原　著

Visualization of the relationship between the geographic distribution of day service facilities for the elderly and local elderly residents using a geographic information system

地理情報システムによる通所介護施設と地域高齢者の地理的分布の可視化

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要　旨

本研究は，通所介護施設と地域高齢者の地理的分布からみた介護福祉サービスの整備状況と利用者の地理的分布から見た施設提供サービスの現状について，特に距離的アクセシビリティの点から検討することを目的とした．
対象地域を埼玉県所沢市とした（通所介護施設：25）．通所介護施設の住所データ，所沢市町丁別地図，所沢市要介護・要支援認定者数，日常生活圏域に関するデータセットを作成した．それらのデータを ArcGIS9.1（ESRI 社製）の ArcView を用い GIS 上で統合した．さらに，一施設を対象として，施設を中心とする距離圏と利用者の地図情報を GIS 上に表示した．

その結果，所沢市内の通所介護施設と高齢者人口の地理的分布との関連では，各通所介護施設のカバー要介護者数でみた場合，市内の北西部で少なく，市の中心部を含む南部で多くなるという地理的な偏りがみられた．1 施設がサービスを提供すると想定される圏域（ボロノイ領域の面積）も南部で大きくなっていた．また，市内 65 歳以上人口の約半数は，最寄りの施設から 1,000m 圏外に居住していた．特定の 1 施設を対象とした分析では，利用者の 40%以上が 2,000m 以上離れて居住している者であった．

本研究の結果から，通所介護施設の地理的空間的分布に偏りがあることが視覚的に明らかとなった．今回の方法論を用いることは，政策立案者にとって地域高齢者福祉政策・活動を評価・立案する際に大いに参考になることに加え，施設経営者にとっても利用者獲得に向けた戦略に用いることが可能と思われる．

Abstract

Objectives: The aim of this study was to investigate the relationship between the geographic distribution of day service facilities for the elderly and local elderly residents, and the status of facilities providing services as viewed from the geographic distribution of users.

Methods: The study area was Tokorozawa City, Saitama, Japan, in which the study targeted 25 day service facilities for the elderly. We used the Voronoi tessellation to determine the facilities nearest to an elderly person's residence, by ascertaining the distance of the users' residences from the facilities with consideration given to distance by road. This data was integrated with the addresses of the facilities on a geographic information system in order to examine geographic maldistribution.

Results: Geographic maldistribution was observed in the relationship between area of service of facilities and the number of elderly residents in need of support or care. The "covered number of elderly residents in need of support or care" were few in the northwestern part of the city and many in the southern part. Further, in the south, the area assumed to be involved in the provision of services by a single facility (i.e., the area of the Voronoi area) was also large. Moreover, in an evaluation of the geographic access to day service facilities for the elderly among local elderly residents, around half of the elderly persons resided in areas <1,000 m from the nearest facility.

In a case study of the geographic distribution of users of a day service facility for the elderly, it was estimated that 40% of the elderly resided persons in areas >2,000 m from the facility they used.

Conclusion: It was visually clear that the geographic distribution of day service facilities for the elderly was uneven. Moreover, the use of the methodology applied in this study can serve as a major reference for policy makers when planning and evaluating regional welfare policies and activities for the elderly.

Keyword: Geographic information system; long-term care insurance; day service facilities for the elderly; geographic distribution; visualization

Introduction

Among the various policies that have been designed in response to Japan's aging society, one of the largest reforms in recent years was the establishment of the long-term care insurance (LTCI) system in April 2000[1-5]. This program ensures that all Japanese citizens who are 65 years old and above are eligible for benefits (institutional and community-based services, but not money) based on physical and mental disabilities[6]. The computer-aided standardized needs assessment used in this study categorizes people into seven levels. With the implementation of this system, there was a major shift in the priority toward home-based welfare, with a further shift toward "pick-and-choose welfare" based on individual choice. Further, ever since the establishment of the LTCI system, there has been a significant increase in the number of LTCI users. This increase has been attributed to the increase in the aging rate and home care service users.

