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STUDY ON THE EVALUATION OF EXISTING TRANSPORTATION NETWORKS AND THE REQUIRED ROAD MAINTENANCE LEVEL IN EMERGENCY MEDICAL CARE

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Abstract: In Japan, compared with national government finance, local fiscal conditions have markedly deteriorated. Consequently, service levels of community roads, which are under the jurisdiction of regional governments, continue to decline. In this study, we evaluate improvement levels of existing transportation networks in Hokkaido, Japan. This study's originality is to take into account the differences of administrative entities of roads, such as the national government, prefectural governments and municipal governments. Regarding the specific analytical method, the shortest path to the emergency medical care center was researched in the GIS using the national land information in a mesh unit of 1 km. As a result, it is clear that the importance of local road in this region.

Key Words: Transportation network, Diverse regions, Quality of life

1. INTRODUCTION

Development of diverse regions is beginning in Japan, where establishment of transportation networks has almost been completed. Investment focused on infrastructure has begun to form a sphere of area communities consisting of multiple municipalities and draw out their uniqueness. Local governments are promoting "selection and concentration" of funds to endure interregional competition with limited revenue sources. A difficult problem that is arising under such circumstances is that, in the field of road maintenance, major road bridges have little useful life remaining. Concern about local financial conditions is serious compared with the national budget, and the difference in the maintenance level between national and local roads is expected to become prominent in the future. While people use community roads, highways and expressways as a network for commuting, shopping, visiting hospitals and other daily activities, the service level of community roads managed by local government will become worse. It is thus becoming necessary to evaluate road service within spheres of area communities, taking into account the difference in road management bodies, such as national, prefectural and municipal governments.

This study has two purposes. One is to evaluate the quality of life in different spheres of

area communities through a comparison of improvement levels of existing transportation networks in Japan and Germany. The other is to analyze the effect of lower maintenance level on the quality of life by clarifying the rate of use of local roads in the transportation network within a sphere of area communities, using Hokkaido, where populations are dispersed over wide regions as a case in point.

As a specific analysis method, the shortest routes to tertiary emergency medical facilities were searched on a GIS, using national land information in mesh units of 1 km^2. For a comparison between Bavaria, Germany, and a sphere of area communities in Japan, special attention was paid to collection of data on Bavaria and maintenance of data accuracy. During the analysis of Hokkaido, special attention was paid to identification of an area where populations are dispersed over a wide area and determination of the size of the sphere of area communities.

2. CHANGES IN SPACE IMPROVEMENT PLANNING

2.1. Space Improvement System in Germany

A planning philosophy defined as a goal of Japan's national land planning is the space improvement plan of Germany.

The goal of space improvement in Germany was changed from establishment of "equal living conditions" as stipulated in the Regional planning law in 1965 to the policy focused on "sustainable space development" as stipulated in the New Regional planning law in 1997.

Under the New Regional planning law, space improvement was conducted using a shaft (development method of spaces using points and axes), especially the central place concept as a point. Its aim was development of national land to enable living with the same sense of values throughout the nation, through concentration of investment to hub cities (points) and improvement in traffic routes (axes) led by the federal government. However, the shaft method was subject to much criticism as a rigid, outdated system for the following reasons: (1) relative autonomy is required in individual regions with the globalization of the EU, (2) traditional uniform standards lost their effectiveness due to the diversification of social structures, and (3) decentralized and regional cooperation, and flexible administrative execution through consensus building are recommended, as the administration system under consolidated management of the federal government lost its function. In response to these criticisms, the German government strove to improve and modernize the central place concept, rather than abandoning it (Blotevogel ed., 2002).

Since the New Regional planning law also requires concentration of social infrastructures in central areas, the importance of central areas has not changed. The role of central areas is beginning to change now, however, as importance is also being placed on development of regions (planes).

2.2. Space Improvement System in Japan

Five national land plans have been developed in Japan. The purpose of the fifth National Comprehensive Development Plan formulated in 1998 differs greatly from that of the first (1962) through the fourth (1987) plans. The purpose of the previous four was correction of the income gap. The purpose of the fifth National Comprehensive Development Plan is, however, improvement in quality of life while paying attention to internationalization with each regional bloc as a unit. Internationalization of regional blocs and independence of spheres of area communities are also required in the new plan currently under consideration, under the concept of the "Two Layered Broader Regions." Figure 1 shows the concept of the Two Layered Broader Regions.

