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Using GIS to Examine the Optimal Location for Long-Term Care Facilities in a Depopulating and Super-aging Society: A case study of Niigata City

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Abstract

The main purpose of this paper is to analyze and discuss a plan for effective and efficient location of long-term care facilities in a depopulating and super-aging society with the use of GIS (geographical information system) data on distribution of communal daily long-term care facilities for dementia patients (group homes) and elderly population in Niigata City, while also taking into consideration future demographics and service lifespan of the facilities. More specifically, we used data on current and projected future population of the elderly aged 75 and over at the small-area level ("Machi," "Cho," and "Aza"), and compared the current and future needs for group homes by service area and the current supply situation of the said facilities.

Our analysis elucidated that a strong sense of insufficiency of these facilities is already being felt in urban areas, including DIDs (densely inhabited districts), while suburban farming communities are relatively over-supplied. It also clarified that, looking to the future, the sense of insufficiency in urban areas is expected to rise increasingly, while the sense of excessive supply is expected to grow further in the suburban farming communities. As this result is based on the current and projected future population data on the elderly aged 75 and over, this finding is considered applicable not only to group homes but also to other residential long-term care facilities.

As the need for these types of facilities is expected to grow more than ever against the backdrop of a further increase in the elderly population in future, we believe that the issue of improved efficiency of these facilities by optimizing their geographical locations (through restructuring or relocation) will become increasingly significant. At the same time, promotion of Care Compact City and urban restructuring will also be required in light of financial constraints.

Keywords: Community-based Comprehensive Care, Compact City, Depopulation, GIS, Voronoi tessellation, Building life span, Finance

***JEL Classification*: H55, H75, I13, J10, R12**

I. Introduction

The main purpose of this paper is to analyze and discuss a plan for efficiently locating long-term care facilities in a depopulating and super-aging society with the use of GIS (geographical information system) data on distribution of communal daily long-term care facilities for dementia

patients (group homes) and the elderly population in Niigata City, while also taking into consideration future demographics and service lifespan of the facilities.

As is well known, with an aim to address the issue of a super-aging society and improve the sustainable medical and long-term care service system, the government enacted the "Amendatory Law to the Related Acts for Securing Comprehensive Medical and Long-term Care in the Community" during the ordinary Diet session in 2014. Based on this law, the government has been promoting a "Community-based Comprehensive Care System" (Article 5 of the said Law) centered mainly on the Long-Term Care Insurance System.

The "Community-based Comprehensive Care System" aims to build by 2025, when the baby boomer generation reaches the age of 75 and over, a framework for providing housing, medical care, long-term care, disease prevention, and livelihood support as an integrated service to enable the elderly and others to continue to live their lives in the way in which they are accustomed in familiar surroundings of homes and communities until the end of their lives, even if they should come to have serious needs for long-term care.

However, three major problems exist in promoting the "Community-based Comprehensive Care System." First is the issue of finance. The graying of society has expanded social security costs, thereby increasing Japan's fiscal deficit. Social welfare benefits, which were about 90 trillion yen in FY2007, rose to about 116 trillion yen in FY2016, accounting for about 20% of GDP. That is, although the social welfare benefits have continued to expand at an annual average of about 2.6 trillion yen over the past decade, it is very likely that the pressure to boost social security costs, including mainly medical care and long-term care costs, will grow even further towards 2025 when all members of the baby boomer generation reach the age of 75 and over. As a matter of fact, according to the "Revision of Cost Projections Related to Social Security (March 2012)" of the Ministry of Health, Labour and Welfare, pension payments are likely to increase marginally from about 56 trillion yen in FY2015 to 60 trillion yen in FY2025 due to application of the macroeconomic slide system, while medical care and long-term care payments are projected to increase sharply from about 50 trillion yen to about 75 trillion yen during the same period.

The second issue concerns measures for a sharply increasing elderly population and depopulation. The elderly in the latter stage of life (people aged 75 and over) tend to have higher demands for medical and long-term care service compared with the early-stage elderly (people aged 65 to 74). According to the population projection (based on median birth rate, median death rate) by the National Institute of Population and Social Security Research, however, the elderly in the latter stage of life (people aged 75 and over), which numbered about 9 million in 2000, is projected to reach about 20 million in 2025.

In addition, compared to the population of elderly in the latter stage of life in 2010, the number will grow by about 1.3 times in 2020, by about 1.6 times in 2030, and by about 1.7 times in 2050, which will inevitably lead to a ballooning of the medical and long-term care needs. In urban areas, in particular, the number of people on waiting lists for admission to special nursing homes for the elderly will increase sharply, thus exacerbating the issue of the lack of long-term care facilities.

The third issue is measures for local communities at a risk of vanishing. The "Grand Design of National Spatial Development towards 2050: Creation of a Country Generating Diverse Synergies among Regions" published by the Ministry of Land, Infrastructure, Transport and Tourism in July 2014 clarified that the grid squares (the entire land is divided into a "grid consisting of squares of 1km^2 each") in which the population in 2050 will fall to below half that of 2010 will account for over 60% of the currently inhabited areas (= 44% + 19%). The plan also anticipates the possibility that about 20% of those grid squares, accounting for over 60% of the currently inhabited areas, might become uninhabited. When this is observed by "population size of municipalities," smaller

communities will face a greater population decline rate, and the population of municipalities with a current population of under 10,000 will drop by about half. While the current population of Japan (as of 2010) will decrease by half in 2083, about 70 years later, the above finding suggests that the speed of population decline in regions where the population is projected to drop by more than half in about 40 years (between 2010 and 2050) is twice the speed of the population decline of the national average or even greater. As a result, municipalities with smaller populations are more likely to face a financial crisis.

Measures to clear up the above three problems simultaneously are limited. One of the conceivable effective measures is, as pointed out in Oguro (2015), the promotion of the "Care Compact City," which combines the "Community-based Comprehensive Care System" and "Compact City," which seeks population consolidation. The "Care Compact City" is an initiative aimed at efficiently and effectively providing medical and long-term care services in a consolidated, high-quality residential and community space, known as a "Compact City."

Pushing forward the above-mentioned initiatives is one effective measure to simultaneously solve the three problems mentioned above. However, it is also extremely significant to analyze in which area long-term care-related facilities should be appropriately located, while determining the distribution status and projection of the demographics.

Such analysis is closely related to the issue of optimal geographical location of facilities. Rapid progress in GIS in recent years has enabled us to visualize understanding and analysis of the situation. Although analysis leveraging GIS on long-term care-related issues is still limited to date, Bojo, Yamada, and Ueno (2005), for instance, analyzes the relationship between the geographical location of facilities and demand for them by performing simulation analysis on commuting care facilities for the elderly (day service centers) in Kanazawa City, while also taking into consideration distribution of the elderly population and other factors such as frequency of visits at and capacity of facilities. Their analysis revealed the following findings: 1) the elderly living in the center of the city are basically adequately served by commuting care service, while those living in mountainous areas are not appropriately served by the service due to lack of nearby facilities, and 2) the percentage of elderly population unable to use facilities even at a maximum commuting distance of 2.5 km is less than 2%.

In addition, Takahashi, Odagiri, and Uchida (2006) performed a Voronoi tessellation for Kofu City, Yamanashi Prefecture by regarding each location of commuting care facilities for the elderly as a kernel, and estimated "the number of elderly with care needs" (the number of persons requiring long-term care in a Voronoi sphere, which was estimated according to the proportional distribution method based on facility floor area). Their analyses revealed the following findings: 1) "the number of elderly with care needs" are concentrated in the center and northwestern part of the city, which supports the idea of preferentially locating facilities in those areas, and 2) the areas of Voronoi spheres in these two regions greatly differ, and in addition to greater demand for long-term care service, the assumed coverage area of each facility is also more extensive in the northwestern part of the city. More recently, Furukawa and Naito (2015) analyzed the locational issue of "senior salons" or gathering places for the elderly by using Voronoi tessellation with the case example of Komatsushima City, Tokushima Prefecture. The results of the analysis elucidated the importance of grasping beforehand the distribution of facility users (the elderly), and drawing up of a geographical location policy in response to the situation upon deciding on where to locate a facility for the elderly.

Although the use of GIS has proven to be effective in studying a facility location policy as discussed above, no research has taken into consideration future population demographics such as in 2030 or in 2050 or the building lifespan of facilities.

Therefore, in this paper, we analyze and discuss a vision for efficiently locating long-term care

facilities in a depopulating and super-aging society with the use of GIS data on distribution of communal daily long-term care facilities for dementia patients (group homes) and the elderly population in Niigata City, while also taking into consideration future demographics and service lifespan of facilities.

This paper is organized as follows. Section 2 gives an overview of long-term care facilities in Niigata City, the target of the analysis in this paper. Section 3 then confirms the present status and projection of the residential long-term care facilities, population, and aging in Niigata City, leveraging GIS. Section 4 performs an analysis on optimal geographical location of facilities by leveraging Voronoi tessellation. Finally, Section 5 gives a summary and discusses the future agenda.

