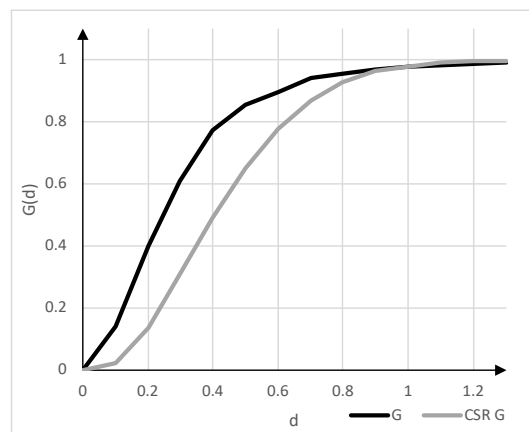


G-curve of Cardiology

There are 275 medical facilities with circulatory organs, mainly specialized in heart and vascular diseases. Although the distribution is more dispersed than that of general Internal medicine, the distance from the nearest facility is only 0.4km, and almost all are in the areas less than 1 km from the nearest facility.

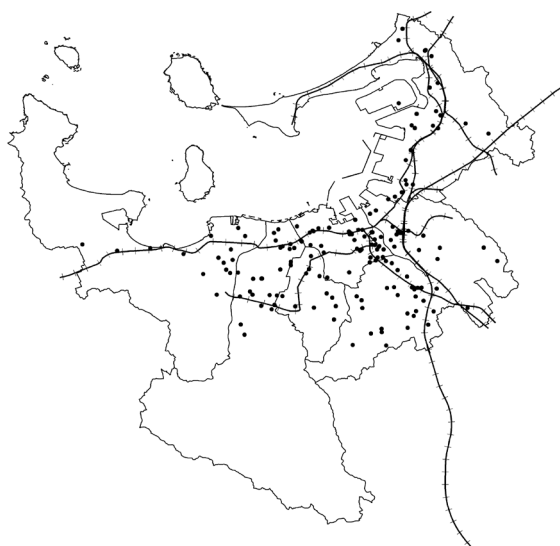


Distribution of Gastroenterology

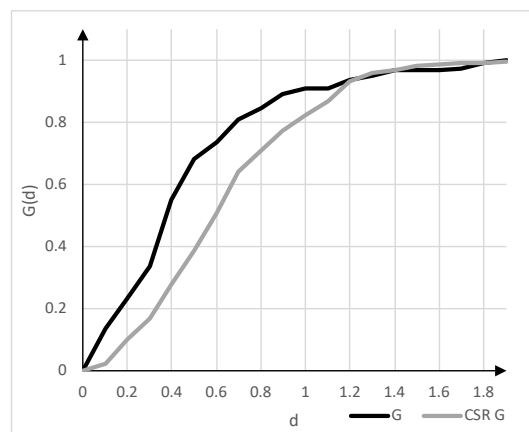


G-curve of Gastroenterology

There are 381 medical institutions with gastroenterology department, which are mainly responsible for gastrointestinal diseases such as stomach, esophagus and intestine. Although widely distributed in the downtown, the facilities are dispersed to the northeast. 80% of the facilities are located less than 0.4km from the nearest facilities, and almost all are in the areas less than 0.8 km from the nearest facility.

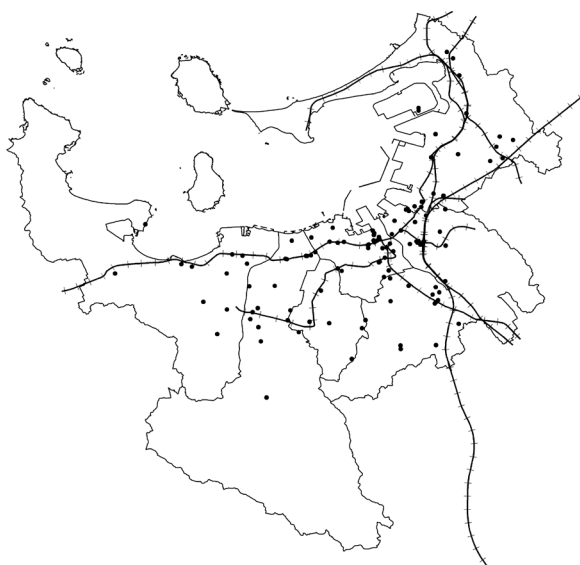


Distribution of Respiratory Medicine

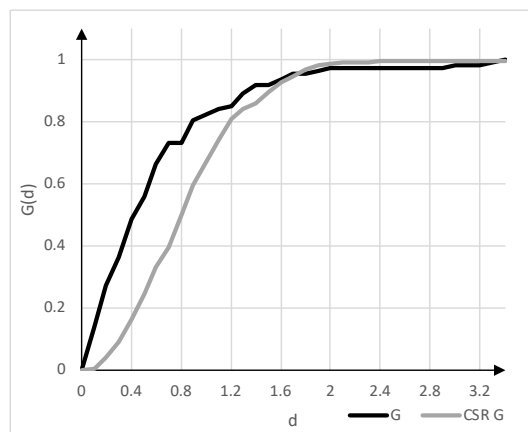


G-curve of Respiratory Medicine

There are 163 medical facilities with respiratory Medicine department, which are specialized in the treatment of respiratory diseases. Including trachea and bronchi, lung, pleura of various diseases. Although it was widespread in the downtown, the facility was dispersed to the northeast. 80% of the facilities are located less than 0.6 km from the nearest facility, and most facilities are in less than 1.2 km from a facility.



Distribution of Neurology

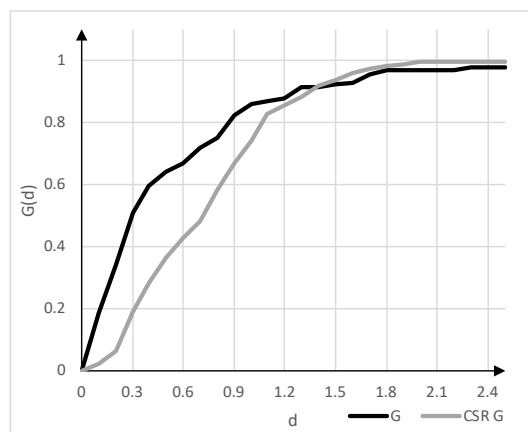


G-curve of Neurology

There are 113 medical facilities with neurology department, which mainly treat diseases of the brain, spinal cord, nerve, muscle and other diseases and physical inconvenience. The distribution outside the downtown became sparse. More than half of the facilities are located within 0.8 km of the nearest facility, while most are within 1.6 km.

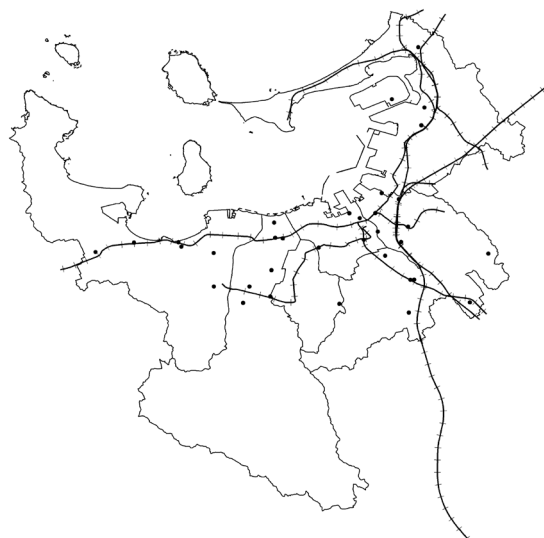


**Distribution of
Psychosomatic Internal Medicine**

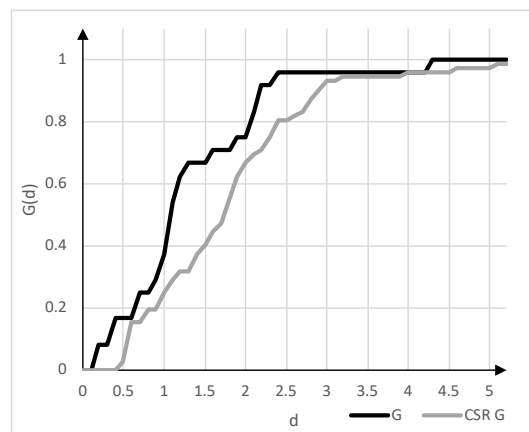


**G-curve of
Psychosomatic Internal Medicine**

There are 129 medical facilities with the department of cardiac therapy, not only for the physical aspects of patients, but also for the psychological and social aspects. It is a field of medicine aimed at comprehensive diagnosis of people. The distribution outside the downtown became sparse. More than 80% of the facilities are located within 0.9 km from the nearest facility, while most are within 1.6 km.

