

## Article

# Quantitative Evaluation of Difficulty in Visiting Hospitals for Elderly Patients in Depopulated Area in Japan: Using National Health Insurance Data

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**Abstract:** Depopulation is occurring in rural areas of Japan due to the outflow of the population to urban areas, the declining birthrate, and the aging population. Within depopulated areas, there is a problem of declining accessibility to medical facilities due to the decline of the medical system and transportation infrastructure. Therefore, measuring accessibility to medical facilities in underpopulated areas is an important issue. In this study, we calculated an accessibility index (APMI) to medical facilities in underpopulated areas in Japan using geographical information such as elevation, distance to medical facilities, and distance to bus stops. Furthermore, we estimated the number of patients who are considered to have difficulty visiting hospitals by using the National Health Insurance data (KDB) owned by all local governments in Japan. Through the analysis in this study, it became clear that accessibility was extremely low in the mountainous area of Hakui, Ishikawa Prefecture, and the number of patients living there could be determined. In addition, priority areas for improving the environment for visiting the hospital were identified.

**Keywords:** national health insurance database; aged person; quantitative assessment; regional characteristics; vulnerable persons for making hospital visits



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## 1. Introduction

### 1.1. Current State and Problems of Depopulated Areas

In the course of the rapid economic growth in Japan since the 1950s, the Japanese population has become more concentrated in urban areas, owing to large-scale population movement. This trend has led to the problem of depopulation that is accompanied by the decrease in the population of agricultural, mountainous, and fishing village areas. In Japan, which is on the verge of becoming a society with a majority of elderly persons, the problems of decay in education, healthcare, fire prevention, and transportation infrastructure that have accompanied the decline of vitality of Japan's regional cities and agricultural, mountainous, and fishing village areas where depopulation is progressing cannot be ignored. In particular, in view of today's so-called "super-aging" trend, the fact that many elderly persons are living in depopulated areas (Figure 1) [1], and the risks posed by the higher susceptibility of elderly persons to contracting diseases, it is essential that the following issues are addressed as soon as possible: enhancement of the healthcare system in depopulated areas, facilitation of access to healthcare institutions, and provision of public transportation infrastructure. Figure 1 shows that when it comes to the population ratio by age strata of the depopulated areas, the proportion of elderly persons has increased while the proportion of young persons

has decreased as a secular trend. In addition, when comparing depopulated areas as of 2010 with the population composition ratio across the country, the percentage of people over the age of 65 is as large as 32.8% in depopulated areas.

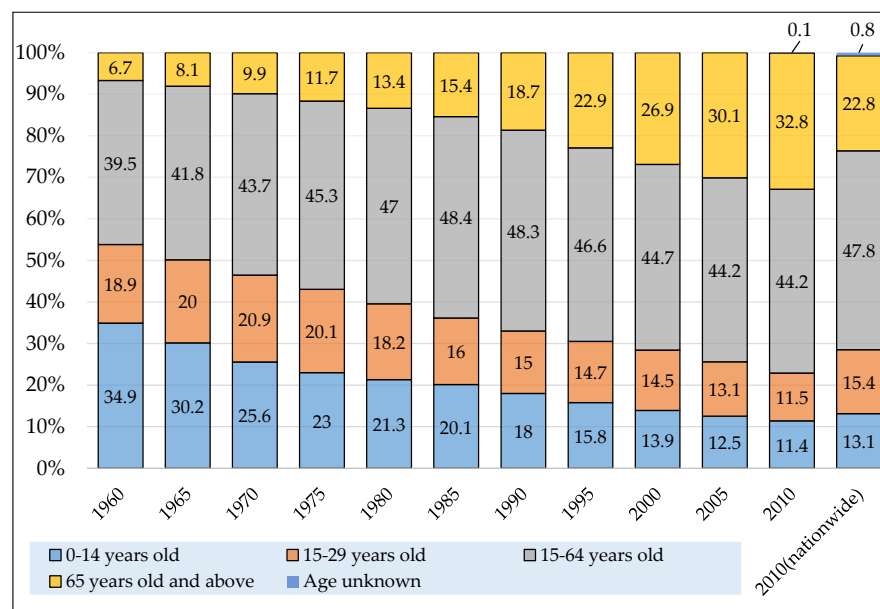


**Figure 1.** Population Composition Ratios by Age Strata in Depopulated Areas.

In addition, regarding the various problems arising in depopulated areas, results of a questionnaire survey about the settlement countermeasures in depopulated areas in three parts, which are described in the Report on the Survey for Grasping the Current State of the Situation in Settlements in Depopulated Areas [2] by the Ministry of Internal Affairs and Communications, provided the following insights. 49.3% out of the 800 depopulated cities, towns, and villages, which are the subjects of the questionnaire, regard “decline in the convenience of public transportation” as a problem, while 33.1% regard “weakening of the healthcare provision system” as a problem. The above-mentioned results also show that the provision of healthcare and public transportation in the depopulated areas are important issues. These issues are major problems occurring in depopulated areas in Japan.

### 1.2. Purpose of This Study

In this study, elderly persons at high risk of contracting a disease were included as subjects. The purpose of the study was (a) to conduct a quantitative assessment about the extent of the difficulty of visiting a hospital from a detailed unit of the machi-aza, or, loosely, the “town neighborhood” in depopulated areas and (b) to inhibit the decay and obsolescence of the provision of healthcare and public transportation in the future. The variables to be considered in the quantitative evaluation were created using a geographic information system (GIS). Variables such as the topography of the region, the state of road development, and the state of public transportation are set to evaluate the difficulty of visiting a medical institution. In addition, by utilizing the National Health Insurance data (hereafter “KDB data”), which is a collection of medical data, the distribution of the number of elderly patients within the town population was clarified. The relationship between the index of difficulty in visiting a medical institution and the number of patients obtained from the KDB data was clarified. The analysis and detailed procedures are described in Part 4. This study examines sustainable living conditions for the elderly in rural depopulated areas from the viewpoint of the medical examination environment.

## 2. Prior Studies

### 2.1. Studies Focusing on Elderly Patients Living in Depopulated Areas

Studies examining medical accessibility in Japan, the subject of this study's analysis, have been conducted in the fields of urban and civil engineering planning. For example, Moriyama et al. [3] focused on the importance of ensuring life transportation for elderly persons living in hilly and mountainous areas; they proposed a demand forecast model for public transportation services based on a discrete continuous model. To consider the population trends, Morita et al. [4] selected areas that were depopulated and had a population with an advanced age; they clarified the reasons why people settle in or move from such areas. In addition, they classified the settlements based on their characteristics and proposed a mode of intensive habitation for the target areas. In addition, studies focusing on elderly persons with diseases living in depopulated areas were also conducted. To examine the characteristics of the quality of life of elderly persons with chronic diseases living in depopulated areas, Takahashi et al. [5] focused on the following three regions: Iwate Prefecture, Miyagi Prefecture, and Tokyo Metropolitan Area. These authors conducted a comparative analysis with factorial analysis of variance. In addition, Koizumi et al. [6] clarified the circumstances of the social activities and lives of elderly patients with chronic diseases and examined the support methods for life management. Ide et al. [7] conducted a geographical information-type analysis about the difficulty encountered by elderly persons in depopulated areas in visiting hospitals using Voronoi analysis, which is a mathematical index of neighborliness.