In general, a greater demand for home-care services, due to the demand for welfare services, is expected in the future. The insurance and welfare policies among the elderly that have been undertaken hitherto have lacked a geographic focus, such as computing numerical infrastructure targets based on relative population ratios[7].

Recently, a number of reports pertaining to the geographic distribution of medical care facilities and the use of these facilities by local residents have been published. In addition to reports stating that the geographic accessibility of medical care facilities affects the use of these facilities by local residents, there have been numerous reports investigating the geographic distribution of local health care plans by medical care facilities[8–11].

Among home-care services, day service facilities for the elderly may be used on a daily basis by those who require support or care The location or geographic accessibility of such facilities is perceived as a very important factor from the perspective of potential users.

Nevertheless, there exist relatively few reported investigations on geographic accessibility vis-à-vis the current location of day service facilities for the elderly compared with the number of related reports

investigating health care facilities.

This study investigates the current infrastructure of long-term care welfare services from the perspective of the geographic distribution of day service facilities for the elderly among local residents, as well as the current status of services provided by the facilities from the perspective of the geographic distribution of the users.

Materials and Methods

Study area

The study area was Tokorozawa City, Saitama, Japan (Fig. 1, Table 1, area: 71.99 km2; population: 337,883; population density: 4,626 inhabitants/km2; population of individuals of 65 years and above: 54,966; aging rate: 16%).

A large geographic variation was seen in the certified number of elderly residents in need of support or care among the 14 daily living areas that were publicized by the city authorities. While the area with the largest population had 858 persons, the area with the smallest population had 284 persons (Fig. 2). The percentage of the certified population in need of support or care was an estimated 15% in each area.

There are 25 day service facilities for the elderly in the city; the service areas for 14 comprehensive regional support centers were set up in accordance with the daily living areas[12].

Analytical methods

We analyzed the data in the following three stages: (1) investigation of the relationship between day service facilities for the elderly, provision areas, and the certified number of elderly residents in need of support or care; (2) evaluation of geographic access to day service facilities for the elderly among local elderly residents; and (3) a case study on the geographic distribution of elderly day service facility users.

These analyses were made using the data in Table 2. The data presented in Table 2 can be obtained without having to apply special methods. The analysis in each of the three stages is described in the following.

1. Relationship between day service facilities for the elderly, provision areas, and the number of elderly residents in need of support or care

First, we collected data sets of the addresses of day service facilities for the elderly, an area map of Tokorozawa City, the certified number of elderly residents in need of support or care, and the daily living area (Table 2). This data was then integrated into a geographic information system (GIS) using ArcView (ArcGIS ver. 9.1) obtained from ESRI Inc. (California City, CA, USA).

To determine the facility nearest to an elderly person's residence using the ArcGIS ver. 9.1, Voronoi tessellation, which assumed that each facility was the center, was applied. Voronoi tessellation is a mathematical method that, by drawing a vertical bisector toward a straight line that links two points that are next to each other on a plane, divides the domain nearest to each point. The figure resulting from the Voronoi tessellation is called the Voronoi diagram. In this study, wherein multiple facilities set on a plane generate points, a division is made from the nearest generating point within the entire city area. The generating point of each area obtained using the Voronoi tessellation shows that the area "at a random point within the area (i.e., a random residence of a facility user) is the nearest in a straight-line distance." Further, areal weighting interpolation was used to compute the certified number of elderly residents in need of support or care within the cell of each facility. We assumed that these calculated values "covered number of elderly residents in need of support or care." The areal weighting interpolation is a method whereby it is hypothesized that the population is evenly distributed within a single area, and when a certain area has been divided into two or more areas according to each areal ratio using Voronoi tessellation, the population is divided among those divided areas. The Areal Weighting Interpolation Totaling Tool ver. 1 (Exceed Corp. Saitama, Japan) was used for this purpose.