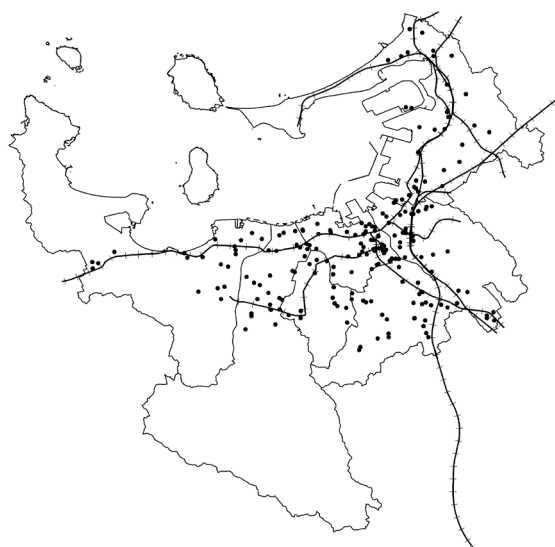


Distribution of Nephrology and Diabetes

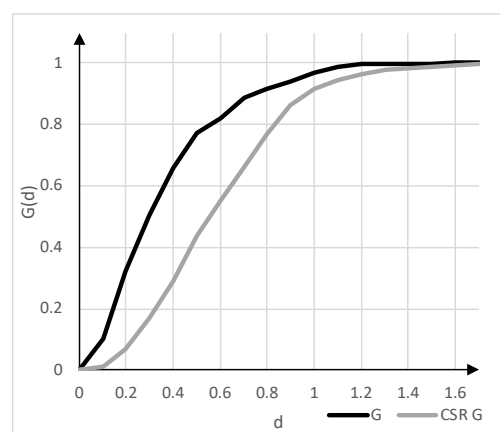


**G-curve of
Nephrology and Diabetes**

There are only 24 medical facilities with the Nephrology and Diabetes department, which are the subjects for the treatment of nephritis, nephrotic syndrome, renal insufficiency, diabetic nephropathy and other symptoms. Although it is distributed in a few places, it has the tendency of random distribution. However, from the distribution of the distance from the nearest facility, it can be seen that the curve extends rapidly within a range of 1 ~ 1.5 km. Therefore, many facilities are within 1 ~ 1.5 km from the nearest facility, and it is basically stable for more than 2.5 km.

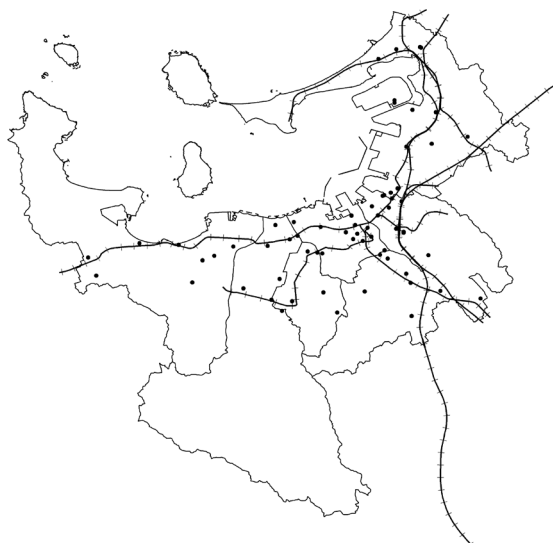


Distribution of General Surgery

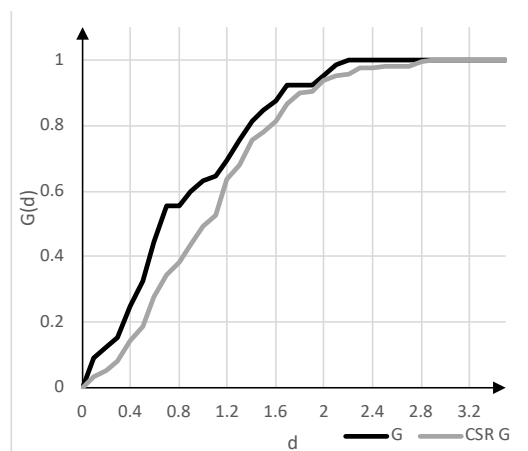


G-curve of General Surgery

There are 211 medical facilities with the general surgery department, mainly for the diagnosis and treatment of patients. Although widely distributed in the downtown, the facilities are dispersed to the northeast. 80% of facilities are in 0.6 km from the nearest facility, and most are located within 1.2 km from the nearest facility.

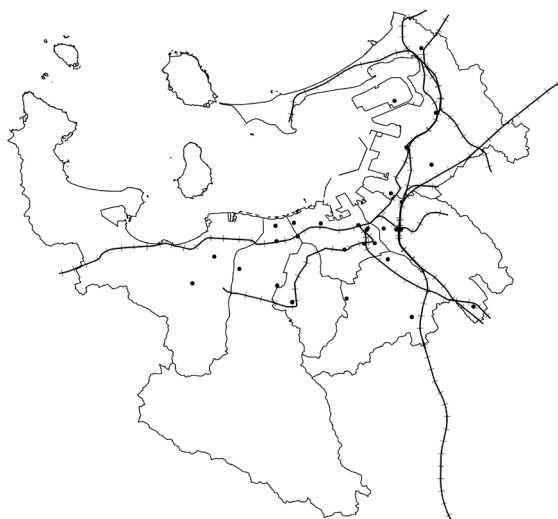


Distribution of Neurosurgery

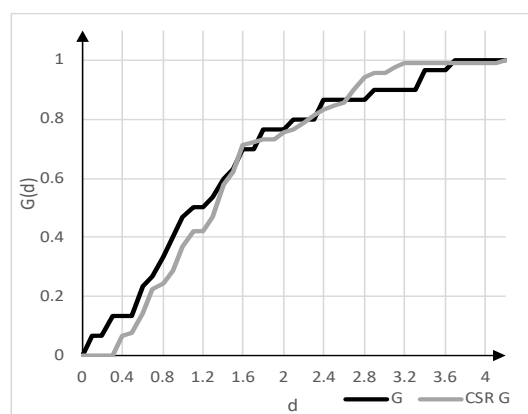


G-curve of Neurosurgery

There are 65 medical facilities with neurosurgery for diseases of the brain and nervous system (mainly the spinal cord) and diseases requiring surgery. The distribution is relatively sparse in the downtown, but from the perspective of G-curve, it almost overlaps with CSR-G-curve, so it can be considered as random distribution.