There have also been many studies of medical accessibility outside of Japan. Methods used to calculate and develop medical accessibility vary, and many of them are based on spatial analysis using GIS. For example, studies using floating catchment as a tool for analysis [8–11]. These studies evaluated medical accessibility using a floating catchment area, considering the distance to medical facilities and their location. This is an effective method for identifying regional disparities in medical care. There is also a research case study that calculated medical accessibility considering the time required to reach a medical facility using mobility data obtained from GPS [12]. There are many other studies that have calculated accessibility by considering the location of medical facilities, road networks, population at demand points, and quality of medical services. For example, the following studies exist [13–18]. Le et al. [13] investigated how the quality of health care facilities varies across Ho Chi Minh City. They also examined the extent to which residents ( $N = 9$  million) have access to medical facilities. Kazazi [14] focused on the spatial accessibility to four different types of healthcare services, including hospitals, pharmacies, clinics, and medical laboratories at Isfahan's census blocks level, in a multivariate study. Ursulica [15] used Romanian statistical data to calculate population dependence on health care services. Wang & Luo [16] evaluated accessibility to primary healthcare in Illinois, considering both spatial and non-spatial factors. Paez et al. [17] showed large disparities in accessibility between seniors and non-seniors, between urban and suburban seniors, and between vehicle owning and non-vehicle owning seniors. Shen et al. [18] evaluated the time and distance between medical demand points and medical facilities using the AutoNavi web mapping system in China. Some studies have identified barriers to healthcare from the user's perspective based on interviews, without using GIS [19]. This study identified health care issues for women with disabilities in Nepal and stated that the lack of accessibility to health care facilities is a major problem. The studies listed above were conducted in various regions of the world, including Japan, China, Vietnam, Iran, the United States, India, and so on. In addition to this, Sun et al. [20] also quantitatively investigated the level of medical accessibility development from 2000 to 2018 for 186 countries around the world.

Furthermore, a number of studies have calculated "accessibility of emergency medical care" as a different perspective from that of medical accessibility in normal times [21–25]. These are important studies to evaluate public health services in emergency situations. Some studies have calculated accessibility to medical facilities considering earthquakes, floods, and landslides [26–30]. These studies take into account road closure, risk of damage,

etc., and are important for maintaining the medical system in the event of a disaster. Thus, it can be seen that studies on accessibility evaluation of medical facilities are being conducted all over the world. Furthermore, these studies are being conducted not only during normal times, but also during disasters and emergencies [31–37].

## 2.2. Positioning of This Study Based on Prior Studies

As noted in Section 1 this study conducts quantitative assessment to measure the difficulty in visiting healthcare institutions from each town neighborhood in depopulated areas. It also clarifies the actual state of the environment for seeing a doctor in depopulated areas by comparing the assessment values with the number of patients calculated using KDB data. This study mainly focuses on elderly persons with diseases. Differences with the studies of Moriyama et al. [3] and Morita et al. [4] can be clearly observed in regard to the methods used for the quantitative assessment of the difficulty in visiting a healthcare institution. Moreover, although Takahashi et al. [5] and Koizumi et al. [6] focused on elderly persons with diseases living in depopulated areas, but their data acquisition methods differed from those used in this study. In this study, one difference from the standpoint of novelty is that the number of patients was calculated by utilizing KDB data, which are a form of healthcare big data. Finally, while the study of Ide et al. [7] is similar to this study as it conducted geographical information-type analysis using GIS, this study carries out quantitative assessment by considering the regional characteristics of the analysis target area, such as the difference in elevation and distance to a bus stop. In addition, research cases outside Japan [8–18] have calculated accessibility using GIS, taking into account the location of medical facilities, road networks, etc. This is similar to this study, however, this study utilizes medical big data (KDB data) to calculate the number of patients actually living in areas with low medical accessibility. This is different from other studies.

Paez, A. [17] set up a very detailed regional unit called a “town section unit”, and, utilizing the KDB data (national health insurance data) for the town section area, they conducted a quantitative evaluation of the number of people who require special help during disasters. This evaluation ascertains the extent to which town section areas will be taken care of and offers a clear and detailed understanding of the number of people living in disaster-prone areas and of the citizens who may actually be affected by a disaster. Using the detailed “town section unit”, this study focuses on elderly people who are at a high risk of contracting a disease and conducts a quantitative analysis of the level of difficulty people experience in depopulated areas in seeing a doctor. Furthermore, by using the KDB data and similar methods of analysis, this study aims to arrest the decline and decay of medical supply systems and public transportation services. In addition, regarding the variables that were considered while conducting the qualitative evaluation, the study utilized GIS to pay attention to the special regional characteristics of regional topography, road maintenance conditions, and public transportation service conditions in defining the variables. The study is clearly different from past research in that it evaluates the difficulty experienced by people in utilizing the services of medical institutions. Research on accessibility indicators in Japan has been widely conducted. However, most studies have focused on public transportation services. There are very few studies that focus on “difficulty in accessibility”, as in this study. As mentioned in the previous section, studies examining accessibility to medical facilities have been conducted all over the world. This study was conducted in a small city in Japan.

## 3. Summary of Hakui City, Ichikawa Prefecture, the Analysis Target Area

In this study, the target of analysis is Hakui City, Ishikawa Prefecture, which meets the criteria of a depopulated area as defined by the Act on Special Measures for the Promotion of the Independence of Depopulated Areas. It was designated as a depopulated area as of 1 April 2014.

Hakui City is located within Ishikawa Prefecture on the Sea of Japan (Figure 2). It has a population of 22,268 persons with 8530 households (as of 1 April 2017) and an area of

81.85 km<sup>2</sup>. In addition, comparing the population composition ratios of the depopulated areas with those of all of Japan as of 2010, the percentage of persons aged 65 years and above is high at 32.8%. The aging rate, which is the proportion of the population accounted for by elderly persons, was 36.2% as of 1 April 2016, which demonstrates an extremely high level compared with the aging rate of Japan as a whole, which is only 26.7% (as of 1 October 2015) [14]. Moreover, Hakui City can be divided into 65 town neighborhood districts, and this study assesses the difficulty encountered in visiting a hospital for each one of these 65 town neighborhoods and calculates the number of patients based on KDB data. Figure 3 shows Hakui City divided into the 65 town neighborhood districts.

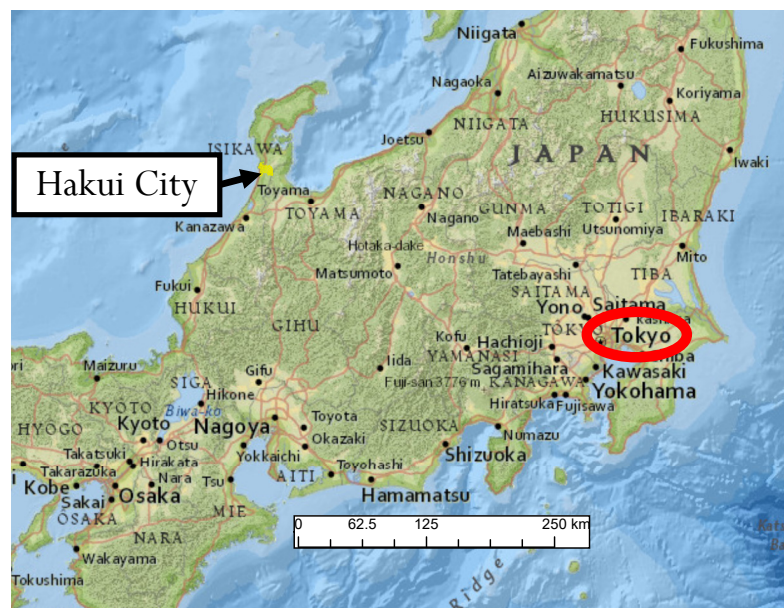


Figure 2. Location of Hakui City, Ishikawa Prefecture.