Table 1. Demographical characteristics

Daily living area	65 years old and above			The certified number of elderly residents in need of support or care	Aging rate
	Male	Female	Total		
A	2,297	2,603	4,900	760	18.4
B	1,994	2,984	4,978	858	16.2
C	1,985	2,637	4,622	763	16.2
D	1,321	1,585	2,906	404	19.1
E	1,641	1,976	3,617	557	17.4
F	1,531	1,779	3,310	494	15.8
G	2,448	2,837	5,285	820	15.0
H	2,270	2,706	4,976	760	15.6
I	1,900	2,399	4,299	672	15.3
J	1,072	1,350	2,422	284	15.6
K	1,964	2,411	4,375	703	19.5
L	800	1,018	1,818	376	9.5
M	1,756	2,005	3,761	583	17.5
N	1,752	1,945	3,697	570	17.1
Total	24,731	30,235	54,966	8,604	16.2

Table 2. Data sets

Data base	Date of issue	Source
①Addresses of day service facilities	July, 2006	List of companies concerned with Long-Term Care Insurance in Tokorozawa city (Department of Long-Term Care Insurance, Tokorozawa city)
②Area map of Tokorozawa City	February, 2003	Digital map 2500 Kanto-2 (Geographical survey institute, Japan)
③The Certified number of elderly residents in need of support or care	June, 2006	Plan of Health and welfare plan for the elderly and Long-Term Care Insurance services in Tokorozawa city (Department of Long-Term Care Insurance, Tokorozawa city)
④Daily living area	March, 2006	Plan of Health and welfare plan for the elderly and the Long-Term Care Insurance service in Tokorozawa city (Department of Long-Term Care Insurance, Tokorozawa city)
⑤Entire city map of Tokorozawa city	February, 2003	Digital map 2500 Kanto-2 (Geographical survey institute, Japan)
⑥Road map of Tokorozawa city	February, 2003	Digital map 2500 Kanto-2 (Geographical survey institute, Japan)
⑦Population of Tokorozawa city	April, 2000	Census mesh data (Japan Statistical Association) [533953 Tokorozawa・533954 Shiki・533963 Southern part of Kawagoe]
⑧Addresses of users of Facility	December, 2006	From research facility
⑨Residential map of Tokorozawa city	December, 2004	Residential map 200602 Saitama eastern and western parts of Tokorozawa (Zenrin Co, Japan)

Analysis1(①, ②, ③, ④), Analysis 2(①, ⑤, ⑥, ⑦), Analysis3(①, ④, ⑧, ⑨)

2. Evaluation of geographic access to day service facilities for the elderly among local elderly residents

First, data sets of the addresses of day service facilities for the elderly, an area map of Tokorozawa City, a Tokorozawa City road map, and Tokorozawa City population data were tabulated (Table 2). Using these data sets, the Network Analyst function of ArcGIS ver. 9.1 was used to calculate, in five stages (<500 m, 500–1,000 m, 1,000–1,500 m, 1,500–2,000 m, >2,000 m), the distance areas from the facilities taking into consideration the distance via road.

Next, population data was entered into the GIS using grid square statistics from the National Census data for the year 2000 (Japan Statistical Association, Tokyo, Japan). Then, the Areal Weighting Interpolation Totaling Tool ver. 1 was used to calculate the number of elderly residents (population of individuals of 65 years and above) for each of the five stages and the overall number of residents in the city.

3. Case study on the geographic distribution of elderly day service facility users

Among the day service facilities for the elderly within the city, Facility No. 1 in Fig. 2 and Table 3 was selected. The fixed number of users of this facility was 45 in December 2006. The procedure of the present study was reviewed and approved by the staff. The subjects were then informed about the study, and were requested to sign an informed consent form. Further, this study was approved by the Ethical Committee of the School of Human Sciences, Waseda University.

The subjects included 70 users who gave informed consent for this study. We did not use personal information such as users' names, gender, or age. We used only the addresses for plotting on the map, confirmed by the lot number information. The data sets are shown in Table 2, and the address of the facility was displayed on the GIS.

Next, a map displaying each town (machi) and district (cho) of the entire area was entered and displayed. Based on the address data of the users, a comparison of the city's east portion and western areas (Zenrin Residential Map 200602 SAITAMA, Zenrin Co. Ltd., Fukuoka, Japan) was made and displayed on the GIS with a road map. Using the Network Analyst function of ArcGIS ver. 9.1, we calculated, in the five stages, the distance areas from facilities with consideration of the distance via road. Finally, keeping the facility as the center, the distance areas and map information of users were displayed on the GIS.