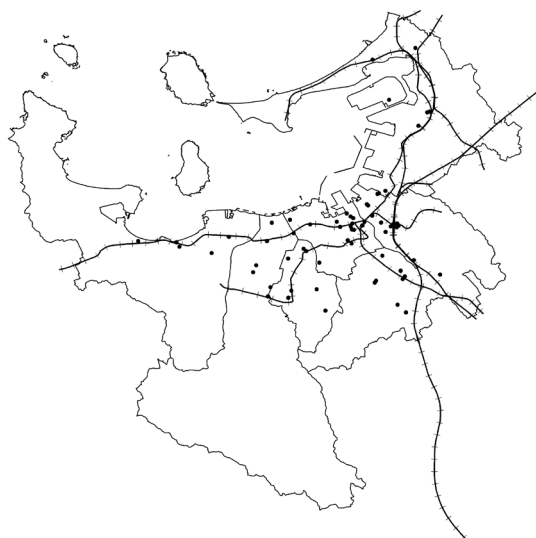


Distribution of Neurosurgery

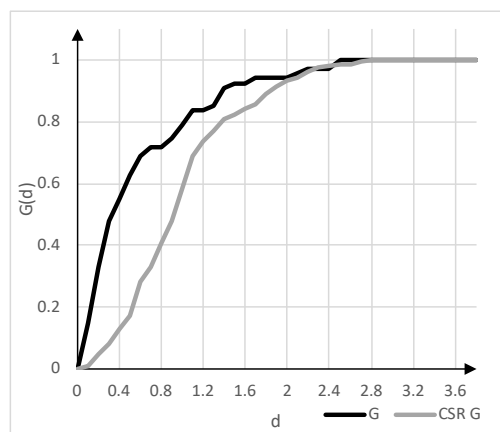


G-curve of Neurosurgery

There are 30 medical facilities with cardiovascular surgery for the surgical treatment of vascular diseases of the heart and (except for the head) the whole body. The number of cardiovascular surgery is relatively small, however, the G-curve and CSR-G-curve elongate at the same tendency and are thought to be randomly distributed.



Distribution of Urology

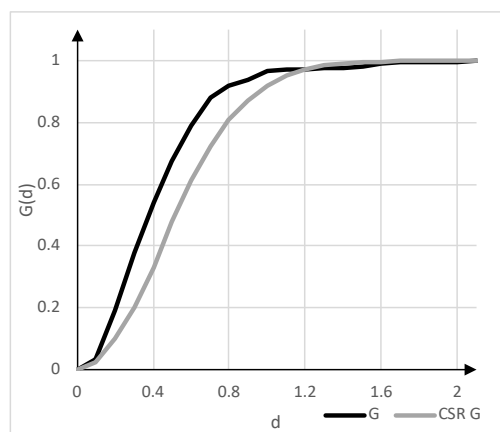


G-curve of Urology

There are 67 medical facilities with urology department, which are mainly for the diagnosis and treatment of diseases of kidney, ureter, bladder and urethra, which are basically part of the surgery. The number of urologists is also relatively small, but, unlike the G-curve of cardiovascular surgery, has a large elongation in a small area and is considered to be dense.



Distribution of Orthopedic surgery

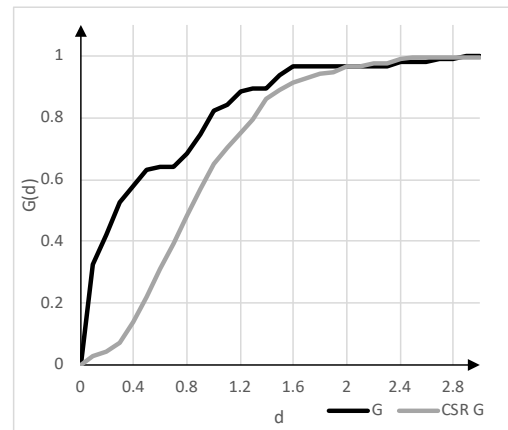


G-curve of Orthopedic surgery

There are 229 medical facilities with orthopedic surgery, which are used to treat pain and paralysis caused by abnormal bone and joint in the whole body. The G-curve of orthopedic surgery is a little higher than the CSR-G-curve, but the inclination tends to be the same as the CSR-G-curve.



Distribution of Plastic and Reconstructive Surgery

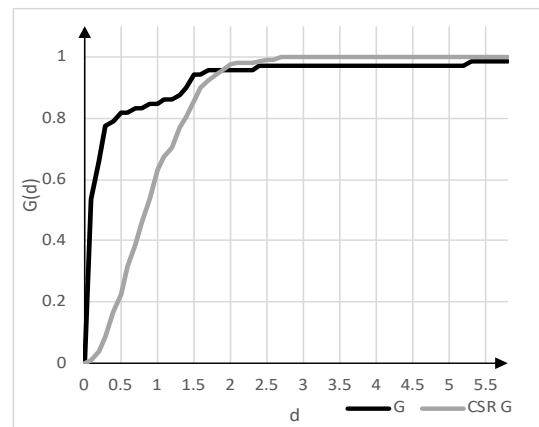


G-curve of Plastic and Reconstructive Surgery

There are 95 medical facilities with plastic and reconstructive surgery, which mainly deals with the deformation and trauma of the body surface. Plastic and reconstructive surgery is randomly distributed outside the downtown, and is concentrated in the downtown. According to G- function, 60% of facilities are in 0.4 km from the nearest facility.



Distribution of Aesthetic Plastic Surgery

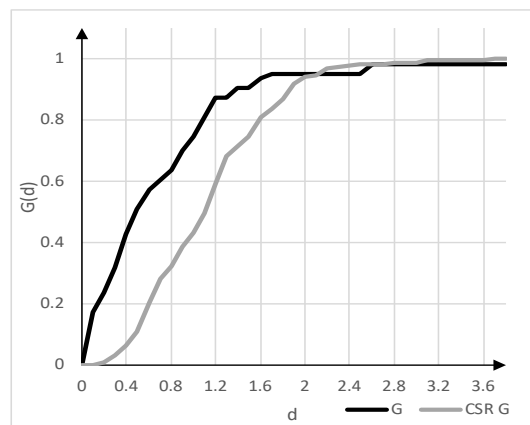


G-curve of Aesthetic Plastic Surgery

There are 71 medical facilities with aesthetic plastic surgery, which are normal from the medical point of view, and are the diagnosis and treatment department that carries out surgery and so on from the appearance. The G-curve extends sharply in the range of 0 ~ 0.5km, and then increases gradually. More than 80% of facilities are in 0.5 km from the nearest facility. On the other hand, if the distance is more than 0.5km, the increase rate decreases. It is considered a typical dense distribution.



Distribution of Gynecology

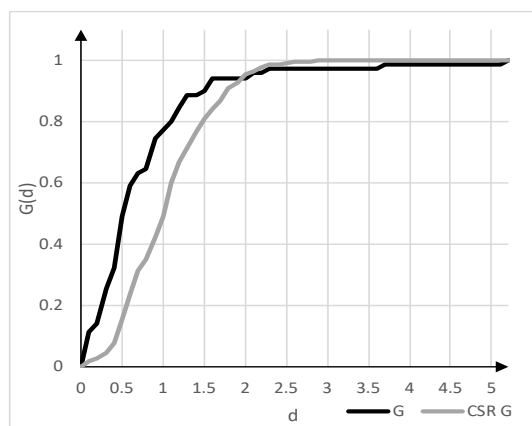


G-curve of Gynecology

There are 63 medical facilities with gynecology, which are specialized in the treatment of female-specific diseases. Although gynecology is distributed in a few places, it is widely distributed in the downtown. From the perspective of the G-curve, the inclination is the same as that of the CSR-G-curve. Most are located within 1.6 km from the nearest facility.