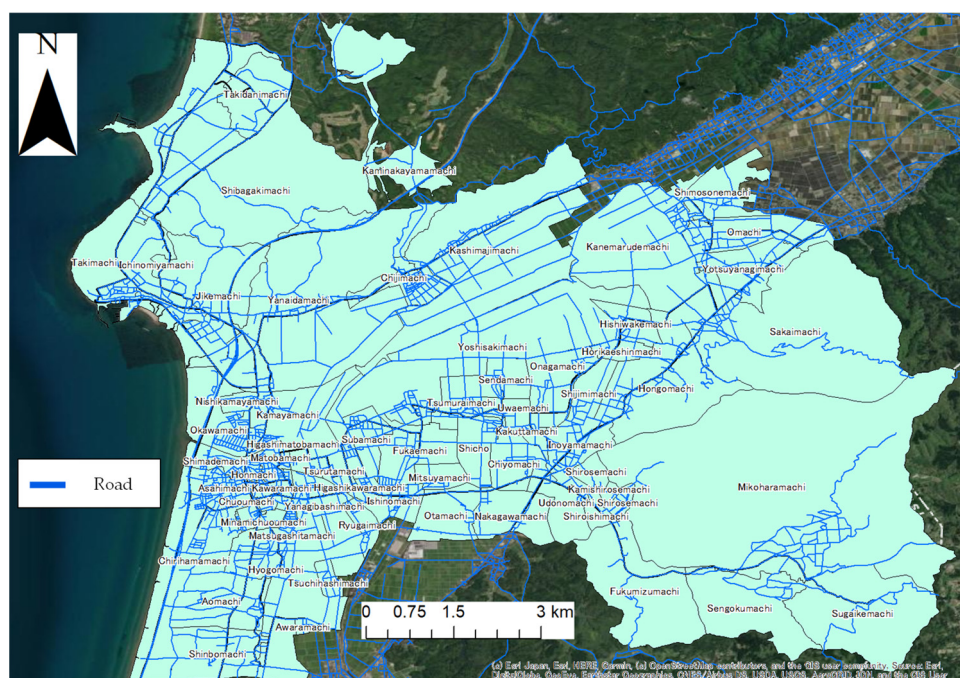


Figure 3. Sixty-Five Town Neighborhood Districts Inside Hakui City.

#### 4. Analysis, Methods, and Results

In this section, a detailed account of the analysis methods used in this study and their results is provided. Figure 4 shows the analysis flow and the data utilized in this study.

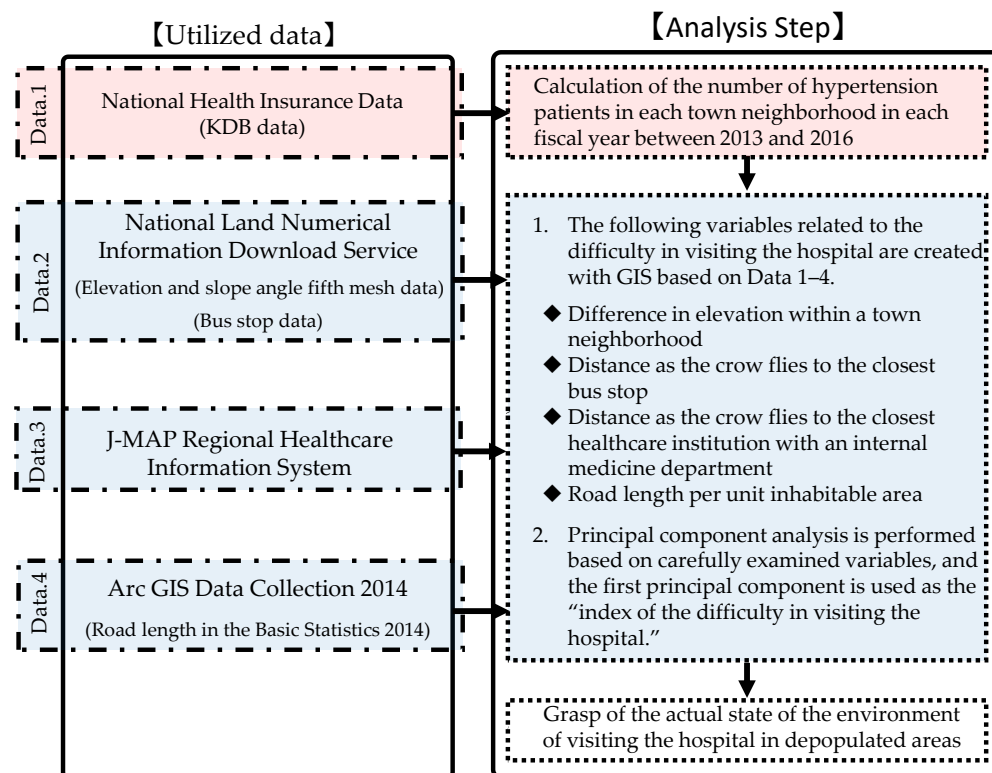


Figure 4. Flow of the Analysis in This Study.

##### 4.1. Calculation of the Number of Patients by Town Neighborhood Employing the KDB Data

As noted in Section 1.2, in this study, a detailed calculation of the number of patients for the town neighborhood units is carried out using KDB data. Here, the analysis target disease is hypertension, which has many patients both worldwide and in Japan. This disease has the tendency to worsen [19,20] and requires routine visits to the hospital. Moreover, the calculation is carried out by narrowing the scope to elderly persons (persons aged 65 years and above), who are at a particularly high risk of contracting the disease among all hypertension patients and who may need to make regular hospital visits for treatment. This is especially a problem in depopulated rural areas where the aging population is increasing rapidly. Therefore, hypertensive patients were selected for analysis in this study.

Among the forms output by the KDB data, the “Ministry of Health, Labour and Welfare Form (Form 1-1)” contains monthly records of whether or not a patient has been hospitalized or treated on an outpatient basis; the total of the costs; and whether or not a patient has any major diseases such as lifestyle diseases, including diabetes, hypertension, ischemic heart disease, and cerebrovascular disease. These data make it possible to ascertain the history of each individual’s visits to the hospital on a monthly basis. Figure 5 shows a part of the “Ministry of Health, Labour and Welfare Form (Form 1-1)” with an example of items that might be used to identify an individual. This example is processed to leave the remainder blank. The KDB data contains the patient’s address (information up to the town) and age as basic information. Using this information, the group of target patients was extracted from the KDB data for analysis. The black dots in the figure indicate the presence or absence of the corresponding disease.

| Sex | Age | Birthdate (Year) | Address | Inpatient /Outpatient | Cost    | Hypertension | Diabetes mellitus | Dyslipidemia | Hyperuricemia | Ischemic heart disease | Cerebrovascular | Individual number |
|-----|-----|------------------|---------|-----------------------|---------|--------------|-------------------|--------------|---------------|------------------------|-----------------|-------------------|
|     |     |                  |         | Outpatient            | 29,740  |              | ●                 | ●            |               | ●                      |                 | 1                 |
|     |     |                  |         | Outpatient            | 11,870  | ●            |                   | ●            |               |                        |                 | 2                 |
|     |     |                  |         | Inpatient             | 535,930 |              |                   |              |               |                        |                 | 3                 |
|     |     |                  |         | Inpatient             | 25,800  | ●            | ●                 | ●            |               |                        |                 | 4                 |
|     |     |                  |         | Outpatient            | 12,410  |              |                   |              | ●             |                        |                 | 5                 |
|     |     |                  |         | Outpatient            | 7,880   |              |                   |              |               |                        | ●               | 6                 |
|     |     |                  |         | Outpatient            | 5,500   |              |                   |              |               |                        |                 | 7                 |
|     |     |                  |         | Outpatient            | 7,200   | ●            |                   |              |               |                        | ●               | 8                 |