II. Overview of the long-term care facilities in Niigata City

Let us start with an overview of the long-term care facilities in Niigata City. Long-term care facilities are classified broadly into commuting care facilities including day service and day care facilities, and residential facilities including special nursing homes for the elderly, group homes, health care facilities for the elderly requiring long-term care, and sanatorium-type medical care facilities for the elderly requiring care. According to the investigation we carried out on long-term care facilities in Niigata City by leveraging the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare, we found a total of 347 commuting long-term care facilities in Niigata City and a total of 187 residential long-term care facilities (See Table 1).

While the average total floor space of day service centers is 536 m^2, that of nursing homes for the elderly, a typical residential facility, is 4,101 m^2, which implies that the latter facilities, with a larger total floor space on average, require a higher spatial cost, such as for building management. For this reason, our analysis and consideration of data in this paper is entirely focused on residential long-term care facilities.

Table 1: Long-term care facilities located in Niigata City

Long-term care facilities	Number of facilities
Commuting care facilities	328
Residential facilities	187

Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare. (The investigation was carried out in December 2014.)

The residential long-term care facilities (187) are classified into seven types. The number of facilities of each type in Niigata City is shown in Table 2. With regard to these 187 residential long-term care facilities, we gathered data on their addresses, number of employees, capacity, number of current residents/inpatients and the number of people on the waiting list, etc. as location information, as well as data on type of structure, total floor area, year of construction, etc. as building information, and prepared a partial overview of the findings, which is shown in Table 3.

Table 2: Residential long-term care facilities located in Niigata City

Type	Number of facilities
Welfare facilities for the elderly requiring long-term care	57
Health care facilities for the elderly requiring long-term care	38
Sanatorium-type medical care facilities for the elderly requiring care	6
Daily life care for residents of specified facilities Fee-based homes for the elderly, etc.	14
Communal daily long-term care for dementia patients	48
Community-based daily life care for residents of welfare facilities for the elderly requiring long-term care	23
Community-based daily life care for residents of specified facilities Fee-based homes for the elderly	1
Total	187

Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare.
(The investigation was carried out in December 2014.)

Table 3: Overview of employees, users, and buildings of residential long-term care facilities in Niigata City

	Item		Total	Per facility
Employees	Number of employees		7,551 persons	40.4 persons
Users	Capacity		10,135 persons	54.2 persons
	Number of residents/inpatients		9,847 persons	52.7 persons
	Occupancy ratio		97.2 %	
	Average age of residents		82.9 years old	
	Male to female ratio of residents	Male	19.6 %	
		Female	80.4 %	
	Number of residents/inpatients according to the level of care needed	Support level 1	35 persons	(0.4 %)
		Support level 2	32 persons	(0.3 %)
		Care level 1	532 persons	(5.4 %)
		Care level 2	1,436 persons	(14.5 %)
		Care level 3	2,313 persons	(23.4 %)
		Care level 4	2,584 persons	(26.2 %)
		Care level 5	2,951 persons	(29.9 %)
	Average length of stay		864 days	
	Number of people on the waiting list		23,236 persons	124.3 persons
Buildings	Total floor area (of 149 facilities)		581,449 m^2	3,902 m^2

Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare. (The investigation was carried out in December 2014.) We used the "Registry Information Service" provided by General Incorporated Foundation of Civil Legal Affairs as reference for the total floor area. It should be noted, however, that the hospital area and day service area are often housed in one building under single real-estate registration, in which case the total floor area comprises that of the entire building, including service areas other than those used for residential long-term care.

This table shows that, as of today, the occupancy ratio at residential long-term care facilities in Niigata City is close to 100%, reflecting the sharply increasing number of elderly and the comparatively limited capacity of facilities. Also, there is a strong sense of insufficiency from the fact that about 23,000 people are on the waiting list for the capacity of about 10,000 persons. The table also shows that about 80% (79.5% to be precise) of the residents/inpatients require care level 3 or over. Now, let us look at the yearly trends of the accumulated number of residential long-term care facilities in Niigata City and accumulated floor area of those facilities.

As shown by Figures 1 and 2, a large supply of health care facilities for the elderly requiring long-term care (called “Roken facilities”) started in the latter part of 1980s, and yet another major increase was observed in the middle of the 1990s. This increase is considered to indicate that many of them were supplied as sanatorium-type medical care facilities for the elderly requiring care (so-called “recuperation beds” or “elderly hospitals”). It also should be noted that following the Long-Term Care Insurance Act enacted in 2000, the “recuperation beds” were actively converted into “Roken facilities” as part of the government measures taken, and as a result, health care facilities for the elderly requiring long-term care grew in number.

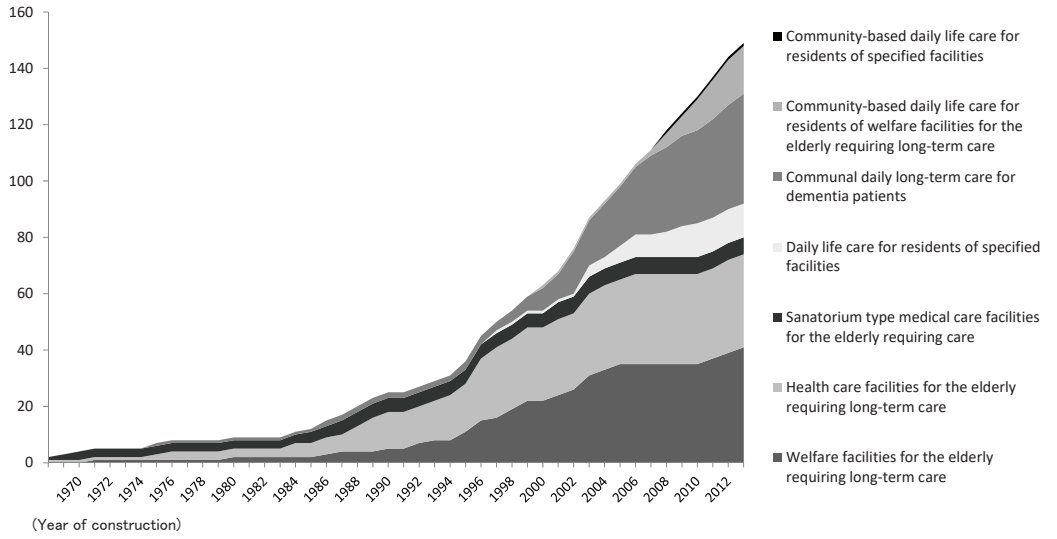
However, in and after the latter part of the 2000s, when such conversion support measures were terminated, the number of health care facilities for the elderly requiring long-term care has almost flattened. In addition, the welfare facilities for the elderly requiring long-term care (called “special nursing homes for the elderly”), which had shown a dramatic increase in number in the 1990s, has also shown a minor increase in the 2000s due to downsizing of generous support measures for the opening of such facilities. However, a slightly increasing trend has been observed in recent years.

Although daily life care for residents of specified facilities (called “fee-based homes for the elderly”) started to increase in the 2000s, it has almost flattened in recent years, which is considered to have been an impact of quantitative control.

On the other hand, the types of facilities which have shown a steady increase are those that provide communal daily long-term care for dementia patients (called “group homes”) and those that provide community-based daily life care for residents of welfare facilities for the elderly requiring long-term care (called “community-based, fee-based homes for the elderly”). These types of facilities are considered to be increasing in line with government policy. However, as the capacity and floor area of these facilities are small in scale, the accumulated floor area of these facilities remains at a relatively low level.

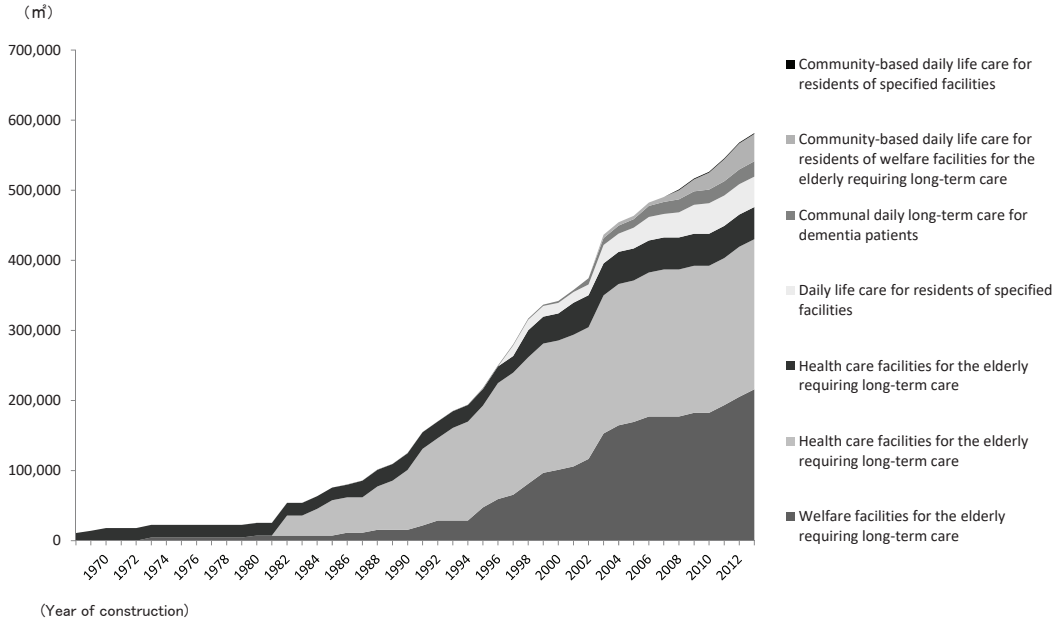
Although residential long-term care facilities have largely increased both in number and area, as shown by the figures above, the overall scale of this type of facility will not increase in the way it has to date due to a shift that has occurred in supportive measures from large-scale facilities to community-based small-scale facilities.