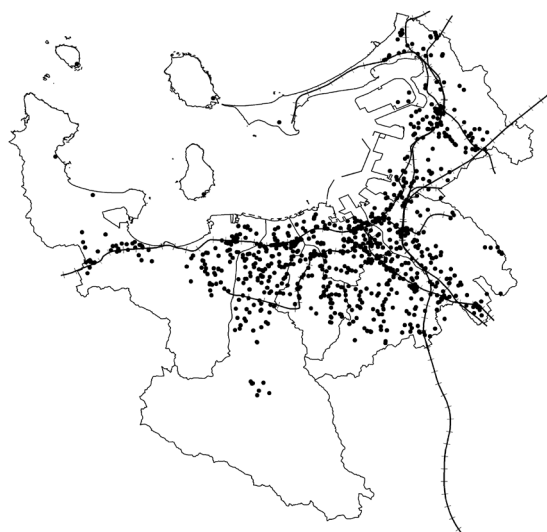


Distribution of Obstetrics and Gynecology

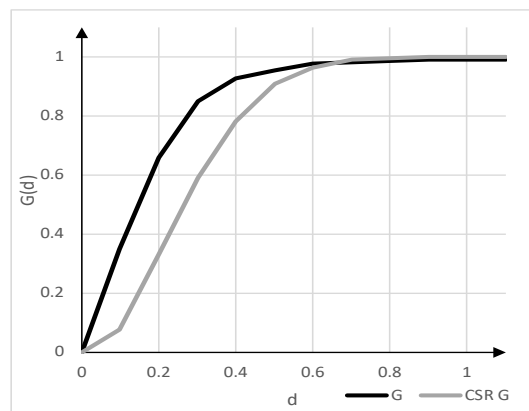


G-curve of Obstetrics and Gynecology

There are 71 medical facilities with obstetrics and gynecology, which are responsible for pregnancy examination, diagnosis of pregnant women, obstetrics of delivery and treatment of prospective gynecology. Obstetrics and gynecology show the same tendency as gynecology, the number is less, but distributed in the downtown. Most of the facilities are located within 2 km from the nearest facility.



Distribution of Pediatrics

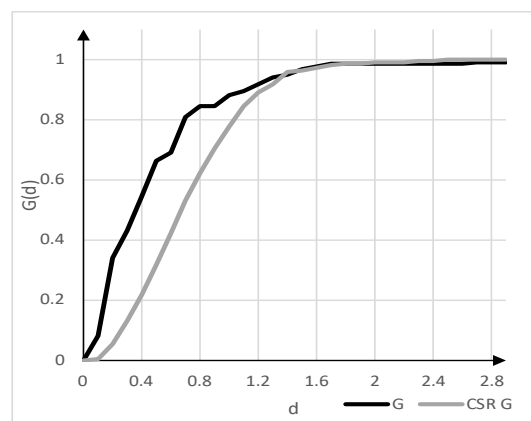


G-curve of Pediatrics

There are 884 medical facilities with pediatrics, which are responsible for the diagnosis and treatment of diseases related to infants from newborns to 15 years old. On the whole, the distance of pediatrics from the nearest facility is smaller than that of other subjects. Most of the facilities are located within 2 km from the nearest facility, and the distance below 0.2km accounts for 60%.



Distribution of Ophthalmology

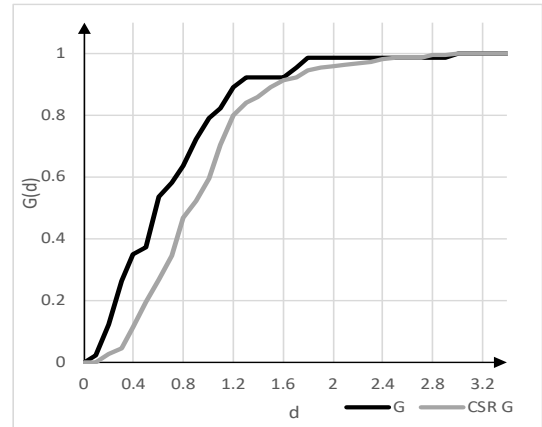


G-curve of Ophthalmology

There are 137 medical facilities with ophthalmology for the treatment and operation of eye diseases. They are thought to be numerous, scattered in the central and northern parts of the city, and few in the west and south. According to the G-curve, more than 60% of the facilities are located within 0.4km from the nearest facility.

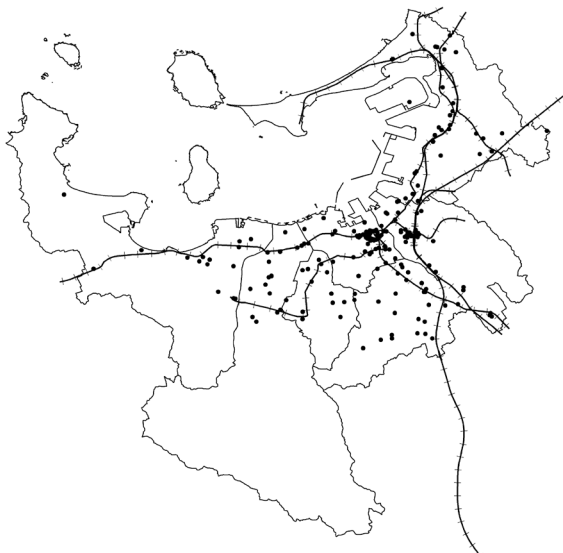


Distribution of Otorhinolaryngology

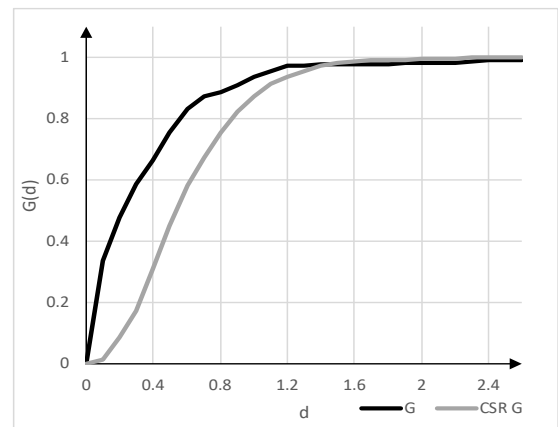


G-curve of Otorhinolaryngology

There are 91 medical facilities with otolaryngology department, which are the diagnosis and treatment department for the treatment and surgery of ear, nose and throat related diseases. From the characteristics of the G-curve, it is considered to be a random distribution due to the same tendency of elongation as the CSR-G-curve. Most of the facilities are located within 1.8 km from the nearest facility.

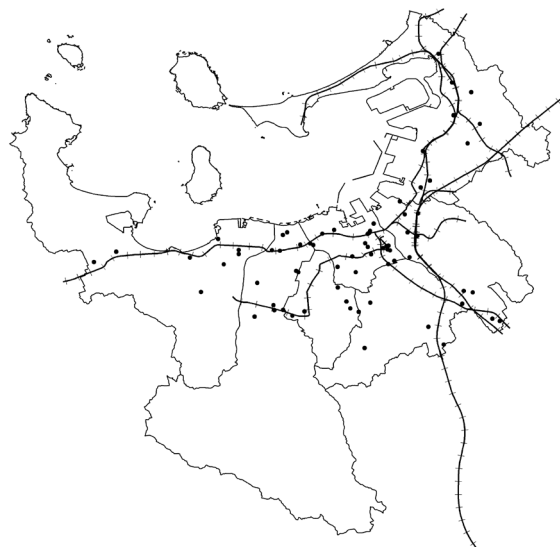


Distribution of Dermatology

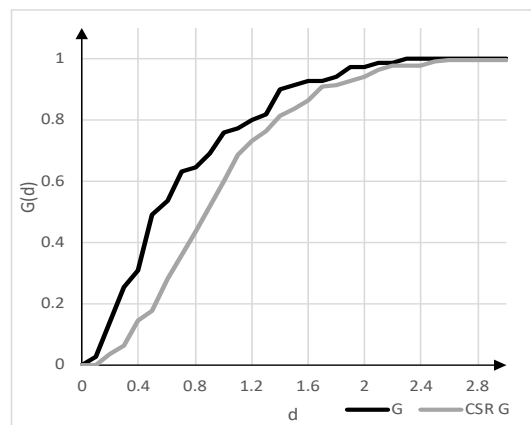


G-curve of Dermatology

There are 209 medical facilities with dermatology, which are the diagnosis and treatment of skin diseases. The slope of the curve was very steep at first, but later it was found that it was concentrated in the center of the city and gradually decreased.