**Figure 5.** An Example of the Ministry of Health, Labour and Welfare Form (Form 1-1).

In this study, KDB data for a period of approximately four years, from June 2013 to March 2017, were used, and the subjects were those living in Hakui city who are enrolled in the National Health Insurance and aged 40 years and above, as described in the KDB data. As noted above, the “Ministry of Health, Labour and Welfare Form (Form 1-1)” provides data that make it possible to grasp the circumstances of both diseases and hospital visits by month. Thus, as shown in Figure 6, the data for June 2013 to March 2014 were compiled as data for the fiscal year 2013, and data for April 2014 to March 2015 were treated as data for the fiscal year 2014. This method is used for data up to the fiscal year 2016; thus, four sets of data (for fiscal years 2013, 2014, 2015, and 2016) were employed in this study. In the data for the fiscal year 2013, the starting month is June, because the collection of KDB data only started in June 2013. This means that data for two months, April and May, are lacking, and therefore the number of patients calculated may be undercounted. As already noted, the “Ministry of Health, Labour and Welfare Form (Form 1-1)” that was employed to calculate the number of hypertension patients in this study provides data that make it possible to ascertain the history of each individual’s visits to the hospital on a monthly basis. Moreover, hypertension is a disease that requires routine hospital visits, so it is natural for persons visiting the hospital during the blank period in April and May to have also visited at least once between June and March of the following year. Therefore, it was decided to undertake the calculation based on the hypothesis that even if April and May indicated a blank period, the omission in the calculation is minor. However, the small sample size was caused by the population of Hakui, which is a limitation of this study. As a result, there were cases in which the number of patients calculated from the KDB was extremely small. When the data used in this analysis were extracted from KDB, no missing values were found.

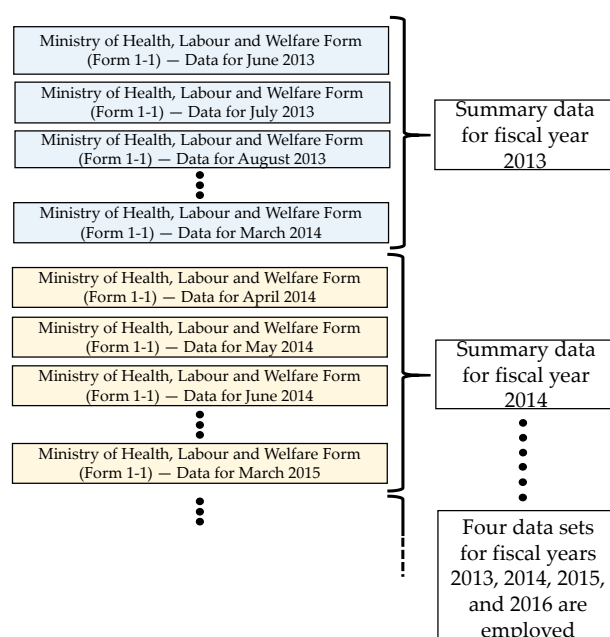


**Figure 6.** Handling of the KDB Data in This Study.

Based on the above-mentioned procedure, this study calculated the number of hypertension patients aged 65 years and above for each fiscal year while breaking down the four sets of compiled data into the 65 town neighborhoods of Hakui City. Figure 7 shows the number of elderly hypertension patients for each fiscal year in all areas of Hakui City. Figure 7 demonstrates that the number of hypertension patients aged 65 years and above has a tendency to increase in a secular trend.

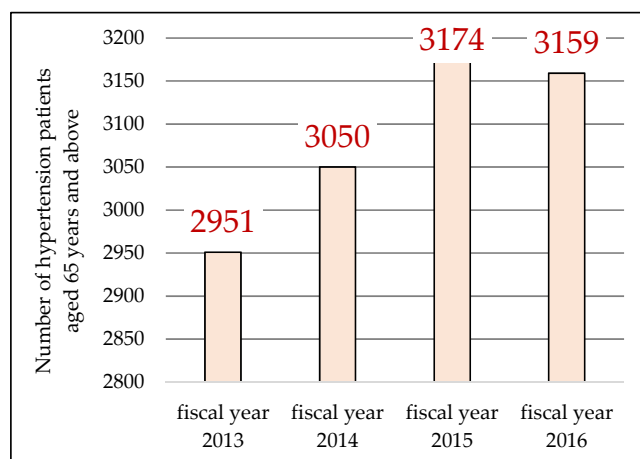


**Figure 7.** Overall Number of Elderly Hypertension Patients by Year in Hakui City.

#### 4.2. Assessment of the Difficulty in Visiting the Hospital

In this section, the variables employed when performing quantitative assessments of the difficulty of visiting the hospital in the 65 town neighborhood units of Hakui City, Ishikawa Prefecture, are described. To consider the actual circumstances and characteristics of the region, such as the terrain, state of local roads, and provision of local transportation infrastructure, it was decided to use the following four variables in the assessments in this study:

- I. The difference in elevation within a town neighborhood.
- II. The distance as the crow flies to the closest bus stop.
- III. The distance as the crow flies to the closest healthcare institution with an internal medicine department.
- IV. The road length per unit of inhabitable area.

These variables focus solely on the geographical features of the region. With respect to “I. The difference in elevation within a town neighborhood”, the elevation and slope angle fifth mesh (as of 1 May 2009), obtained from the National Land Numerical Information Download Service [21], was employed. In this study, the difference between the values of the highest and lowest elevations in the mesh included the scope for each of the 65 town neighborhood districts was used as the difference in elevation in a given town neighborhood district. The variable of difference in elevation was included in order to use the difference of elevation as a proxy indicator of the difficulty of walking around (due to hill roads and steep slopes) in a given district; it therefore expresses the difficulty experienced by elderly patients in going to a healthcare institution. Similarly, for “II. The distance as the crow flies to the closest bus stop”, data for bus stops (around the fiscal year 2010) from the National Land Numerical Information Download Service were employed. The positions of all bus stops for private line buses, public line buses, community buses, and demand buses were plotted on the GIS, and distance (km) from the center of the inhabitable area of each town neighborhood to the nearest bus stop was employed as a proxy indicator of the quality of public transportation services in that district. Regarding “III. The distance as the crow flies to the closest healthcare institution with an internal medicine department”, similar to the above case of bus stops, distance (km) from the center of the inhabitable area of each town neighborhood to the closest healthcare institution was employed as a

proxy indicator of the direct distance to a healthcare institution in that district. Since this study only considers hypertension patients aged 65 years and above, only those healthcare institutions that perform medical examinations in the internal medicine department, which is where the treatment of hypertension is given, were used as subjects. The JMAP Regional Healthcare Information System [22] was employed for extracting the healthcare institutions, and 11 healthcare institutions were found within Hakui City at which medical examinations are conducted in the internal medicine department. Regarding “IV. The road length per unit of inhabitable area”, the value obtained by dividing the total road length included within the scope for each town neighborhood district by the inhabitable area of the town neighborhood was employed as a proxy indicator of the regional characteristics of the state of transportation provision in that district. For data about road length, the Basic Statistics 2014 obtained from the Arc GIS Data Collection 2014 was employed. In Japan, inhabitable area is defined as the national land area minus the area of lakes and forests. This area is widely used in academic research. Variables II, III, and IV use this inhabitable area. The center of gravity of the inhabitable area polygon was calculated in GIS, and a proxy variable for the distance to medical institutions and buses was created.