Results

1. Relationship between day service facility for the elderly, provision areas, and the number of elderly residents in need of support or care

The locations that served as generating points after applying the Voronoi tessellation to the locations of day service facilities for the elderly in the city are shown in Fig. 3 and Table 3. The certified number of elderly residentse in need of support or care (the covered number of elderly residents in need of support or care) within Voronoi areas is also shown.

Geographic deviation was observed in the day service facilities located in the city such that there are many such facilities in the northwestern part of the city, but few in the southeastern part. The maximum number of covered elderly residents in need of support or care was 1,121, while the minimum was 57. Geographic differences were confirmed, with few such numbers (the minimum, 57) in the northwestern part of the city and many in the southern part. Further, in the south, the area assumed to be involved in the provision of services by a single facility (i.e., the area of the Voronoi area) was also large.

2. Evaluation of geographic access to day service facilities for the elderly among local elderly residents

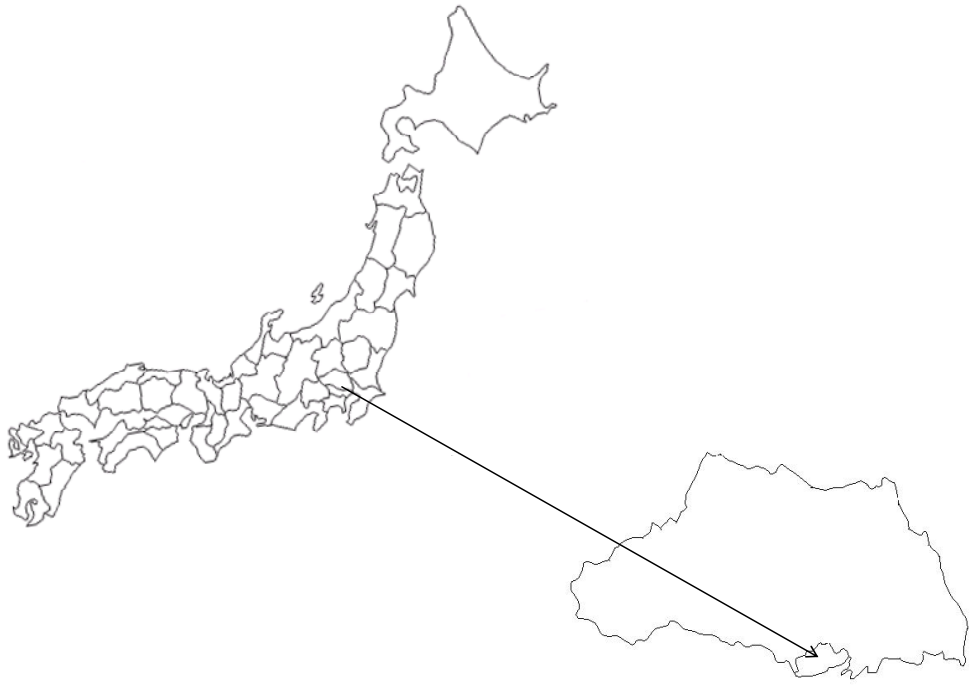
The population of local elderly residents was estimated at 43,131 persons based on grid square statistics values using areal weighting interpolation. The population of local elderly residents in the five stages was arranged according to the road distances with each facility serving as a center, and are as follows: <500 m: 6,910 persons (16.0 %); 500–1,000 m:

17,187 persons (39.8%); 1,000–1,500 m: 12,310 persons (28.5%); 1,500–2,000 m: 4,561 persons (10.6%); >2,000 m: 2,163 persons (5.0%) (Fig. 4).