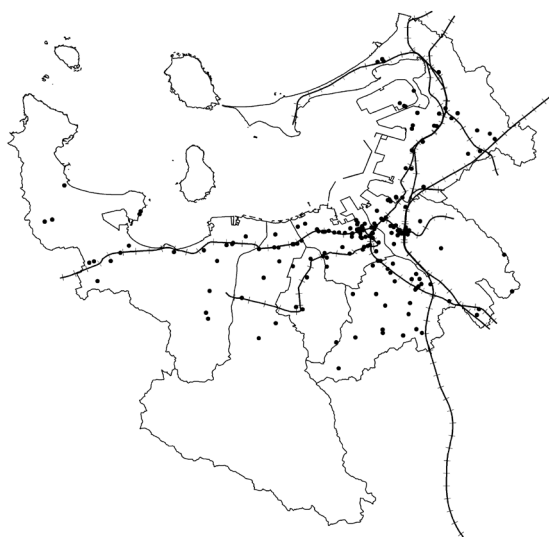


Distribution of Colorectal surgery

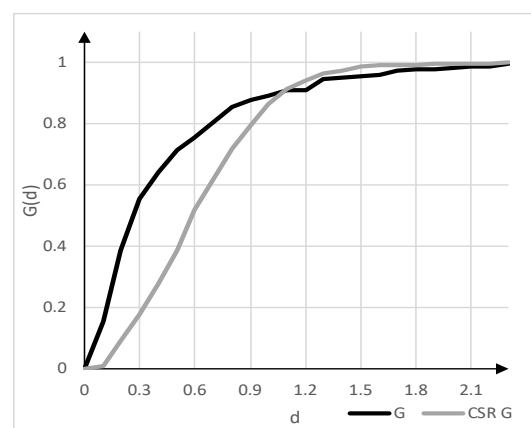


G-curve of Colorectal surgery

There are 71 medical facilities with the colorectal surgery department. The anus is roughly divided into digestive organs, and the department is responsible for everything from treatment to surgery. Because the number is relatively small, the distribution is sparse. From the G-curve, the inclination of the curve is larger in the range of 0 ~ 0.4km, and more than half of the facilities are located within 0.6 km from the nearest facility.

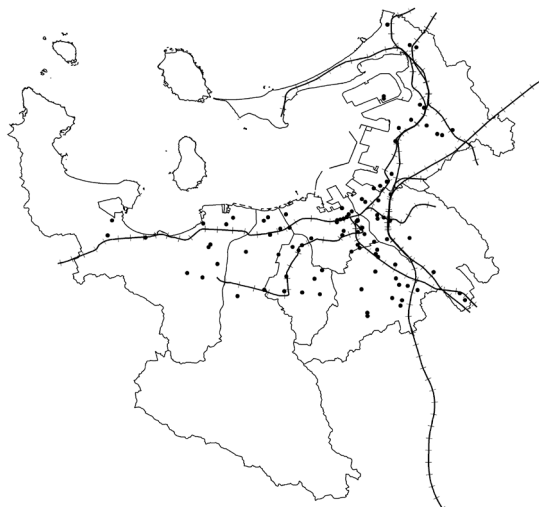


Distribution of Psychiatry

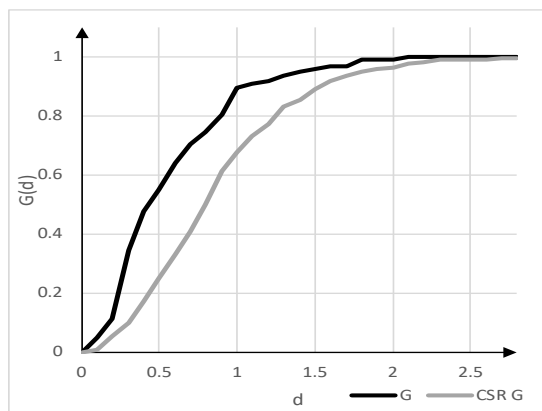


G-curve of Psychiatry

There are 179 medical facilities with psychiatry that treat more severe psychological conditions. Psychiatry facilities are concentrated in downtown, with significant numbers of facilities in the west and northeast. From the G-curve, more than half of the facilities are located within 0.3 km from the nearest facility, and about 10% are between 1km and 2.1km.

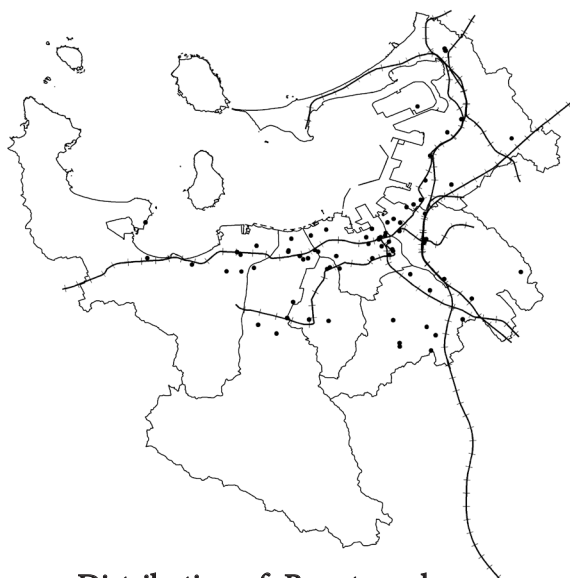


Distribution of Anesthesiology

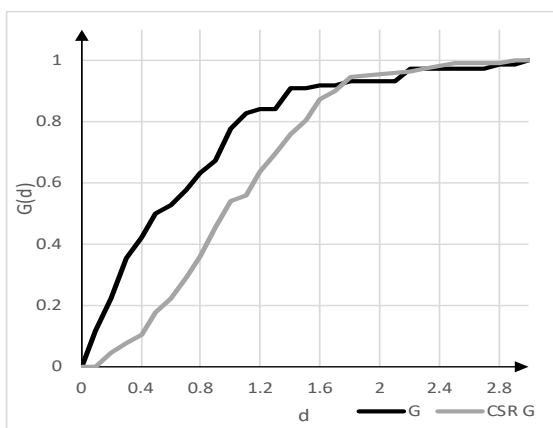


G-curve of Anesthesiology

There are 98 medical facilities with anesthesiology department for the anesthesia during the operation, the specialized diagnosis and treatment department of the patient, in addition, Penn clinic also has the specialized treatment of the pain in life and the elimination of pain. The g-curve is inclined to change from 0.2 km, and most of the facilities are located within the range of 0.2 km to 0.5 km from the nearest facility.

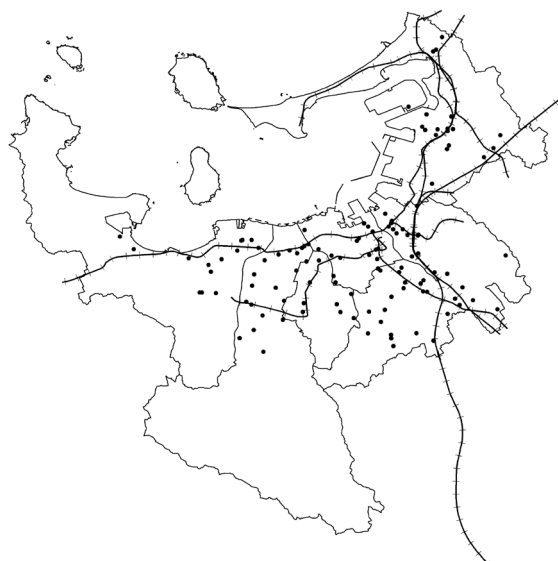


Distribution of Roentgenology

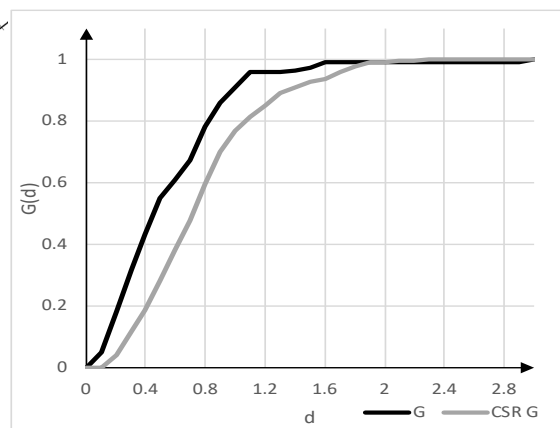


G-curve of Roentgenology

There are 76 medical facilities with radiology department, which are mainly responsible for the radiotherapy of malignant tumors and other diseases to kill cells. The Roentgenology facilities are distributed from the central to the eastern of city, but almost no distribution in the western and southern. Compared with other subjects, the G-curve has little change in inclination and is almost stable over 1.6 km.