With respect to the assessment items in I to IV, the value of each variable for each town neighborhood is calculated and standardized based on geographical information analysis with GIS. As far as standardization is concerned, the mean of each item is subtracted from the values of each data set, and the value obtained by dividing the resulting values by the standard deviation is employed. Regarding each value for each town neighborhood for which standardization is conducted, comprehensive indexation of the four variables was performed using a principal component analysis, and then quantitative assessments were conducted. These variables were set based on the accessibility index of public facilities developed by the Ministry of Land, Infrastructure, Transport and Tourism in Japan, taking into account the distance to the target facility, public transportation network, and road network. In addition, information on the road network and the location of medical facilities were also taken into account, with reference to the study by Rauch, S. et al. [9].

Here, the index of difficulty encountered by elderly persons in visiting the hospital, for which an analysis is conducted in this study, is proposed as the Aged People’s Difficulty of “Medical Examinee” Index (APMI).

#### 4.3. APMI (Difficulty in Visiting the Hospital) Obtained by Principal Component Analysis

In this section, results of the principal component analysis conducted with variables in I to IV above are presented (see Figure 8 and Tables 1 and 2). Table 1 shows the eigenvalues, contribution rates, and cumulative contribution rates of principal components 1 to 4. In this study, the first principal component, whose contribution rate is 47.89%, is used as the APMI as is. In principal component analysis, the first principal component is often taken as the “comprehensive index”. In this study, only the first principal component was adopted because the purpose was to set a single proxy indicator as the APMI value. Figure 8 shows the principal component loading of each variable for the first principal component. The loading is highest for variable III followed by variables I, II, and IV. The principal component loading of variable I is the second highest at 0.7381, and this result indicates that it has a larger effect on the difficulty of visiting the hospital than the variables related to the state of transportation, such as distance to the bus stop and road density. These results, as shown in Figure 8, indicate that variable IV has negative loading. However, the more the density of road length is oriented towards “dense (positive)”, the more negative the load it imparts (the difficulty in visiting the hospital becomes lower, meaning that it is an environment where it is easy to visit the hospital) is. This means that the difficulty in visiting a hospital in an area where the provision of roads is inadequate (a depopulated area) increases, and so these results are thought to reflect reality.

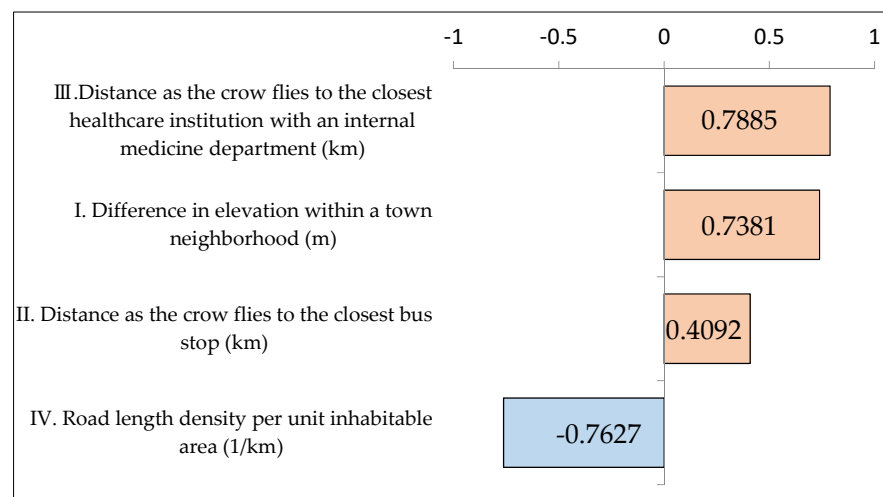


**Figure 8.** Principal Component Loading of Each Variable in the First Principal Component.

**Table 1.** Eigenvalues, Contribution Rates, and Cumulative Contribution Rates of Principal Components 1 to 4.

| Principal Component | Eigenvalue | Contribution Rate | Cumulative Contribution Rate |
|---------------------|------------|-------------------|------------------------------|
| 1                   | 1.916      | 47.89%            | 47.89%                       |
| 2                   | 1.073      | 26.82%            | 74.72%                       |
| 3                   | 0.557      | 13.91%            | 88.63%                       |
| 4                   | 0.455      | 11.37%            | 100.00%                      |

**Table 2.** Correlation Coefficients between the Respective Variables.

|                                                                                                                | I Difference in elevation within a town neighborhood | II Distance as the crow flies to the closest bus stop (km) | III Distance as the crow flies to the closest healthcare institution with an internal medicine department (km) | IV Road length density per unit inhabitable area (1/km) |
|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| I Difference in elevation within a town neighborhood                                                           | 1.000                                                |                                                            |                                                                                                                |                                                         |
| II Distance as the crow flies to the closest bus stop (km)                                                     | 0.000                                                | 1.000                                                      |                                                                                                                |                                                         |
| III Distance as the crow flies to the closest healthcare institution with an internal medicine department (km) | 0.392                                                | 0.361                                                      | 1.000                                                                                                          |                                                         |
| IV Road length density per unit inhabitable area (1/km)                                                        | −0.481                                               | −0.118                                                     | −0.374                                                                                                         | 1.000                                                   |

Table 2 shows the correlation coefficients between the respective variables. The highest correlation is between variables I and III, for which the correlation coefficient is 0.392. No highly correlated variables were found even when the correlation coefficients between all of the variables were examined.

The district with the highest APMI was Mikohara-machi, with an APMI of 5.835, and the district with the lowest APMI was Matoba-machi, with an APMI of −1.759. Even when

the values of the other districts are examined, there is variance in the APMI depending on the district. The APMI is calculated in such a manner that the average becomes 0 based on the characteristics of the analysis method of the principal component analysis.

#### 4.4. Visualization of APMI

The calculated APMI is visualized using GIS. The map of Hakui City employed during the visualization was obtained from e-Stat, the portal site for Japanese Government Statistics [23], in whose development the Statistics Bureau of the Ministry of Internal Affairs and Communications plays a key role. Figure 9 uses this map to show the bus route network, locations of the bus stops, and locations of the 11 healthcare institutions with internal medicine departments. Figure 9 shows that bus stops and hospitals are widely distributed in Hakui. However, they tend to be concentrated in the southwestern part of Hakui, which is the urban area. When comparing the APMI for Hakui City overall, the more distant a region is from the central part of the city, where the bus routes and healthcare institutions performing medical examinations in internal medicine departments are concentrated, the deeper the color coding of the APMI is, and the greater the difficulty in visiting the hospital is. Moreover, regions where the APMI is high are concentrated, to a certain extent, and can be roughly divided into the following two areas: the area of Mikohara-machi, Sengoku-machi, and Sugaike-machi and the area of Takidani-machi, Shibagaki-machi, and Kaminakayama-machi (see Figure 9). Although the APMI tends to be low in areas where healthcare institutions are concentrated, in the case of Sakai-machi, the APMI is relatively high for some healthcare institutions that are located relatively close. Moreover, even though the bus route network extends out from the city center like a spider's web, bus stops have not been provided in the districts around Sakai-machi and Mikohara-machi, and the APMI tends to be higher in these districts. With respect to areas exhibiting high values for the APMI around Takidani-machi and Shibagaki-machi, even though bus routes have been provided fairly extensively, there are no healthcare institutions in the surrounding area. Therefore, from the visualization of the APMI in Figure 9, there exist regional differences in the APMI, and the results show that the further away a district is from the city center, the higher the APMI value is. Thus, one possibility for assessing the difficulty in visiting the hospital is by conducting a principal component analysis and comprehensive indexing based on the four variables set in this study.