Figure 1: Yearly trends of the accumulated number of residential long-term care facilities in Niigata City



Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare. (The investigation was carried out in December 2014.)

Figure 2: Yearly trends of the accumulated floor area of residential long-term care facilities in Niigata City



Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare. (The investigation was carried out in December 2014.)

The reason is that the elderly population is also highly likely to enter a phase of decline around 2030. For instance, the population trends (including projections) of those 75 years old and over in Niigata City and the trends of accumulated floor area of residential long-term care facilities up to the present can be illustrated by Figure 3 below. It is considered that the challenge ahead for us will be how we should respond to the needs for these facilities in response to an increasing elderly population in the future, and how we should consider and act on community-based facilities and their services.

Specifically, it is considered unwise to greatly expand the overall scale of residential long-term care facilities as has been done previously in terms of area, as the population of the elderly in the latter stage of life (aged 75 and over) is highly likely to decline from around 2030. However, until that time, the number of the elderly in the latter stage of life is projected to continue to increase. Hence, how effectively existing facilities can be used on a continuous basis will become an increasingly significant perspective.

For this reason, we made an estimate on what percentage of existing facilities is likely to be considered questionable as of 2030 and 2050 due to building lifespan by making a certain assumption regarding the useful lifespan of buildings. We considered the useful lifespan of buildings as follows.

First, although the useful lifespan of buildings in terms of tax code (i.e. 24 years for wooden buildings, 50 years for RC or reinforced-concrete structured buildings, and 38 years for steel-framed buildings) is used in some cases, in this paper, we consider a useful lifespan of buildings that is focused on the actual and physical aspect of the building life span. In doing so, we could set the useful lifespan of buildings (building lifespan) at “50 years for a wooden building,” “60 years for an RC structured building,” and “50 years for a steel-framed building” on the basis of the building structure skeleton and survey-based estimates on building lifespan (Komatsu, 2008 and 2011).

For instance, in 2050, wooden and steel-framed buildings that were built before 2000 and RC structured buildings that were built before 1990 will be considered questionable. However, as many of the buildings that have been built under the old earthquake-resistance standards (based on the Building Standards Act prior to 1981) pose a problem in terms of aseismic performance in the first place, these were included in our study as questionable buildings.

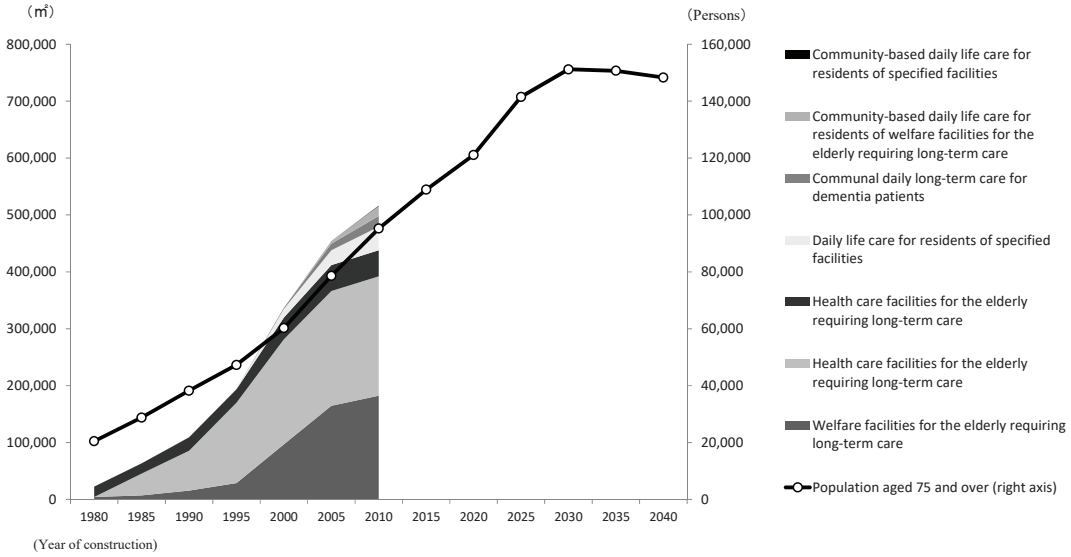
Talking about the notion of useful lifespan of buildings as the building lifespan, we can find a number of cases in which use of a building itself is hindered as a result of evasion or negligence regarding renewal or maintenance/management of required equipment towards the end of the building’s lifespan.

If we also take this issue into account, many of the buildings in their last 10 years of useful lifespan, as mentioned above, will be considered “potentially” questionable” as they are approaching the end of the building lifespan. In other words, it would be appropriate to set the “useful lifespan of buildings that are considered questionable (including “potentially” questionable buildings that are approaching the building lifespan)” at “40 years for a wooden building,” “50 years for a RC-structured building,” and “40 years for a steel-framed building.”

In this instance, in 2050, wooden and steel-framed buildings that were built before 2010 and RC structured buildings that were built before 2000 will become questionable or “potentially” questionable buildings. It is needless to say that, at the minimum, measures including proper maintenance, necessary repair work, and renewal of equipment must be properly taken, as buildings increasingly deteriorate or become obsolete without such upkeep.

Based on the above prerequisites, the percentage of facilities that are likely to be considered questionable in terms of building lifespan in 2030 and 2050 are shown in Table 4. As is clear from the table, it is projected that problems will surface in many of the buildings by around 2050, and how facility renewal should be conducted by that time is likely to become a significant issue.

Figure 3: Trends of accumulated floor area of residential long-term care facilities and population trends (including projections) of 75 years old and over in Niigata City



Source: Prepared based on the "long-term care service information disclosure system" of the Ministry of Health, Labour and Welfare
(the investigation was carried out in December 2014), "Population Projection for Japan" by National Institute of Population and Social Security Research, and "National Census" by the Ministry of Internal Affairs and Communications.

Table 4: Projection of the building lifespans of residential long-term care facilities in Niigata City

Questionable as of present	Questionable in 2030 (including "potentially" questionable buildings)		Building considered problem-free in 2030
Building built before 1981	Wooden or steel-framed building built before 1990*	RC-structured building built before 1980*	
6	1	0	
		Total 7	142
		(percentage) 5%	(percentage) 95%

Questionable as of present	Questionable in 2050 (including "potentially" questionable buildings)		Building considered problem-free (including potentially problem-free building) in 2050
Building built before 1981	Wooden or steel-framed building built before 2010*	RC-structured building built before 2000*	
6	62	38	
		Total 106	43
		(percentage) 71%	(percentage) 29%

* "Buildings built before 1981" are excluded.
Source: Prepared by the author.

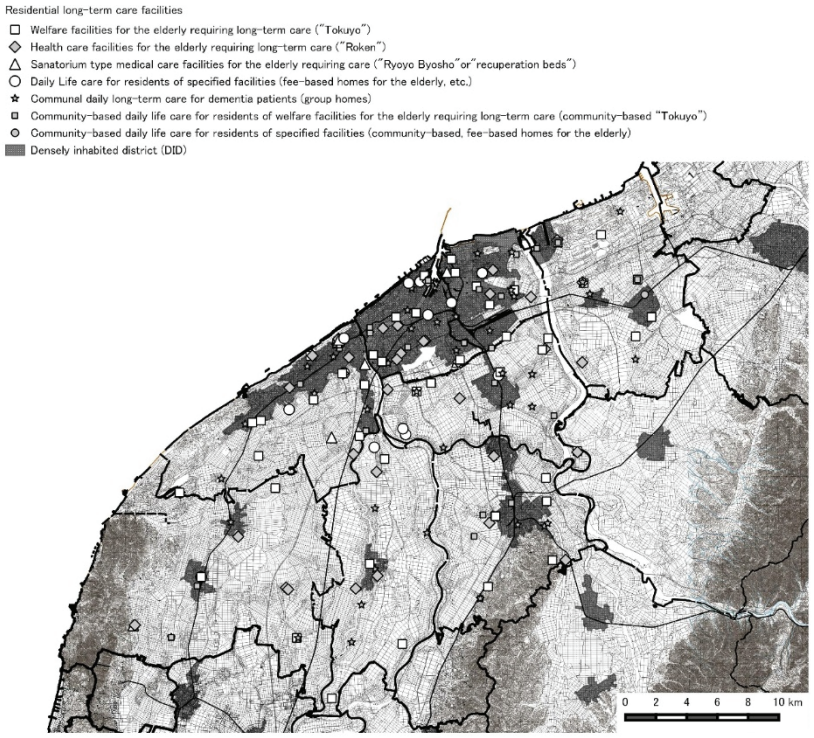
III. Current status and projection of GIS-leveraged residential long-term care facilities and population/aging

With regard to the residential long-term care facilities in Niigata City, let us first present how "long-term care service," "total floor area of building," and "number of residents/inpatients" are distributed according to geospatial information (Figures 4 to 6). As reference, information on railroads, roads, rivers, urban area (buildings), densely inhabited districts (DIDs[1]) is also included.