Table 3. Capacity of day service facilities for the elderly and the covered number of elderly residents in need of support or care*

Num. of Facility	Capacity	The covered number of elderly residents in need of support or care*	District		Num. of Facility	Capacity	The covered number of elderly residents in need of support or care*	District
1	40	554	A		14	25	384	J
2	15	117	A		15	40	57	K
3	40	1,121	B		16	30	116	K
4	40	545	C		17	10	110	K
5	9	191	C		18	30	100	K
6	18	330	D		19	40	89	L
7	43	808	E		20	40	205	L
8	25	338	F		21	6	526	M
9	30	613	F		22	40	129	N
10	40	614	G		23	30	142	N
11	20	591	H		24	40	84	N
12	30	312	I		25	25	83	N
13	45	439	I		Total	751	43,131	

*The number of elderly residents needing support or care in each Voronoi diagram



Tokorozawa City, Saitama Prefecture, Japan

Fig. 1 Study area

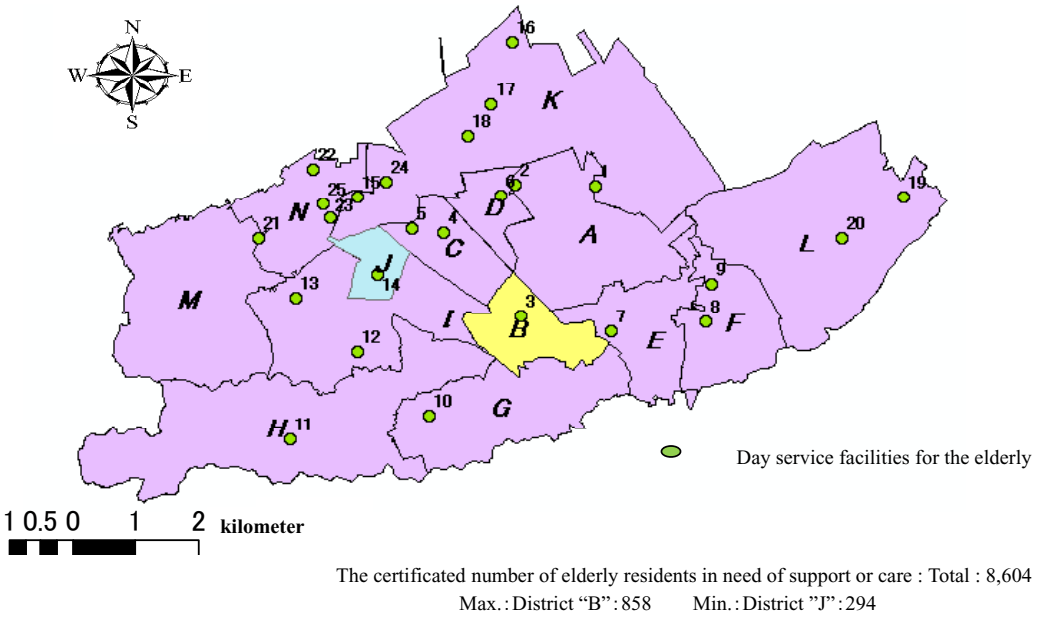


Fig. 2 Day service facilities for the elderly and daily living areas

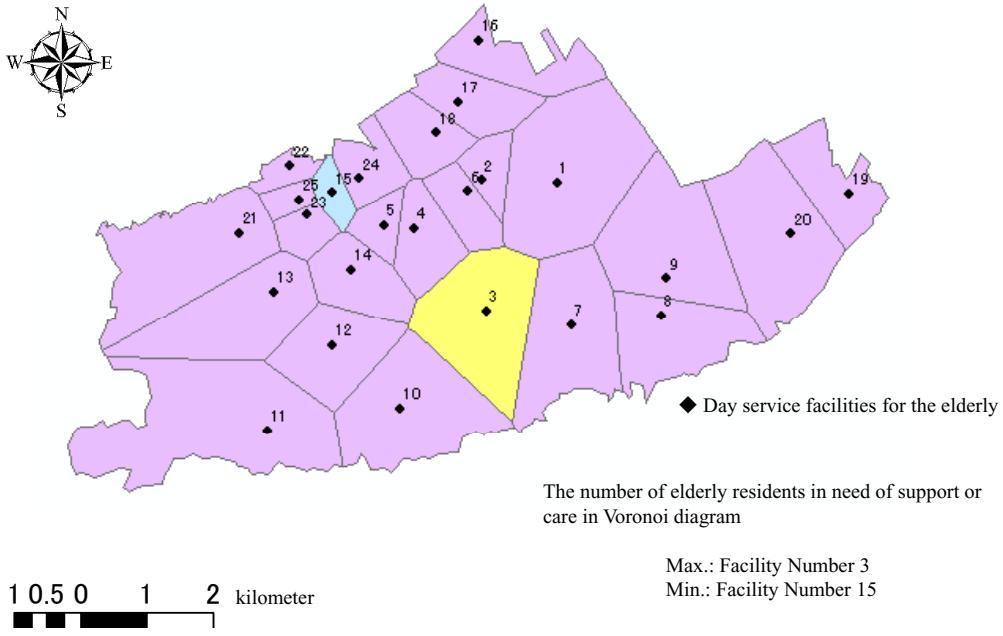
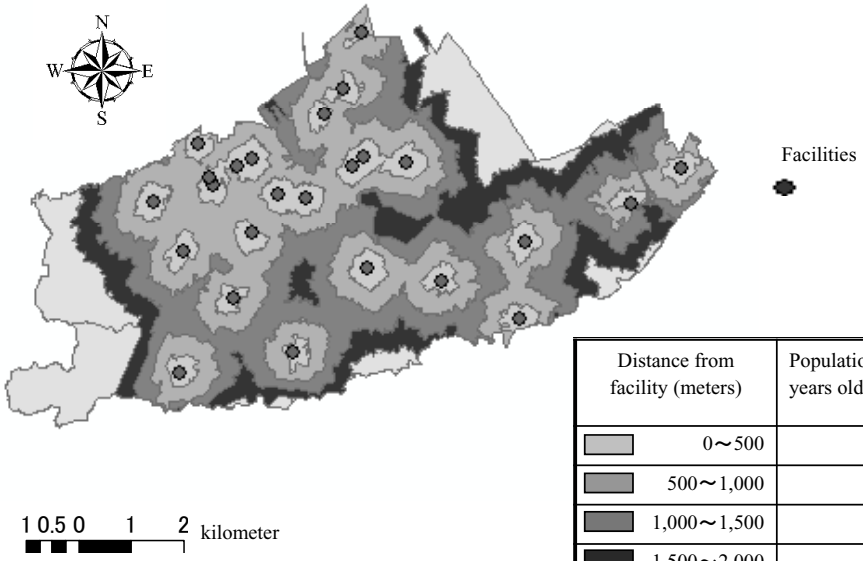


Fig. 3 The city represented by Voronoi diagrams



Distance from facility (meters)	Population of 65 years old and above	%
0～500	6,910	16.0
500～1,000	17,187	39.8
1,000～1,500	12,310	28.5
1,500～2,000	4,561	10.6
2,000 over	2,163	5.0
Total	43,131	100

Fig. 4　Geographical accessibility to day service facilities for the elderly using road map

Distance from the facility (meters)	Number of users	%	Users within daily living area	Users outside daily living area
0～500	17	8.6	16	1
500～1,000	52	26.4	46	6
1,000～1,500	47	23.9	32	15
1,500～2,000	11	5.6	1	10
Over 2,000	70	35.5	32	38
Total	197	100	127	70

Fig. 5　Distribution of users of the day service facility for the elderly

Furthermore, it was estimated that in the eastern, western, and central parts of the city, some elderly persons resided at a distance of 1,500 m or more from the nearest facility. Overall, it was deduced that around half of the elderly persons resided in areas <1,000 m from the nearest facility.

3. Case study on the geographic distribution of users of a day service facility for the elderly

Following is the current status of geographic distribution of 70 users of a day service facility located in the northeastern part of the city: <500 m: 5 persons (7.1%); 500–1,000 m: 20 persons (28.6%); 1,000 –1,500 m: 10 persons (14.3%); 1,500–2,000 m: 4persons (5.7%); >2,000 m: 31 persons (44.3%) (Fig. 5).