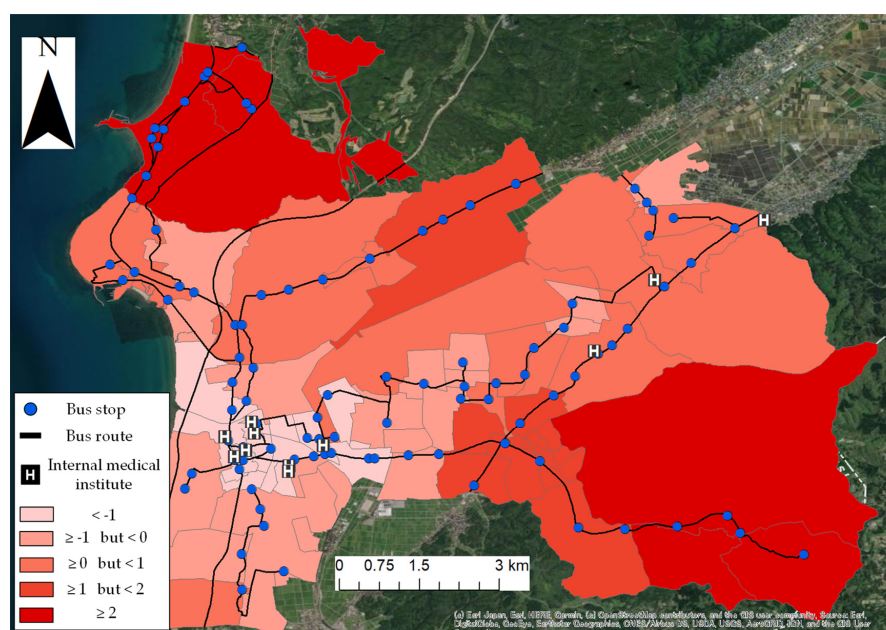


Figure 9. Visualization of the APMI.

## 5. Relationship between KDB and APMI

In this section, scatterplots are prepared for the relationship between the number of hypertension patients aged 65 years and above in fiscal years 2013–2016 and the APMI. The calculation is based KDB data and the APMI, for which assessment was conducted by a principal component analysis, to ascertain the actual state of the environment for making hospital visits in Hakui City. Scatterplots prepared with KDB data and the APMI show the following two patterns.

- i. A scatterplot of the number of hypertension patients in the fiscal year 2016 and the APMI
- ii. A scatterplot of the number of hypertension patients in the fiscal years 2013 and 2016 and the APMI, for which the rate of increase or decrease (change) in the number of patients by town neighborhood was calculated based on information for the four-year period for which data are available.

Scatterplot i was created from the number of hypertension patients aged 65 years and above as of the fiscal year 2016 and the APMI, since it is possible to grasp the environment for making hospital visits by town neighborhood “as of (year)”, namely, the fiscal year 2016. Scatterplot ii was created to utilize the properties of the data. Namely, the period of approximately four years from June 2013 to March 2017, for which KDB data exist, is used to ascertain the number of hypertension patients by town neighborhood and the yearly changes to this number. Compound Average Growth Rate (CAGR) is employed for calculating the annual rate of increase or decrease in the number of hypertension patients aged 65 years and above. CAGR refers to the geometric average calculated as the growth rate per year from the growth rate over the specified period. It is given by the following equation:

$$CAGR = \left( \frac{\text{Number of hypertension patients in the } n^{\text{th}} \text{ fiscal year}}{\text{Number of hypertension patients in the initial fiscal year}} \right)^{\frac{1}{n-1}} - 1$$

where  $n$  is the specified period such as the time period and number of years.

### 5.1. Relationship between the Number of Hypertension Patients in the 2016 Fiscal Year and APMI

Figure 10 shows a scatterplot of the relationship between the number of hypertension patients aged 65 years and above as of fiscal year 2016 and the APMI. Figure 10 shows that the number of hypertension patients aged 65 years and above is less than 150 persons in majority of the cases, and the APMI is concentrated in the range between  $-2$  and  $2$ . With respect to the areas that fall to the eastern side of Hakui City, Mikohara-machi, Sengoku-machi, and Sugaike-machi (see Figure 9), the numbers of hypertension patients calculated from KDB data were 61, 7, and 9, respectively. In Takidani-machi, Shibagaki-machi, and Kaminakayama-machi, which are on the northern side of Hakui City, the APMI is relatively high, and the numbers of patients were 26, 121, and 5, respectively. Thus, it was possible to put in relief the actual state of the environment for seeing a doctor in Hakui City, namely, how many hypertension patients aged 65 years and above are present in towns where the APMI is found to be high. However, the small sample size was caused by the population of Hakui, which is a limitation of this study. As a result, there were cases in which the number of patients calculated from the KDB was extremely small.

### 5.2. Relationship between the Annual Average Rate of Increase or Decrease in the Number of Hypertension Patients and APMI

From the information about the number of hypertension patients in fiscal years 2013 and 2016 and the period of four years for which data exist, the annual rate of increase or decrease in the number of hypertension patients aged 65 years and above by town neighborhood in Hakui City is calculated. Figure 11 shows the scatterplot of the relationship with the APMI. The figure indicates that the CAGR is roughly concentrated in a range from  $-0.1\%$  to  $0.2\%$ . In addition, even though the rate of change is not very large, the tendency

toward an increase or decrease of the number of hypertension patients aged 65 years and above by town neighborhood can be confirmed. In Nishikamaya-machi, the CAGR was highest at 0.24% and the APMI was  $-0.72$ ; given that the CAGR is positive and the APMI is calculated as negative, the number of hypertension patients tends to increase. Thus, one can conclude that the difficulty in visiting the hospital is low within Hakui City (i.e., it is relatively easy to visit the hospital within Hakui City). As indicated by the areas shown in orange and blue in Figure 11, the difficulty in visiting the hospital is high, and the annual average rate of increase or decrease is also high.

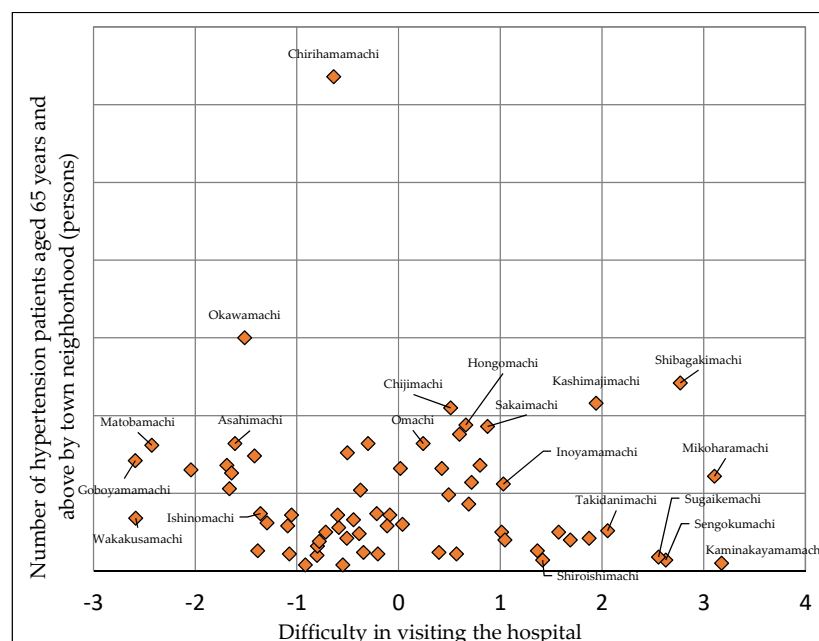


**Figure 10.** Relationship between the Number of Hypertension Patients Aged 65 Years and Above as of the Fiscal Year 2016 and the APMI.