Please note that the types of long-term care services reflect those that are currently available. Some facilities have previously been classified into a different long-term care service category. For instance, some of the formerly sanatorium-type medical care facilities for the elderly requiring care (elderly hospitals) have been converted into health care facilities for the elderly requiring long-term care ("Roken" facilities).

If you look at the relationship between the scale of facilities (number of residents/inpatients) and their distribution status, many of the large-scale facilities are located in the outlying areas of the urban areas (DIDs).

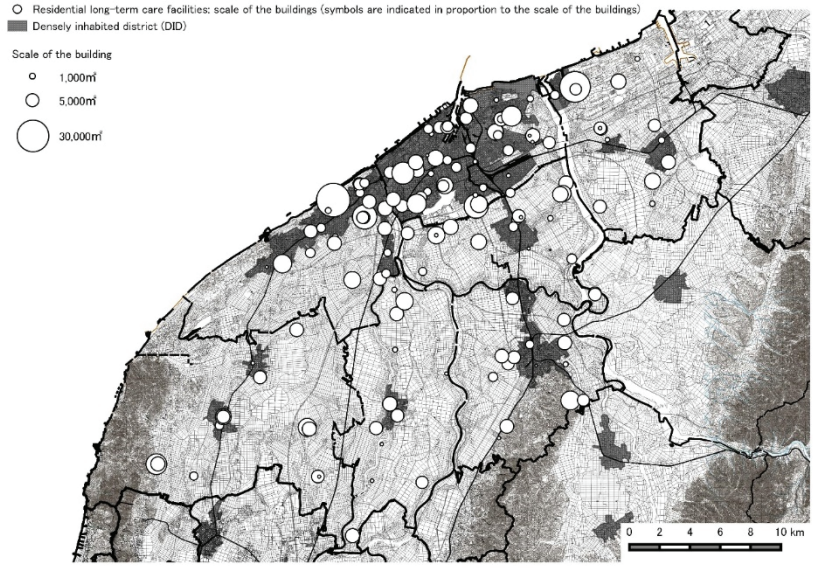
Figure 4: Distribution status of residential long-term care facilities by category in Niigata City



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan.)

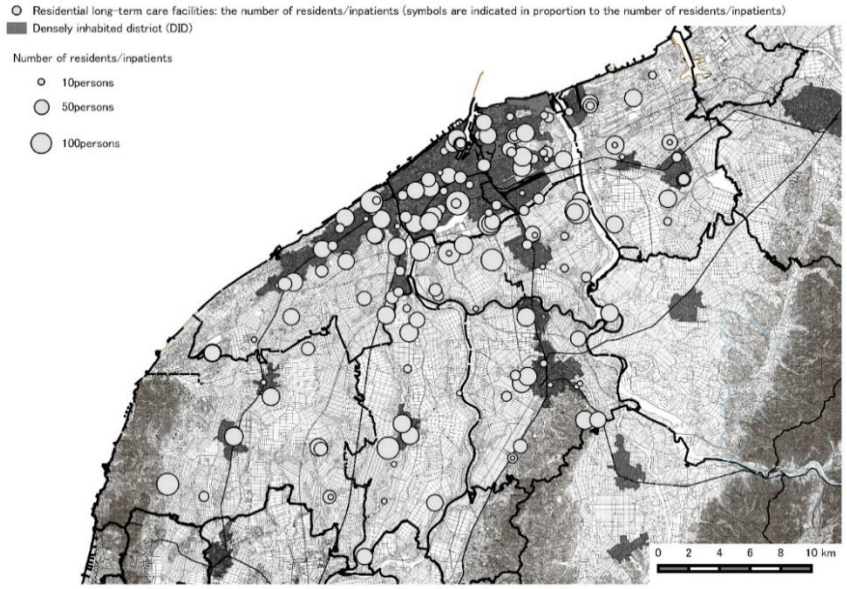
[1] A densely inhabited district is abbreviated as "DID." If two or more districts whose population density is 4,000 or more people per square kilometer lie next to each other on the municipality border, and make up a population of 5,000 and over at the time of National Census, the district is referred to as a DID.

Figure 5: Distribution of residential long-term care facilities in Niigata City by scale of building



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 6: Distribution of residential long-term care facilities in Niigata City by number of residents/inpatients



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Although the population projection performed by the National Institute of Population and Social Security Research is considered the most well-known of all projections, the smallest geographical unit in their projection is municipality (village, town, city), and the projection covers the period up to 2040. As demographics is considered to vary greatly by region, even within the same administrative district, the projections do not offer a clue to project small area-based demographics in the future.

With regard to the small area-based population projection, the projection itself has not been performed to date due to difficulty of obtaining, in general, vital statistics (statics on births and deaths) by small area. In 2015, however, Prof. Takashi Inoue, Faculty of Economics, Aoyama Gakuin University unveiled a projection of the whole nation by small area for the period up to 2060 ("System of Small Area Population Projection for Nationwide Japan" https://goo.gl/lSoL6O). The population projection was performed based on the conventional cohort-change rate method by importing the concept of population potential, which asserts that geographically close areas also present similar population statistics. In this paper, we visualized and analyzed the said projection data in geographical space. The population projection for Niigata City performed by the National Institute of Population and Social Security Research and the total of small area-based population projections for Niigata City performed by Prof. Takashi Inoue, Faculty of Economics, Aoyama Gakuin University are shown in comparison below (Table 5 and 6).

Table 5: Population projection for Niigata City performed by the National Institute of Population and Social Security Research

Population	2010	2020	2030	2040
0 to 14 years old	103,398	88,644	72,519	63,220
15 to 64 years old	519,787	459,236	418,861	355,904
65 to 74 years old	93,475	114,068	89,718	100,899
75 years old and over	95,241	121,101	151,200	148,322
Total	811,901	783,049	732,298	668,345

Source: "National Census" (2010 data) by the Ministry of Internal Affairs and Communications and "Regional Population Projections for Japan" by National Institute of Population and Social Security Research

Table 6: Total of small area-based population projections for Niigata City performed by Prof. Takashi Inoue, Aoyama Gakuin University

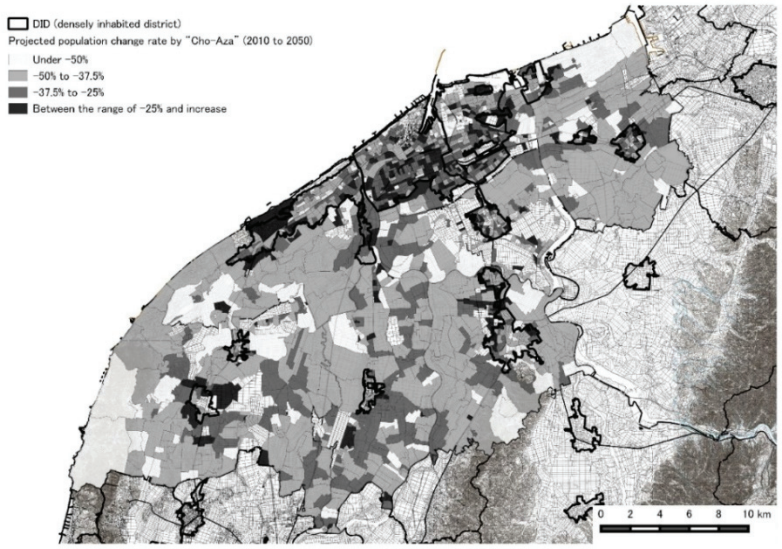
Population	2010	2020	2030	2040	2050
0 to 14 years old	103,398	91,075	72,636	60,155	51,167
15 to 64 years old	519,787	451,140	401,016	329,169	265,609
65 to 74 years old	93,475	115,194	91,613	102,794	88,147
75 years and over	95,241	114,197	137,750	128,480	133,655
Total	811,901	771,606	703,015	620,598	538,578

Source: "National Census" (2010 data) by the Ministry of Internal Affairs and Communications and "System of Small Area Population Projection for the Whole Japan" by Prof. Inoue of Department of Economics, Aoyama Gakuin University

The projected population change rate in Niigata City at the small area level ("Cho and Aza") between 2010 and 2050 is shown in Figure 7 below. ("Cho" and "Aza" are subdivisions of a municipality.) Most of the area is projected to face a population decline of 25% or more with the exception of some areas including the outer edge of the urban areas. By comparison, the population decline rate for the country between 2010 and 2050 is 24.2% according to the National Institute of Population and Social Security Research, and that for the city of Niigata is 33.7% according to the projection performed

by Prof. Takashi Inoue of Aoyama Gakuin University. In addition, although the population decline rate is not so high in the currently densely populated urban areas including DIDs, the reduction in terms of the population number will be greater, because the population base is large to start with.