Discussion

In the process of planning for the construction of public and commercial facilities, it is necessary to consider the user accessibility of those facilities. GIS enables comprehensive management and information processing with regard to the geographic location, as well as the visual display of such information. Moreover, since it enables the analysis of spatial factors, GIS is widely used not only in resource management[13] and land use planning14) but also in environmental pollution[15, 16, 17], planning of health care facilities[18, 19], and decision-making in public health services[20, 21].

This study, we investigated the current status of the long-term care welfare service infrastructure from the perspective of the geographic distribution of day service facilities for the elderly among local elderly residents, as well as the current status of services provided by facilities from the perspective of the geographic distribution of users.

First, in terms of the relationship between the day service facilities for the elderly within Tokorozawa City and the geographic distribution of elderly residents, regional differences were observed in the number of elderly residents in need of support or care who were covered by each facility. In the city's northwestern part, the covered numbers were less than that in the southern area. Furthermore, on including the central area of the city, the covered numbers were comparatively larger. A regional difference was also observed for the respective areas assumed to be responsible for the provision of services by a single facility (i.e., the area of the Voronoi area). In this regard, the southern part of the city is large. For residents of an area with a large number of covered elderly residents in need of support or care, it is possible that, considering the fixed number of users of a facility within that area, such residents are unable to fully utilize their area's facility services. In other words, it is possible that the needy are unable to use the services of the nearest facility. Moreover, one could imagine that when a covered area is large, the distance between some users' residence and the services may also be large. The users of a day care facility generally utilize the transport service provided by the facility, and depending on the extent of care required, an increase in transport distance and time could increase the physical and mental burdens of users. In fact, when an elderly person desires to use a facility located far from his or her residence, there may be instances when the person has to refrain from using the facility because of the transportation cost. From this perspective alone, the use of a nearby facility is ideal. Increased transport distance and time could also increase the physical and mental burden of those in charge of transportation at these facilities.

It is believed that, while expanding the number of users of a facility or establishing a new facility, priority should be given to improving areas maldistribution area such as those shown in this study. In the Voronoi division based on direct distance from a facility, since the population distribution characteristics within a district thus divided were not taken into consideration[22], actual road distances were used in this study, which has not been done in previous studies[22–25] that investigated the geographic accessibility of day service facilities.

Thus, this study investigated the relationship between the distance from facilities and the geographic distribution of local elderly residents. We found that around half the individuals who were 65

years old and above resided within 1,000 m of the nearest facility. Visual clarification also illustrated the existence of users who reside in the area outside the (i.e., farther than) 2,000 m distance. The estimated population of elderly persons calculated from grid square statistics values using area weighting interpolation was 43,131 persons; however, the actual elderly population was 40,404 persons. Areal weighting interpolation is a method used to estimate a population of an area based on population data such as census data. This error was assumed to have been due to the characteristics of this method [26].

Although this study clarified the number of elderly persons residing at relative distances from a facility, some individuals may not be able to use the nearest facility for a variety of reasons. Moreover, previous studies have not clarified how far away users reside from the facilities they actually use.

This study focused on the one-day service facilities within the city and investigated the actual usefulness of that day service facility for the elderly from the aspect of the geographic distribution of users.

Approximately 60 % of the users were residents within the daily living area where the facility was located. In fact, a trend with regard to the nearest facility was observed. Certain cases where were observed in which users lived side-by-side as neighbors. The distance of users' residences from a facility does not seem to be the only factor responsible for whether or not they will use the services of that facility; other likely factors include the content of the facility services and users' desire to use services together with a neighbor.

Future studies should include cases where the nearest day service facility is not being used, with a detailed analysis of the underlying reasons. Such research would not only contribute to future facility infrastructural planning within Tokorozawa City but would also contribute to the overall provision of improved facility services. It will also be necessary to supplement the data set with road-related information such as that of one-way streets and speed limits, investigation regarding optimization, and efficiency improvements in transport routes for users. This information would be beneficial to people responsible for operating the facilities. Despite the above-mentioned limitations, the use of the methodology employed in this study can serve as a major reference for policy makers while planning and evaluating regional welfare policies and activities for the elderly population. In addition, this methodology could also be used by facility operators in designing strategies to ensure that their services are used.

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