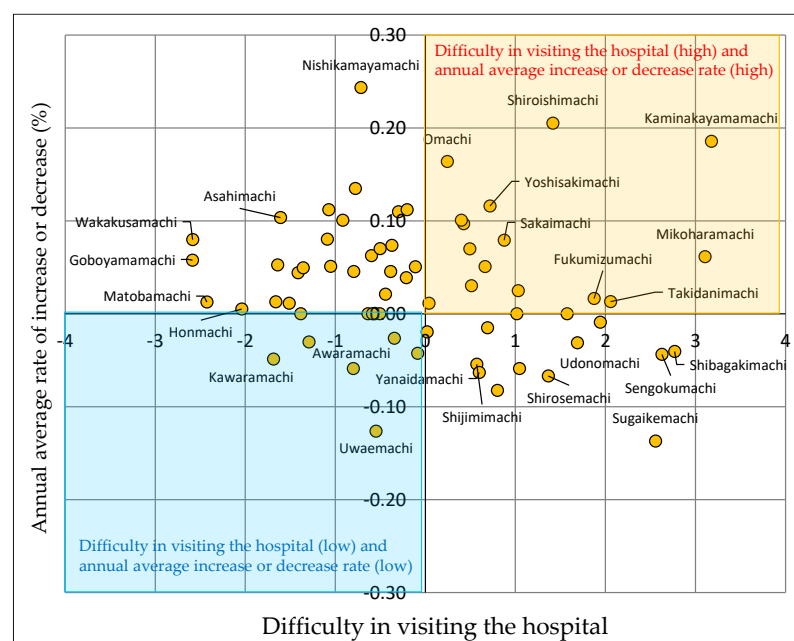


**Figure 11.** Relationship between CAGR and APMI.

As indicated above, it was possible to grasp the tendency toward an increase or decrease of the number of hypertension patients aged 65 years and above by town neighborhood and the difficulty experienced by these patients in visiting the hospital.

## 6. Summary and Future Issues

In this study, we used KDB data and proposed an index of difficulty in visiting the hospital (or APMI) from the town neighborhood units of Hakui City, Ishikawa Prefecture, which is a depopulated area. Thus, one possibility for proposing the index of the APMI using principal component analysis and for assessing the difficulty in visiting the hospital was identified. Kaminakayama town (APMI: approximately 3.18) and Mikohara town (APMI: approximately 3.11) have significantly higher APMI values, indicating that they are located in mountainous areas. The introduction of demand cabs and home-visit medical services by the government may be considered for these towns. Thus, by utilizing KDB data and spatial analysis, it was possible to identify the townships with high difficulty in receiving medical examinations.

Countermeasures such as increasing in the number of bus stops, introducing demand buses and taxis and enhancing visiting care have been proposed in regions where it is difficult to visit the hospital. However, it is difficult for local governments in depopulated areas such as Hakui City, which was the target place of analysis in this study, to grasp information about regions and town neighborhoods where it is difficult to visit hospitals. Moreover, given budgetary constraints, there exists a problem that measures for improving the environment for visiting a hospital cannot be adopted blindly, and pinpointing their application is required. The method of ascertaining the circumstances of visiting the hospital by each town neighborhood based on the APMI, the index of difficulty in visiting the hospital proposed here, and calculation of the number of patients using KDB data made it possible to identify the town neighborhoods for which priority countermeasures for improving the environment for visiting the hospital are needed.

With respect to the variables of the principal component analysis employed in the calculation of the APMI, the observed values were measured using distance as the crow flies to the closest healthcare institution and bus stop. However, for research in the future, the analysis can be refined by calculating the distance to the bus stop and healthcare institution using the actual road network. Upon such refinement, it will be necessary to implement a large-scale questionnaire survey in Hakui City, Ishikawa Prefecture, the analysis target area, to verify the difficulty in visiting hospitals based on a qualitative understanding of the environment for visiting hospitals for the residents of Hakui City. This study is a case study of a small regional city in Japan. Therefore, it is necessary to conduct similar analysis and verification in other regions in Japan. In this study, we used data from 2013 to 2016, which is relatively old. However, the accumulation of KDB data is still ongoing in all Japanese municipalities. Authors plan to acquire the latest data and continue to conduct similar analyses in the future. Finally, in this study, we only examined medical facilities in Hakui. However, there is a possibility that outpatient visits will be made to medical facilities outside Hakui. Therefore, it is necessary to expand the number of target medical facilities.