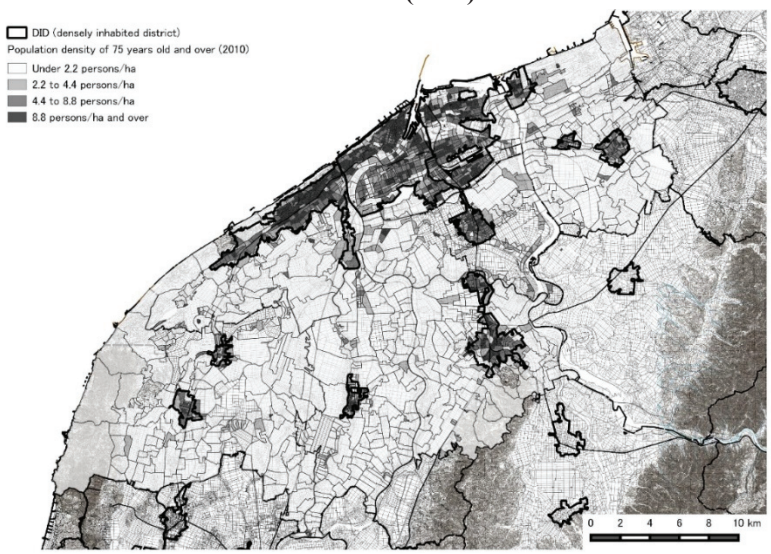
Figure 7: Projected population change rate in Niigata City between 2010 and 2050



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

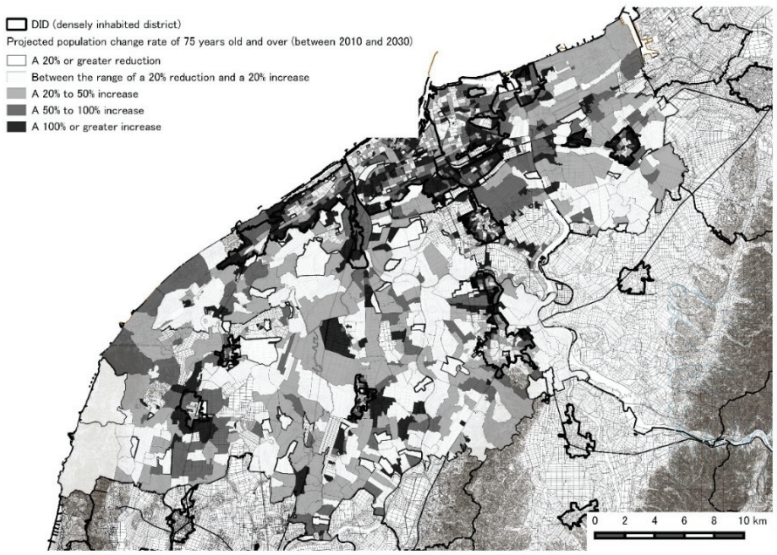
Next, with regard to the population aged 75 and over, population density at "Cho-Aza" area level in 2010 is shown in Figure 8, and then, the projected population change rates between 2010 and 2030 as well as between 2030 and 2050 are shown in Figure 9 and Figure 10, respectively.

Figure 8: Population density of persons 75 years old and over in Niigata City at "Cho-Aza" area level (2010)



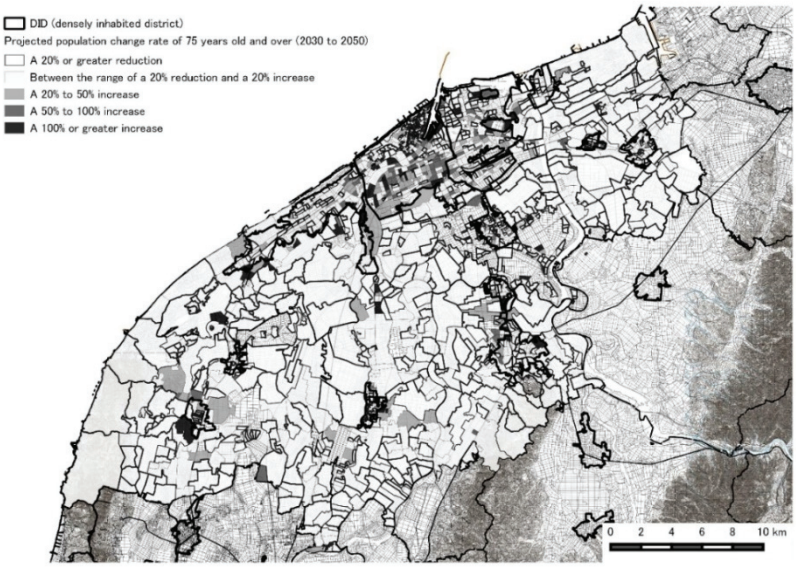
Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 9: Projected population change rate of persons 75 years old and over in Niigata City between 2010 and 2030



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 10: Projected population change rate of persons 75 years old and over in Niigata City between 2030 and 2050



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

The population of persons 75 years old and over is projected to increase in many districts of Niigata City between 2010 and 2030, mainly in urban areas (DIDs). In particular, a very large number of outlying areas of DIDs show a 100% or greater increase. A relatively large number of suburban farming communities also indicate an increase, and areas that indicate a 20% or greater reduction are limited.

On the other hand, between 2030 and 2050, the population of persons 75 years old and over is projected to decline by over 20% in many of the districts. The projection also indicates that an increase will be observed in the outlying areas of DIDs and the center of Niigata City. As the total population of persons 75 years old and over is projected to decrease slightly, it is considered that the decline in numbers in the suburbs and increase in the DIDs are at a comparable level.

Based on the year of construction, the distribution of residential long-term care facilities that are projected to be considered questionable or become potentially questionable in 2030 or 2050 is shown in Figures 11 and 12 below.

Although there is a small number of facilities that are likely to be questionable in 2030, over 70% of the existing facilities are considered to have problems in 2050 due to building lifespan. The projection also indicates that many of those problematic facilities are located in the outlying areas of DIDs and suburban farming communities. This result reflects the fact that this area contains a large number of relatively old buildings.

As discussed above, although it is considered that problems such as aging facilities and renewal of facilities will occur only rarely before 2030 due to building lifespan, a large number of problems is anticipated in the period 2030 to 2050, such as demolition or rebuilding of facilities, mainly among those located in the outlying areas of DIDs and suburban farming communities.

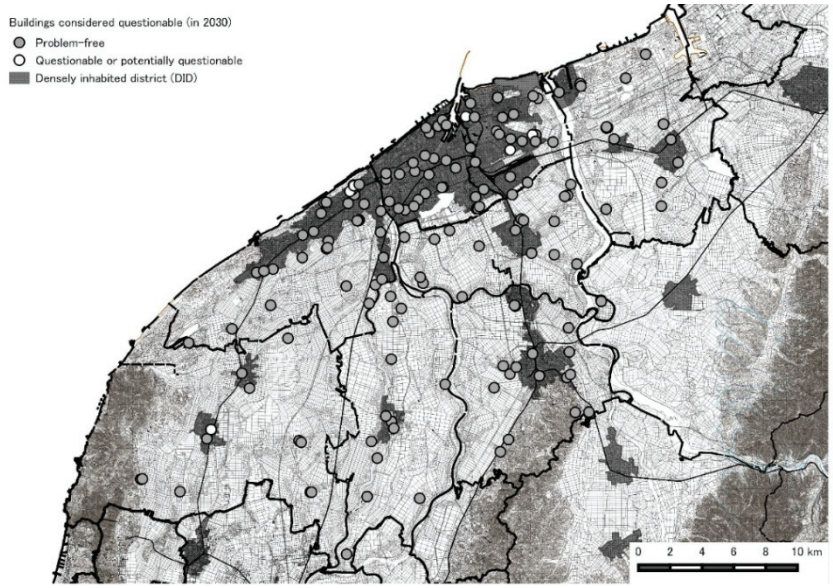
The residential long-term care facilities that have recently been built have shifted their focus to community-based facilities. It is considered desirable that such facilities be located to match the distribution of their core users, i.e., the population of persons 75 years old and over, coupled with promotion of the “Community-based Comprehensive Care System.”

However, as discussed above, many of the residential long-term care facilities in Niigata City are located in the outlying areas of urban areas (DIDs) or their suburban farming communities, while users of such facilities who are 75 years old and over are concentrated in urban areas. This finding apparently shows that there is currently a major gap between facilities and their users in terms of their locational relationship.