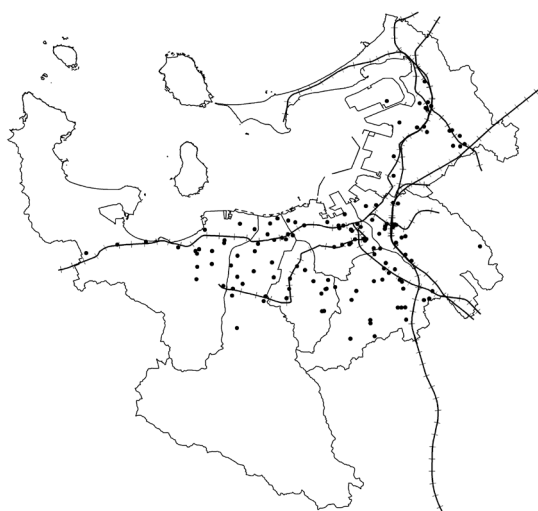


Distribution of Rheumatology

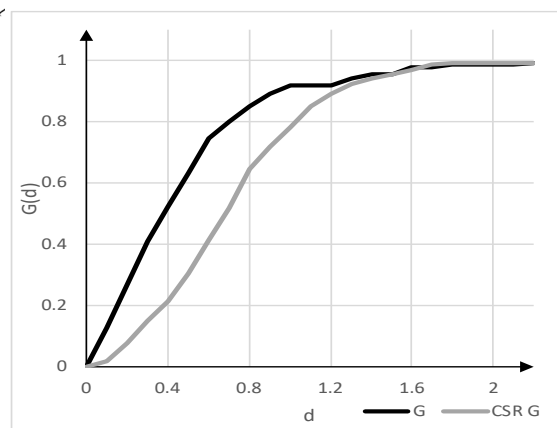


G-curve of Rheumatology

There are 120 medical facilities with rheumatology department, for arthritis, various collagenous diseases, related diseases, gout and other joint pain diseases. Rheumatology facilities is widely distributed, no obvious dense, a relatively average distribution form. In the range of 0 ~ 0.2 km, the g-curve gradually elongates, and tends to be stable beyond 1.2 km.



Distribution of Allergy

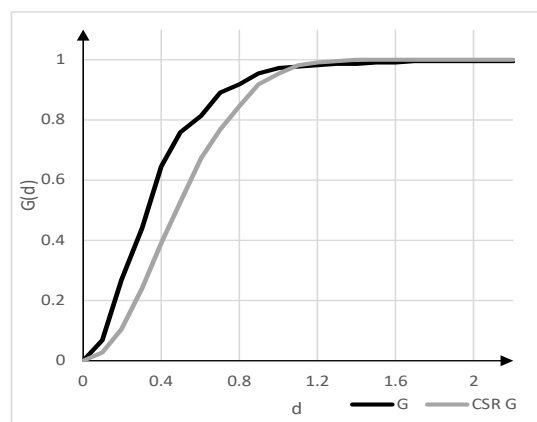


G-curve of Allergy

There are 139 medical facilities with the department of allergy, which are for the treatment of allergies caused by food, residential environment, metal, animals and other reasons. From the characteristics of g-curve, the change of inclination is not significant. Nearly 50% of the facilities are located within 0.4km from the nearest facility, and over 1km, the extension rate becomes smaller and cannot be seen as stable as other curves.

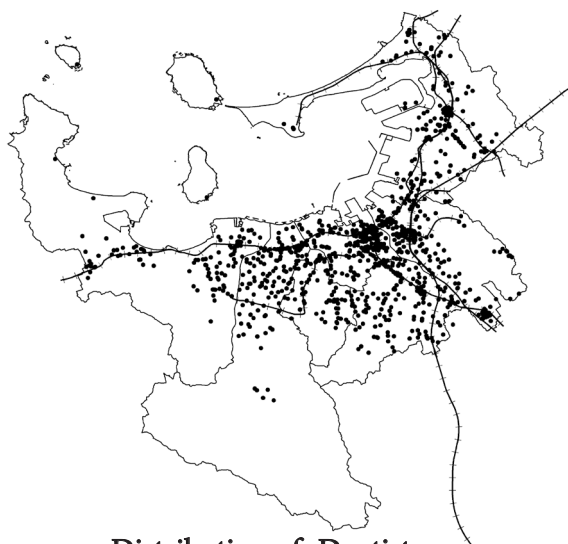


Distribution of Rehabilitation

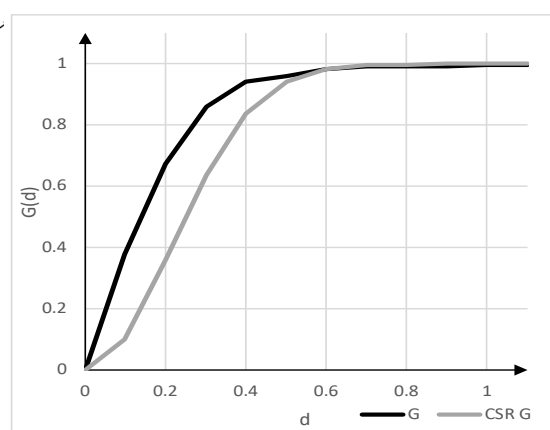


G-curve of Rehabilitation

There are 287 medical facilities of rehabilitation department in total, which are the diagnosis and treatment department for training in daily life to a certain extent in case of mental and physical dysfunction. The inclination of the G-curve did not change, but slowly rose to elongate in a manner similar to that of the CSR-G-curve, which was considered random distribution.

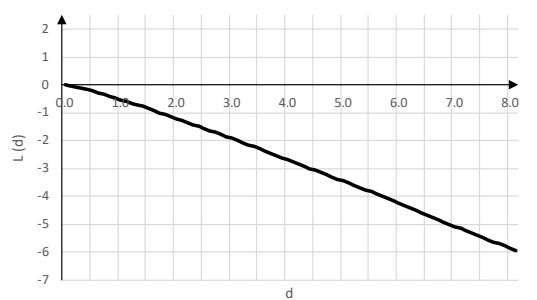


Distribution of Dentistry

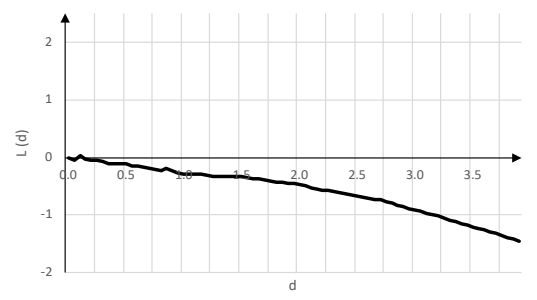


G-curve of Dentistry

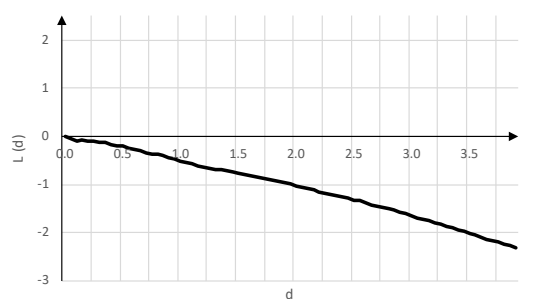
There are 1046 dental facilities, which are specialized in the treatment of dental or dental related tissue diseases. Dentistry facilities is widely distributed throughout Fukuoka. From G-curve, more than half of the facilities are located within 0.2 km from the nearest facility, and the inclination of the curve decreases from 0.2km. Over 0.5km, it overlaps with CSR-G-curve.