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## References

1. Ministry of Internal Affairs and Communications. *Current State of the Depopulation Countermeasures*; Depopulation Countermeasures Office; Group for Creating Regional Potential; Ministry of Internal Affairs and Communications: Tokyo, Japan, 2016.
2. Ministry of Internal Affairs and Communications. *Report on the Survey for Grasping the Current State of the Situation in Settlements in Depopulated Areas, etc.*; Depopulation Countermeasures Office; Group for Creating Regional Potential; Ministry of Internal Affairs and Communications: Tokyo, Japan, 2011.
3. Moriyama, M.; Fujiwara, A.; Zhang, J.; Sugie, Y. Proposal of a demand forecast model for public transportation services for helping elderly persons in hilly and mountainous areas. *J. Jpn. Soc. Civ. Eng.* **2005**, *786*, 39–51.
4. Morita, T.; Tsukada, S.; Sano, K. Analysis of population trends and residential intentions oriented towards intensive habitation in depopulated and advanced age areas: A case study in Kuni-Mura, Gunma Prefecture. *J. City Plan. Inst. Jpn.* **2010**, *45*, 511–516.
5. Takahashi, R.; Fukazawa, H.; Degumo, Y.; Shimizu, Y.; Araki, A.; Inoue, J.; Ito, H. A comparative of the actual state of the lives of elderly diabetes patients living in local areas. *Abbreviated J.* **1994**, *31*, 404–410.
6. Koizumi, M.; Hoshino, M.; Miyamoto, M.; Ito, M. Support methods for health management from the standpoint of the state of health and disease and the social activities of the elderly chronic disease patients residing in depopulated areas. *Abbreviated J.* **2000**, *50*, 287–293.
7. Ide, M.; Hayakawa, T.; Kashiwada, R.; Yoneda, E.; Ando, N.; Watariguchi, T.; Suzuki, Y.; Kobayashi, S.; Tsuzuki, M.; Esaki, Y.; et al. A geoinformatics-type analysis of the difficulty encountered by elderly persons residing in hilly and mountainous areas in visiting the hospital. *J. Jpn. Assoc. Rural Med.* **2012**, *61*, 582–601.
8. Wei, Z.; Bai, J.; Feng, R. Evaluating the spatial accessibility of medical resources taking into account the residents' choice behavior of outpatient and inpatient medical treatment. *Socio-Econ. Plan. Sci.* **2022**, *83*, 101336. [\[CrossRef\]](#)
9. Rauch, S.; Stangl, S.; Haas, T.; Rauh, J.; Heuschmann, P. Spatial inequalities in preventive breast cancer care: A comparison of different accessibility approaches for prevention facilities in Bavaria, Germany. *J. Transp. Health* **2023**, *29*, 101567. [\[CrossRef\]](#)
10. Aziz, A.; Li, J.; Hu, S.; Hu, R. Spatial accessibility of township to county hospital and its disparity among age and urbanizing groups in Anhui, China- a GIS analysis. *Comput. Urban Sci* **2022**, *2*, 9. [\[CrossRef\]](#)
11. Luo, W.; Wang, F. Measures of Spatial Accessibility to Healthcare in a GIS Environment: Synthesis and a Case Study in Chicago Region. *Env. Plann B Plann Des.* **2003**, *30*, 865–884. [\[CrossRef\]](#)
12. Pan, X.; Kwan, M.-P.; Yang, L.; Zhou, S.; Zuo, Z.; Wan, B. Evaluating the Accessibility of Healthcare Facilities Using an Integrated Catchment Area Approach. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2051. [\[CrossRef\]](#)
13. Le, K.H.; La, T.X.P.; Tykkylainen, M. Service quality and accessibility of healthcare facilities: Digital healthcare potential in Ho Chi Minh City. *BMC Health Serv. Res.* **2022**, *22*, 1374. [\[CrossRef\]](#)
14. Khosravi kazazi, A.; Amiri, F.; Rahmani, Y.; Samouei, R.; Rabiei-Dastjerdi, H. A New Hybrid Model for Mapping Spatial Accessibility to Healthcare Services Using Machine Learning Methods. *Sustainability* **2022**, *14*, 14106. [\[CrossRef\]](#)
15. Ursulica, T. The Relationship between Health Care Needs and Accessibility to Health Care Services in Botosani County-Romania. *Procedia Environ. Sci.* **2016**, *32*, 300–310. [\[CrossRef\]](#)
16. Wang, F.; Luo, W. Assessing spatial and nonspatial factors for healthcare access: Towards an integrated approach to defining health professional shortage areas. *Health Place* **2005**, *11*, 131–146. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Paez, A.; Mercado, R.; Farber, S.; Morency, C.; Roorda, M. Accessibility to health care facilities in Montreal Island: An application of relative accessibility indicators from the perspective of senior and non-senior residents. *Int. J. Health Geogr.* **2010**, *9*, 52. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Shen, C.; Zhou, Z.; Lai, S.; Lu, L.; Dong, W.; Su, M.; Zhang, J.; Wang, X.; Deng, Q.; Chen, Y.; et al. Measuring spatial accessibility and within-province disparities in accessibility to county hospitals in Shaanxi Province of Western China based on web mapping navigation data. *Int. J. Equity Health* **2020**, *19*, 99. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Pita, Y.; Bigler, C.; Sony, K.; Amacker, M. The right to health: An examination of health care access for women with disability in Nepal. *SSM-Qual. Res. Health* **2023**, *4*, 100315. [\[CrossRef\]](#)
20. Sun, Z.; Sun, Y.; Liu, X.; Tu, Y.; Chen, S.; Qian, D. A Refined Evaluation Analysis of Global Healthcare Accessibility Based on the Healthcare Accessibility Index Model and Coupling Coordination Degree Model. *Sustainability* **2022**, *14*, 10280. [\[CrossRef\]](#)
21. Xia, T.; Song, X.; Zhang, H.; Song, X.; Kanasugi, H.; Shibasaki, R. Measuring spatio-temporal accessibility to emergency medical services through big GPS data. *Health Place* **2019**, *56*, 53–62. [\[CrossRef\]](#) [\[PubMed\]](#)
22. Xu, N.; Bai, J.; Yan, R. Identifying the vulnerable regions of emergency medical services based on the three-stage of accessibility: A case study in Xi'an, China. *Int. J. Equity Health* **2022**, *21*, 54. [\[CrossRef\]](#) [\[PubMed\]](#)
23. Shin, K.; Lee, T. Improving the measurement of the Korean emergency medical System's spatial accessibility. *Appl. Geogr.* **2018**, *100*, 30–38. [\[CrossRef\]](#)
24. Xiong, Q.; Liu, Y.; Xing, L.; Wang, L.; Ding, Y.; Liu, Y. Measuring spatio-temporal disparity of location-based accessibility to emergency medical services. *Health Place* **2022**, *74*, 102766. [\[CrossRef\]](#)
25. Li, M.; Wang, F.; Kwan, M.; Chen, J.; Wang, J. Equalizing the spatial accessibility of emergency medical services in Shanghai: A trade-off perspective. *Comput. Environ. Urban Syst.* **2022**, *92*, 101745. [\[CrossRef\]](#)
26. Bakioglu, G.; Karaman, H. Accessibility of medical services following an earthquake: A case study of traffic and economic aspects affecting the Istanbul roadway. *Int. J. Disaster Risk Reduct.* **2018**, *31*, 403–418. [\[CrossRef\]](#)

27. Li, J.; Liu, J.; Di, B.; Pan, J.; Shaw, R.; Shoji, T. Medical resource accessibility in areas with frequent and hazardous debris flows. *Int. J. Disaster Risk Reduct.* **2023**, *95*, 103873. [\[CrossRef\]](#)
28. Pei, S.; Zhai, C.; Hu, J.; Liu, J.; Song, Z. Seismic functionality of healthcare network considering traffic congestion and hospital malfunctioning: A medical accessibility approach. *Int. J. Disaster Risk Reduct.* **2023**, *97*, 104019. [\[CrossRef\]](#)
29. Li, M.; Kwan, M.; Chen, J.; Wang, J.; Yin, J.; Yu, D. Measuring emergency medical service (EMS) accessibility with the effect of city dynamics in a 100-year pluvial flood scenario. *Cities* **2021**, *117*, 103314. [\[CrossRef\]](#)
30. Petricola, S.; Reinmuth, M.; Lautenbach, S.; Hatfield, C.; Zipf, A. Assessing road criticality and loss of healthcare accessibility during floods: The case of Cyclone Idai, Mozambique 2019. *Int. J. Health Geogr.* **2022**, *21*, 14. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Fujiu, M.; Morisaki, Y.; Takayama, J.; Yanagihara, K.; Nishino, T.; Sagae, M.; Hirako, K. Evaluation of Regional Vulnerability to Disaster by People of Ishikawa, Japan: A Cross Sectional Study Using National Health Insurance Data. *Int. J. Environ. Res. Public Health*. **2018**, *15*, 507. [\[CrossRef\]](#) [\[PubMed\]](#)
32. Hakui City Official Site. Available online: <http://www.city.hakui.ishikawa.jp/> (accessed on 5 March 2018).
33. Ministry of Health, Labour, and 8333 Welfare. 2014 Outline of Patient Survey. Available online: <http://www.mhlw.go.jp/toukei/saikin/hw/kanja/14/index.html> (accessed on 5 March 2018).
34. World Health Organization. World Health Day 2013: Measure Your Blood Pressure, Reduce Your Risk. 3 April 2013. Available online: <https://www.who.int/news/item/03-04-2013-world-health-day-2013-measure-your-blood-pressure-reduce-your-risk#:~:text=3%20April%202013%20%7C%20Geneva%20%2D%20To,or%20about%20one%20billion%20people> (accessed on 5 March 2018).
35. National Land Numerical Information Download Service. Available online: <http://nlftp.mlit.go.jp/ksj/> (accessed on 11 May 2017).
36. JMAP Regional Healthcare Information System. Available online: <http://jmap.jp/> (accessed on 5 March 2018).
37. e-Stat. The Portal Site for Japanese Government Statistics. Available online: <https://www.e-stat.go.jp/SG1/estat/toukeiChiri.do?method=init> (accessed on 5 March 2018).

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