The gap between the supply of and demand for facilities is anticipated to expand even further for the following reasons. Although the population of persons 75 years old and over shows an increasing trend for the period up to 2030, including suburban farming communities, the said population is projected to decline by over 20% in most districts of such farming communities for the period 2030 to 2050, while that in urban areas (DIDs), mainly in their outer edge, is projected to greatly increase during the same period. Furthermore, another problem is that while only a few existing facilities are anticipated to become questionable before 2030 in terms of their building lifespan, many facilities located mainly in the outlying areas of DIDs and suburban farming communities will become questionable during the period 2030 to 2050.

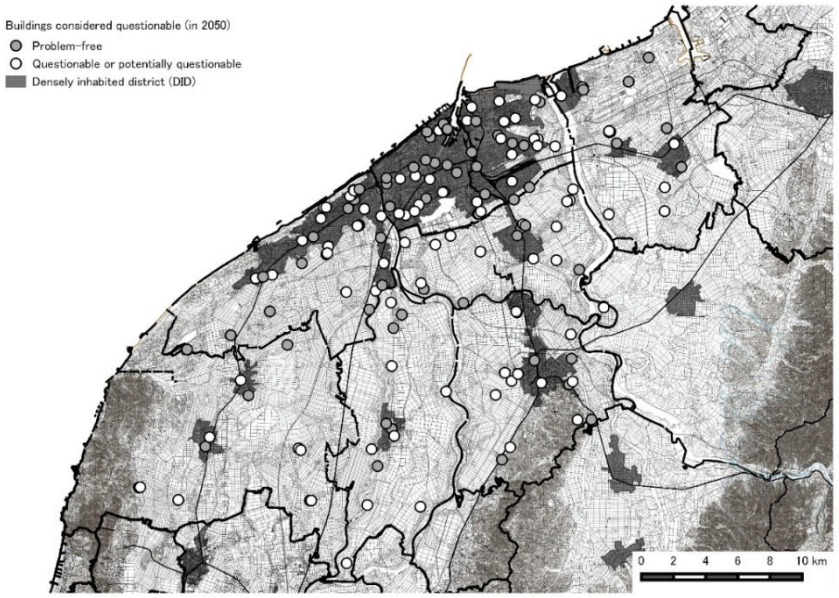
As discussed above, it can be said that we should study the optimal geographical location of residential long-term care facilities in Niigata City based on the present status of disproportionately located facilities, while also taking into account the projection of population changes by small area, etc. and the projection based on the standpoint of facility aging.

Figure 11: Questionable or potentially questionable residential long-term care facility buildings in 2030



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 12: Questionable or potentially questionable residential long-term care facility buildings in 2050



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

IV. Analysis concerning optimal geographical location of facilities leveraging Voronoi tessellation

The concern over the lack of residential long-term care facilities will grow along with an increase in the elderly, particularly those aged 75 and over. As discussed above, however, it is important that we examine the way we think about proper geographical location of facilities in the future by taking into consideration the issue of disproportionately distributed/located facilities in Niigata City, a real difference in increase or decrease of the population of persons 75 years old and over for the period up to 2050, as well as future relocation needs due to aging of residential long-term care facilities.

Therefore, in this section, we focus on group homes as one kind of residential long-term care facility, and study the status of their excess or deficiency based on the projected population data on persons 75 years old and over at the "Cho-Aza" area level. With regard to the index concerning lack of facilities for dementia patients per capita aged 75 and over, we assumed the following indices in estimating the level of deficiency.

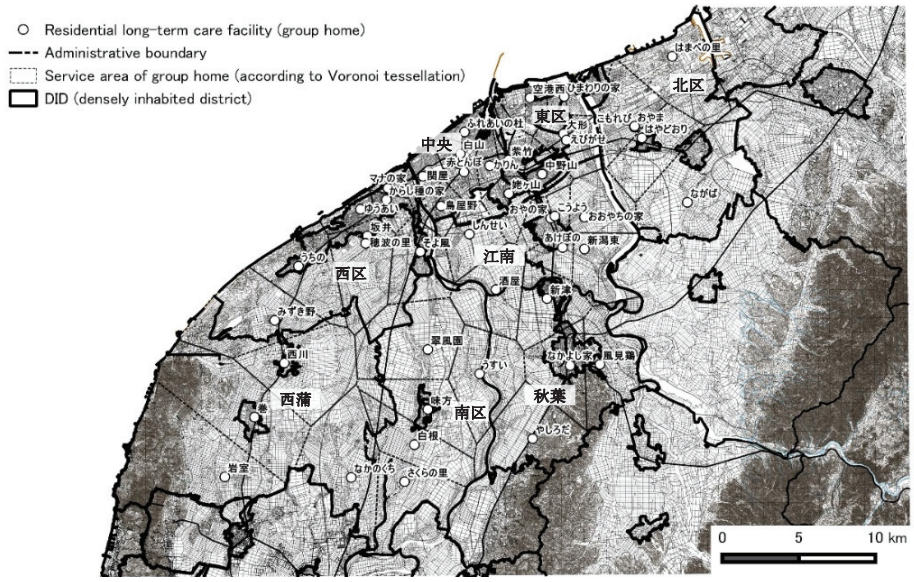
The "probability that the elderly aged 75 and over develop dementia" is calculated to be 17.74% according to the age group-specific data on "elderly people with dementia whose daily life independence level is rated II or higher," which is part of the "Data on Certification of Eligibility for Long-term Care Insurance (2010)" of the Ministry of Health, Labour and Welfare.

On the other hand, however, if we look at "communal daily long-term care facilities for dementia patients" (group homes) as "facilities for dementia patients," there are actually many elderly dementia patients who receive long-term care at home or reside in facilities, including "Tokuyo," "Roken," or sanatoriums. This led us to look for useful data on what percentage of the elderly whose daily life independence level is rated II or higher enter a group home. We found a "breakdown of the residence of elderly dementia patients" in the "Latest Information on the Long-Term Care Insurance System (September 2012)" issued by the Ministry of Health, Labour and Welfare. According to the information, out of the total of 2.8 million elderly dementia patients, 140,000 reside in group homes, which accounts for 5% of the total.

Therefore, when estimating a "shortage of capacity of facilities for dementia patients per capita aged 75 and over," it is considered appropriate to calculate a "probability that the elderly aged 75 and over develop dementia and enter a group home (on national average)" according to the following equation: 17.74% × 5% = 0.89%. As there were 95,241 elderly aged 75 and over in Niigata City in 2010, the capacity of required facilities for dementia patients can be estimated as follows: 95,241 persons × 0.89% = 847 persons. Now, as there are currently 48 group homes with total capacity of 639 persons in Niigata City, there is a 208-persons shortage of capacity. In addition, by using the value 0.89%, the appropriate number of the elderly population aged 75 and over per group home resident within its service area is estimated as follows: 1 ÷ 0.0089 = 112 (persons).

For the purpose of estimating an excess or deficiency status of group home facilities, we performed a Voronoi tessellation by regarding each location of the group homes in Niigata City as a kernel, and set the service area for each group home based on distance. We superimposed this service area map on the "Cho-Aza"-based area map (fractions were reallocated in proportion to the area), and estimated the projected elderly population aged 75 years old and over by service area in 2010, 2030, and 2050, thereby calculating the over- or under-populated status of the elderly aged 75 and over per service area of each group home. In doing so, we used the population of 112 persons per group home resident as the index concerned with excess or deficiency status of facilities, as earlier mentioned. The results are shown in Table 7 and Figures 14 through 16. Figure 13 shows how wards are distributed in Niigata City, the geographical location of group homes and their names (abbreviated).

Figure 13: Service area of group homes in Niigata City (according to Voronoi tessellation)



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Considering that the total capacity of the group homes located in Niigata City in 2010 is 639 persons, and that the national average of the population of persons 75 years old and over per group home resident is 112 persons, the size of the population of 75 years old and over for whom the existing facilities is considered to be capable of providing service is calculated as follows: 639 persons × 112 persons = 71,568 persons. On the basis of the population of persons 75 years old and over in Niigata City in 2010, 95,241 persons, the populational coverage level is 75% (= 71,568 persons ÷ 95,241 persons). Therefore, under the present situation, an insufficiency of facilities is being observed in Niigata City as a whole.

When observed by service area of group homes (Figure 14), the population of persons 75 years old and over per group home resident in some of the urban areas, including DIDs, is 448 persons, which is four times greater than that of the national average, and indicates a seriously deficient situation. On the other hand, the population of persons 75 years old and over per group home resident in many of the suburban farming communities that are not DIDs is less than 112 persons, which indicates that facilities are provided in relative excess of the service required. Nevertheless, as every group home is fully occupied, it is considered that the facilities with excess capacity are filled by people from neighboring service areas. Considering the fact that the populational coverage level of facilities in Niigata City as a whole is 75%, the remaining 25%, or unmet demand, is considered to elucidate a situation in which elderly people are obliged to enter other types of residential long-term care facilities such as fee-based homes for the elderly, or be forced to receive long-term care at their homes.