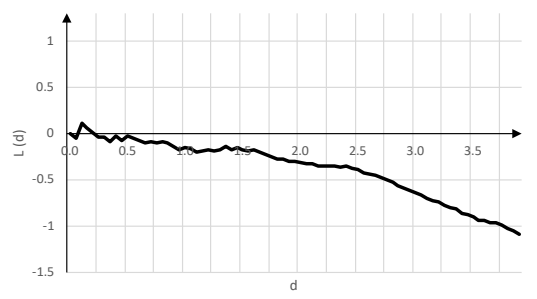
Mutual L-curve of Internal Medicine



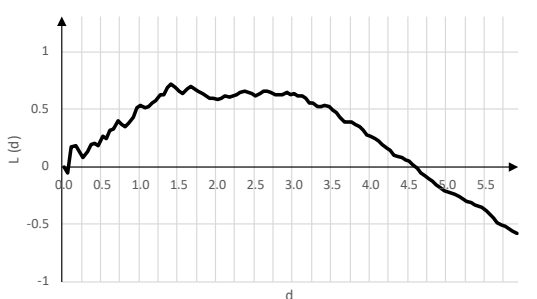
Mutual L-curve of Cardiology



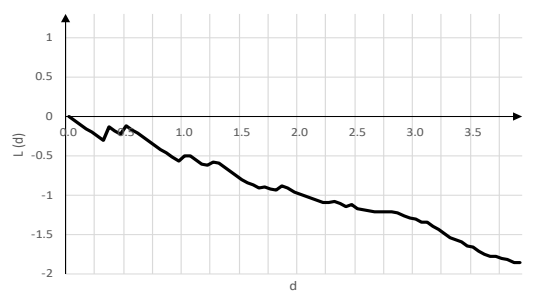
Mutual L-curve of Gastroenterology



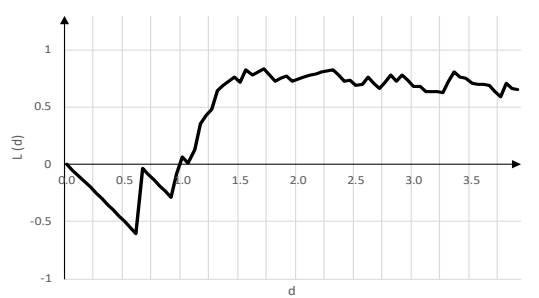
Mutual L-curve of Respiratory Medicine



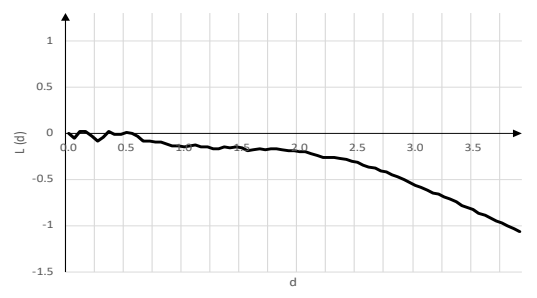
Mutual L-curve of Neurology



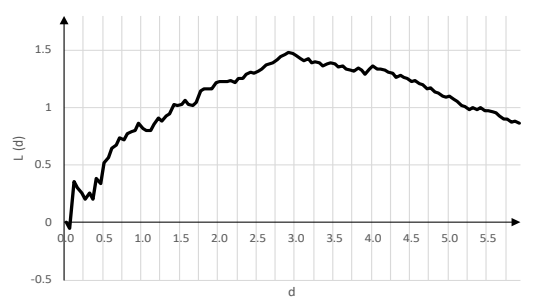
Mutual L-curve of Psychosomatic Internal Medicine



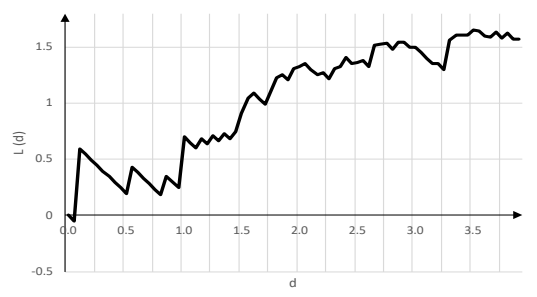
Mutual L-curve of Nephrology and Diabetes



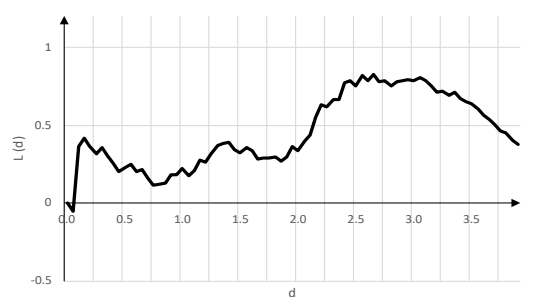
Mutual L-curve of General Surgery



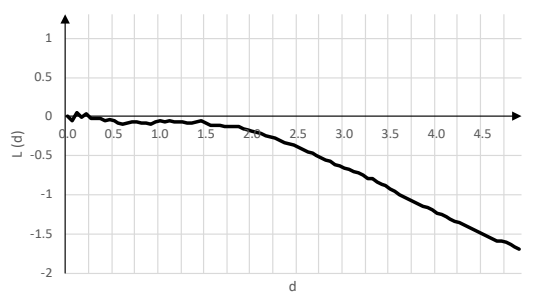
Mutual L-curve of Neurosurgery



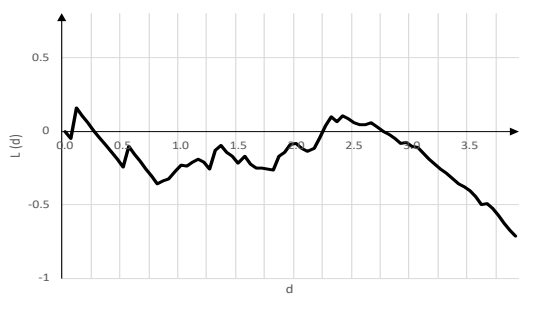
Mutual L-curve of Cardiovascular surgery



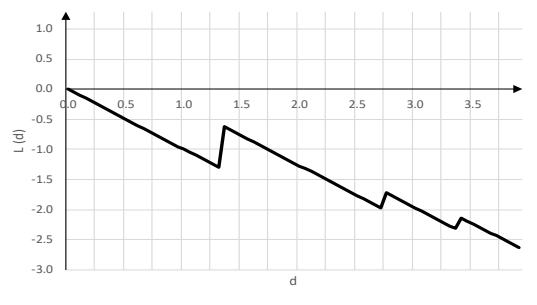
Mutual L-curve of Urology



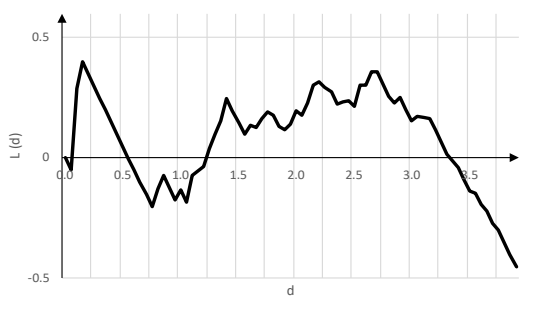
Mutual L-curve of Orthopedic surgery



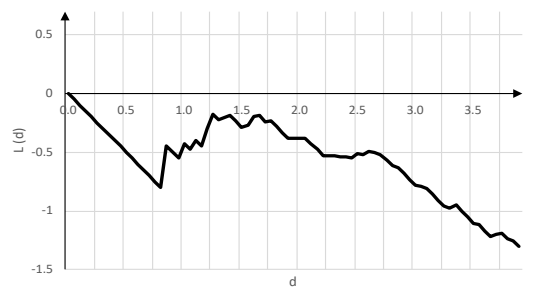
Mutual L-curve of Plastic and Reconstructive Surgery