Table 7: Population of persons 75 years old and over in the service areas of group homes, and population of persons 75 years old and over per group home resident

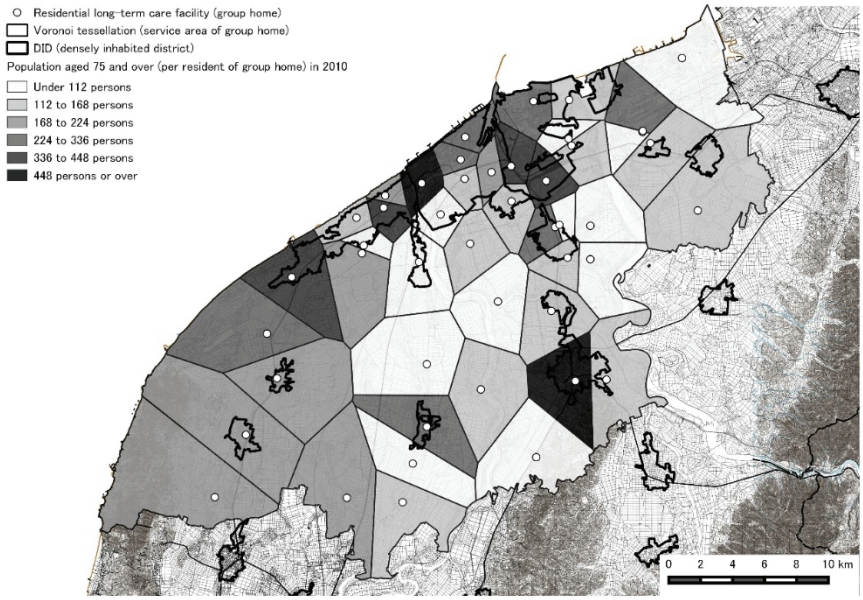
Ward	Group home name (abbr.) (English/Japanese)		Capacity	Population of 75 years old and over in the service area			Population of 75 years old and over per resident of group home			Increase-decrease rate	
				2010	2030 projection	2050 projection	2010	2030 projection	2050 projection	2030/2010	2050/2030
Kita	Komorebi	こもれび	18	511	1,131	1,063	28.4	62.8	59.1	121%	-6%
	Hayado-ori	はやどおり	9	1,397	3,006	2,929	155.2	334.0	325.4	115%	-3%
	Nakaba	ながば	18	2,644	4,124	3,514	146.9	229.1	195.2	56%	-15%
	Hamabe-no-sato	はまべの里	18	1,156	1,541	1,080	64.2	85.6	60.0	33%	-30%
	Oyama	おやま	9	1,191	2,040	1,755	132.3	226.6	195.0	71%	-14%
Higashi	Himawari-no-ie	ひまわりの家	18	2,377	3,782	3,382	132.1	210.1	187.9	59%	-11%
	Oogata	大形	18	1,208	2,318	2,707	67.1	128.8	150.4	92%	17%
	Ku-ko-nishi	空港西	18	4,877	6,917	6,499	271.0	384.3	361.1	42%	-6%
	Ebigase	えびがせ	9	1,044	2,158	2,011	116.0	239.8	223.5	107%	-7%
	Nakano-yama	中野山	9	3,050	5,698	5,822	338.9	633.1	646.8	87%	2%
Chuo	Ubagayama	姥ヶ山	18	2,280	3,964	3,973	126.7	220.2	220.7	74%	0%
	Sekiya	関屋	9	3,948	5,363	5,896	438.7	595.9	655.2	36%	10%
	Fureai-no-yashiro	ふれあいの杜	18	4,257	5,176	4,346	236.5	287.5	241.4	22%	-16%
	Shichiku	紫竹	9	3,708	5,194	5,491	412.0	577.1	610.1	40%	6%
	Hakusan	白山	9	2,552	3,329	3,405	283.5	369.9	378.4	30%	2%
	Toyano	鳥屋野	27	1,913	3,265	4,365	70.8	120.9	161.7	71%	34%
	Karin	かりん	18	3,071	4,652	6,009	170.6	258.5	333.8	51%	29%
	Akatonbo	赤とんぼ	18	2,922	4,378	5,969	162.3	243.2	331.6	50%	36%
Konan	Ooyachi-no-ie	おおやちの家	18	1,124	1,265	1,146	62.5	70.3	63.7	12%	-9%
	Niigata Higashi	新潟東	18	909	1,372	1,382	50.5	76.2	76.8	51%	1%
	Oya-no-ie	おやの家	9	2,001	3,377	3,329	222.3	375.2	369.9	69%	-1%
	Koyo	こうよう	9	550	743	629	61.1	82.6	69.8	35%	-15%
	Sakaya	酒屋	9	923	1,086	808	102.5	120.6	89.8	18%	-26%
	Akebono	あけぼの	9	1,059	1,872	1,989	117.7	208.0	221.0	77%	6%
	Shinsei	しんせい	9	1,229	1,810	1,487	136.5	201.1	165.3	47%	-18%
Akiba	Niitsu	新津	18	2,046	3,390	3,560	113.7	188.4	197.8	66%	5%
	Nakayoshi-ya	なかよし家	9	4,535	5,493	4,540	503.9	610.3	504.4	21%	-17%
	Kazamidori Takiya	風見鶏・たきや	18	2,048	2,429	2,040	113.8	135.0	113.3	19%	-16%
	Yashiroda	やしろだ	18	1,395	1,840	1,607	77.5	102.2	89.3	32%	-13%
Minami	Ajikata	味方	9	2,034	2,767	2,520	226.0	307.4	280.1	36%	-9%
	Sakura-no-sato	さくらの里	9	1,201	1,382	1,118	133.4	153.6	124.2	15%	-19%
	Usui	うすい	9	1,264	1,550	1,263	140.5	172.2	140.3	23%	-19%
	Shirone	白根	9	748	869	716	83.1	96.6	79.5	16%	-18%
	Sui-fu-en	翠風園	18	1,493	1,747	1,779	83.0	97.1	98.8	17%	2%
Nishi	Mizukino	みずき野	9	1,205	1,672	1,425	133.9	185.8	158.4	39%	-15%
	Uchino	うちの	9	2,775	4,522	3,945	308.4	502.5	438.3	63%	-13%
	Sakai	坂井	27	1,236	2,199	2,118	45.8	81.5	78.5	78%	-4%
	Karashi-dane-no-ie	からし種の家	9	3,041	4,486	4,353	337.9	498.5	483.7	48%	-3%
	Yu-ai	ゆうあい	27	3,470	4,855	4,102	128.5	179.8	151.9	40%	-15%
	Honami-no-sato	穂波の里	9	1,504	2,067	2,248	167.2	229.7	249.7	37%	9%
	Mana-no-ie	マナの家	9	2,001	2,156	2,328	222.3	239.5	258.7	8%	8%
	Soyokaze	そよ風	27	2,500	4,577	4,462	92.6	169.5	165.3	83%	-3%
Nishikan	Maki	巻	18	3,061	4,237	3,695	170.1	235.4	205.3	38%	-13%
	Iwamuro	岩室	9	1,710	2,089	1,571	190.0	232.1	174.6	22%	-25%
	Nishikawa	西川	9	1,782	2,213	1,895	198.1	245.9	210.5	24%	-14%
	Nakanokuchi	なかのくち	9	1,422	1,649	1,386	158.0	183.2	154.0	16%	-16%

Population of 75 years old and over per resident of group home: 224 persons or over (double the number of national average)

Population of 75 years old and over per resident of group home: under 112 persons (the national average)

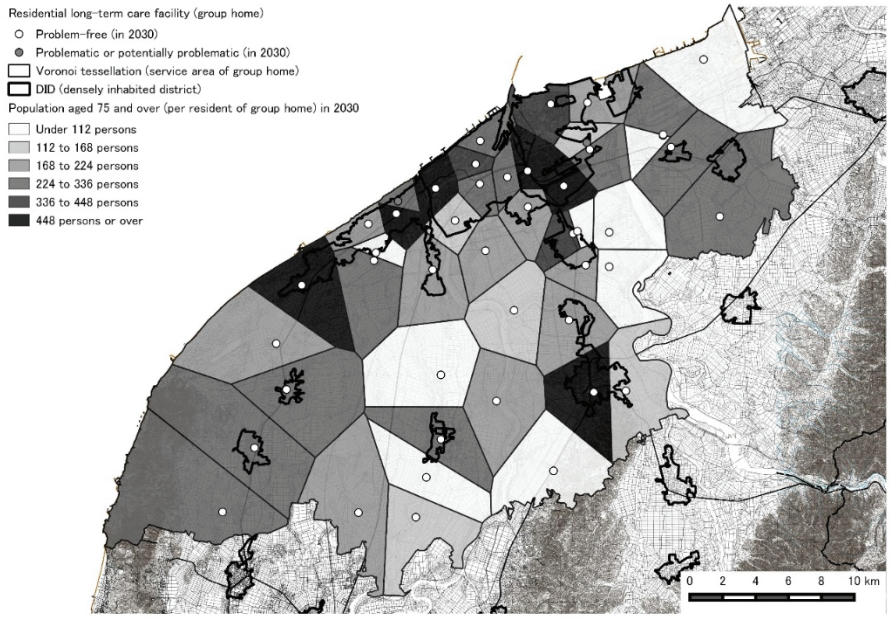
Source: Prepared by the authors.