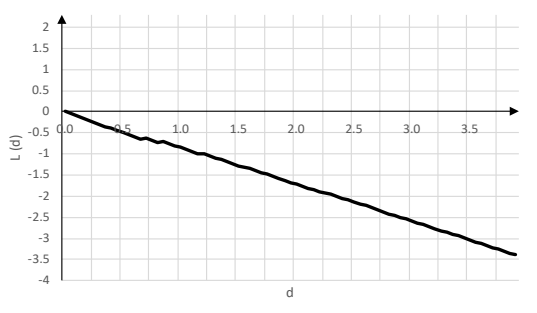
Mutual L-curve of Aesthetic Plastic Surgery



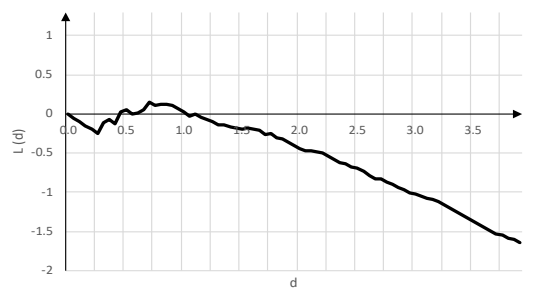
Mutual L-curve of Gynecology



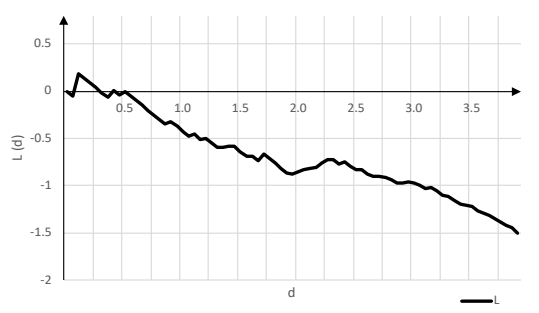
Mutual L-curve of Obstetrics and Gynecology



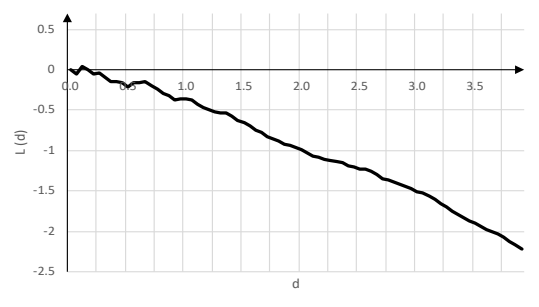
Mutual L-curve of Pediatrics



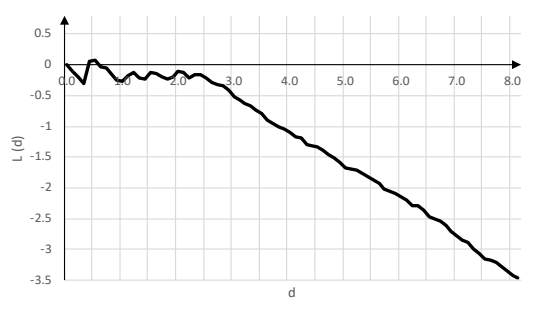
Mutual L-curve of Ophthalmology



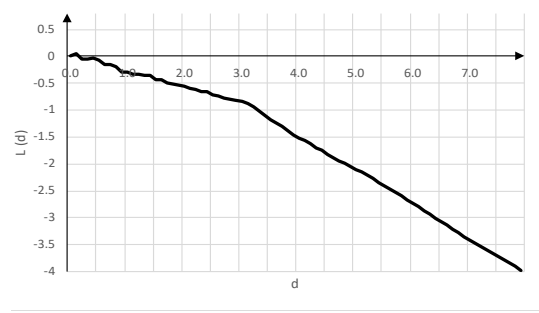
Mutual L-curve of Otorhinolaryngology



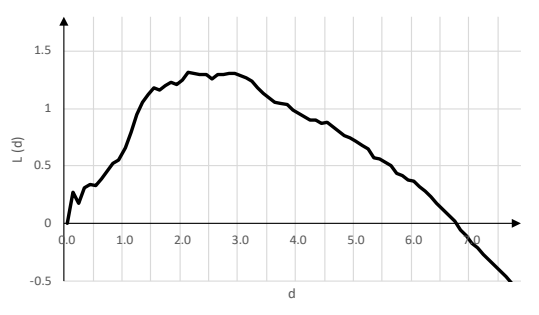
Mutual L-curve of Dermatology



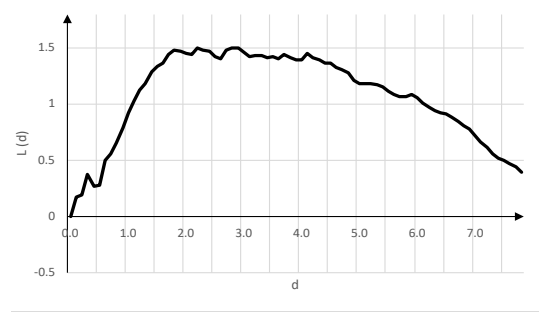
Mutual L-curve of Colorectal surgery



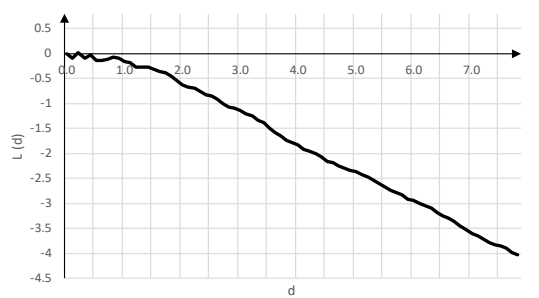
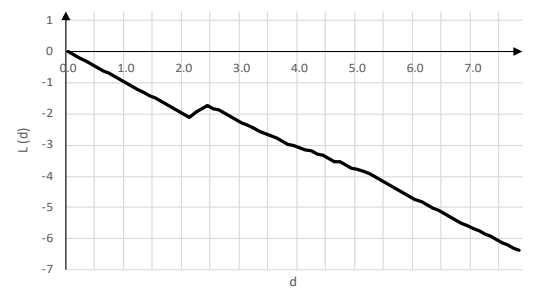
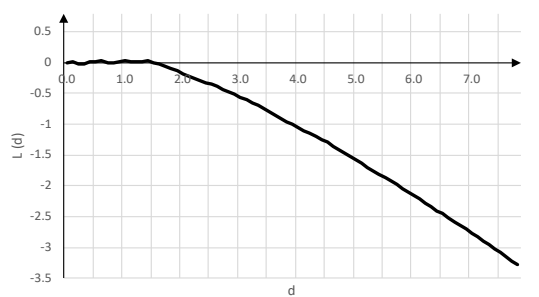
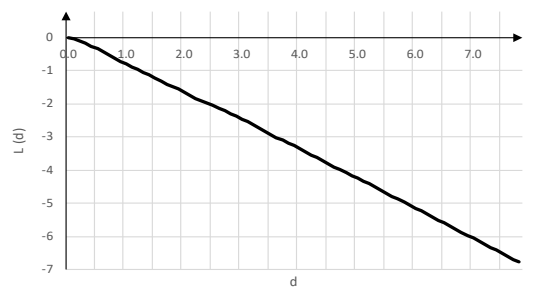
Mutual L-curve of Psychiatry



Mutual L-curve of Anesthesiology



Mutual L-curve of Roentgenology

**Mutual L-curve of Rheumatology****Mutual L-curve of Allergy****Mutual L-curve of Rehabilitation****Mutual L-curve of Dentistry**