Figure 14: Population of persons 75 years old and over per group home resident in Niigata City in 2010



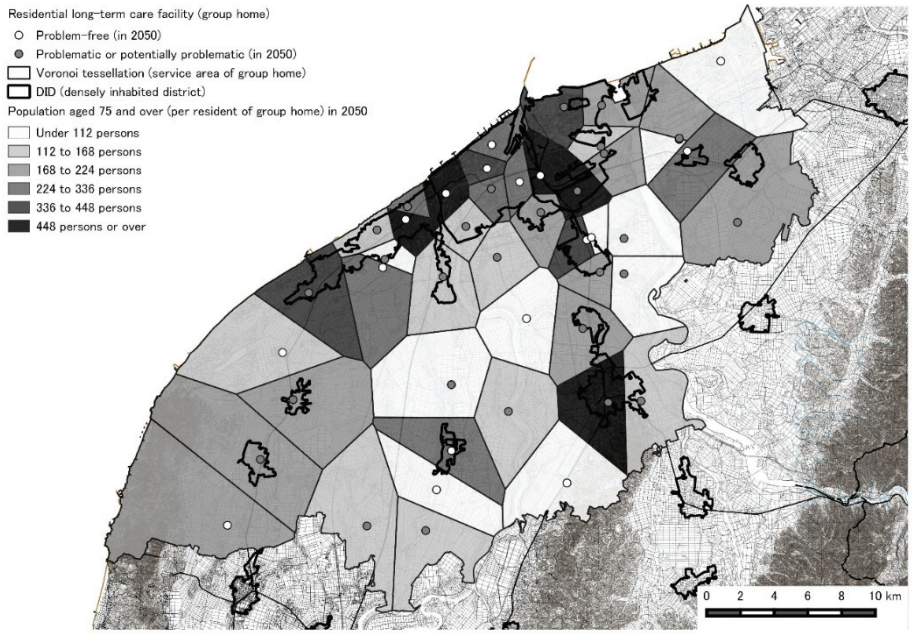
Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 15: Projected population of persons 75 years old and over per group home resident in Niigata City in 2030



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Figure 16: Projected population of persons 75 years old and over per group home resident in Niigata City in 2050



Source: Prepared by the author. (The map is based on the "Fundamental Geospatial Data" of Geospatial Information Authority of Japan. Data are partially based on the "Digital National Land Information" of the Ministry of Land, Infrastructure, Transport and Tourism.)

Next, based on the population projection for 2030, let us look at changes in the populational coverage level of facilities, provided that the geographical locations and capacities of group homes remain unchanged from the present status (Figure 15). The populational coverage level of facilities in Niigata City as a whole in 2030 is 52% (= 71,568 persons ÷ 137,750 persons), indicating a trend that the population of persons 75 years old and over per group home resident will increase in all service areas. In many of the urban areas including DIDs, in particular, the population of 75 years old and over per group home resident is projected to be over 448 persons (fourfold the national average), and similarly, an increase is projected in many of the suburban farming areas. Therefore, if the present situation of the group home facilities remains unchanged, a sense of insufficiency will grow even stronger in urban areas, and a sense of insufficiency will also intensify in many of the farming communities where demand is mostly satisfied under the present situation.

Similarly, if we compare the population projection for 2050 with the current geographical locations and capacities of group homes (Figure 16), a sense of insufficiency comparable to that of 2030 is continuously observed in urban areas including DIDs. On the other hand, a sense of insufficiency that has been felt in farming communities is alleviated due to a decline in the population aged 75 years old and over in many parts of those communities. Incidentally, the populational coverage level of facilities in 2050 is 54% (= 71,568 persons ÷ 133,655 persons). It is also projected that about two-thirds of the existing group home facilities will become questionable in 2050 due to building lifespan. These questionable facilities include many of those located in suburban farming communities, in which needs are anticipated to remain limited into the future.

As discussed above, Niigata City as a whole is short of group homes under the present situation, and regional imbalances are also being observed. It is therefore recommended that both the number of facilities and their capacities be increased in future mainly in areas where there is a strong sense of insufficiency. In order to ensure adequate supply of facilities into the future, the following factors will need to be taken into consideration: 1) disproportionately located facilities, thereby creating an excess or deficiency status, 2) gap in demand projection between that for the period from now to 2030 and that from 2030 to 2050, and 3) a real difference in demand projection, etc.

It is considered that between 2030 and 2050, many of the existing facilities will have to be demolished or rebuilt due to building lifespan. It is therefore considered necessary to also conduct facility renewal based on the idea of where facilities should be properly located, including rebuilding of facilities at their present sites or at relocated sites, or facility consolidation, etc., by taking into account the issue of the aging of facilities mentioned above.

V. Summary and future agenda

The major purpose of this paper was to analyze and study how long-term care facilities should effectively and efficiently be located in a depopulating and super-aging society with the use of GIS data on distribution of residential long-term care facilities and elderly population in Niigata City, while also taking into consideration future demographics and lifespan of facilities.

With an awareness of these issues, we specifically focused on communal daily long-term care facilities for dementia patients (group homes) as part of the residential long-term care facilities. We used data on current and projected future population of the elderly aged 75 and over at “Cho-Aza” area level, and compared the current and future needs for group homes by service area and the current supply situation of the said facilities.

Our analysis showed that a strong sense of insufficiency of these facilities is already being felt in urban areas, including DIDs, while suburban farming communities are relatively over-supplied. It also clarified that looking to the future, the sense of insufficiency in urban areas is expected to rise increasingly, while the sense of excessive supply is expected to grow further in the suburban farming communities. As this result is based on the current and projected future population data on the elderly aged 75 and over, this finding is considered applicable not only to group homes but also to other residential long-term care facilities.

As the need for these types of facilities is expected to grow more than ever against the backdrop of a further increase in the elderly population in future, we believe that the issue of improved efficiency of facilities by optimizing their geographical locations will become increasingly significant. At the same time, promotion of the Care Compact City will also be required in light of financial constraints. Furthermore, as an increasing number of existing facilities is also expected to face the issue of aging, screening for optimization, including reorganization or relocation of facilities, as well as introduction of private-sector initiatives will become extremely significant.

These initiatives will also require in-depth study on reorganization of urban structure, not to mention facility-specific study. It is therefore considered extremely important that they be integrated into and contribute to study on the reorganization of infrastructure in urban and local areas, including roads, bridges, sewage system, schools, and other educational facilities.

In our recent analysis on optimal geographical location of facilities by leveraging Voronoi tessellation, we captured, assessed, and performed analysis on data concerning facilities on the supply side, the population of persons 75 years old and over as the index on the demand side, and their positional relationship in terms of distance by defining the service areas of facilities through the use of GIS. While our analysis covered a total of 48 group home facilities in Niigata City, the

small area-based population data covered as many as about 2,200 small areas, which means that each facility provides service, on average, to nearly 50 small areas. It is therefore also possible to perform an even more finely grained analysis on positional relationship between facility and population in terms of distance. For instance, calculation of the current and projected population of persons 75 years old and over in a 500m radius, 500 to 1,000m radius, 1,000m radius or over from each facility is also possible.

With regard to long-term care facilities and their service, accessibility for users is important for commuting care facilities. For home-visit service, as well, accessibility to users helps increase efficiency of service providers. As for residential facilities, it is most desirable for family members if they are located closer to their homes as it enables them to visit residents more frequently. If an environment that enables the elderly to enjoy support service focused on continued living at home, including medical and long-term care service and retail shopping, is created within walking distance, it will encourage the elderly to go out more actively, improve their quality of life, and prevent long-term care needs. At the same time, this is expected to reduce costs concerned with medical and long-term care.

With this in mind, and also for the purpose of promoting the "Care Compact City," an initiative aimed at efficiently and effectively providing medical and long-term care services in a consolidated, high-quality residential/regional space, we believe that we will be able to perform a detailed assessment on the effects of optimal facility locations by calculating the current and projected population in each radius from the assumedly appropriate hub facility or place in a consolidated environment, while taking into account the relationship between long-term care facilities/public facilities and users in terms of distance.

Furthermore, in addition to the above, studying proactive relocation of housing, for instance, proactive moving to urban areas by leveraging vacant houses or open space, which are expected to increase further, after carrying out renovation required for people in their senior years or rebuilding existing houses geared for the elderly, will lead to the formulation of effective measures and assessment methods. This would be aimed at promoting a more effective "Community-based Comprehensive Care System" and "Compact City" and at building a "Care Compact City," the integration of the two, from the aspect of positional relationship in terms of distance, including not only the supply side (facilities) but also the demand side (housing).

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