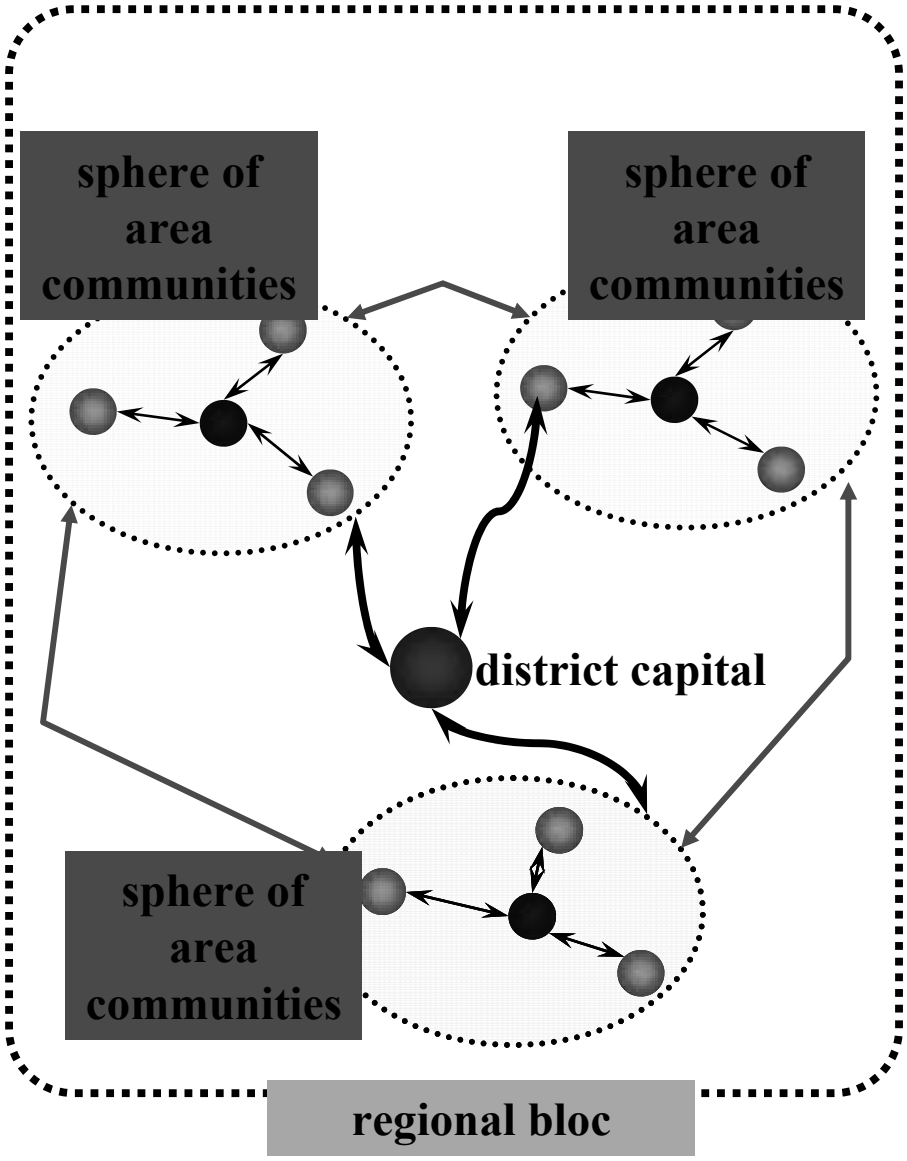


Figure 1.The Concept of the Two Layered Broader Regions

2.3. Collection of Data for Examination of the Space Improvement Policy

In Japan, associations between various data and geographic information are currently carried out by dividing the national land into approximately 390,000 one-km^2 mesh units. Primary data collected in the mesh include land-use classification, industry statistics, natural environment information, topography and census data (see Table 1).

Table 1.Conditions of One-km^2-mesh Data in Japan

	Statistical data	Year of data	Contents	Disclosure format
Designated area	Designated region area	(1975, 1980) 1985	Agricultural, forest, urban planning, natural park, natural environment conservation areas	Electric media
	Forest/public land mesh	1994	9 categories of national land, public forests, public farms	Electric media

Table 1. – continued.

Coastal area	Coastal water mesh	1990	Water quality, bottom sediment, eddy currents, algae zones, surf fishing spots, current (tides, marinas, fishing ports)	Electric media
National land structure	Road density/length mesh	1978	Number. of roads crossing the mesh, road length	Electric media
Industrial statistics	Commercial statistic third mesh	1979, 1982, 1985, 1986 (1988, 1991-1992, 1994, 1997)	Number of shops by industry, Number of employees, sales amount, floor space	Electric media
	Industrial statistics mesh	1977, 1980, 1982 (1990, 1995)	Number of business establishments by industry, Number of employees, shipment value	Electric media
	Agricultural census mesh	1975, 1980	Population, arable land area, machines used, Number of domestic animals, etc.	Electric media
	Business establishment statistics	1975, 1978, 1981, 1991, 1996	Number of business owners by industry, Number of employees, Number of employees by sex, etc.	Electric media
Hydrology	Channel length mesh	1977	Channel length by type (Class 1, 2, etc.)	Electric media
	Lake third mesh	1982	Lake data, basin data (basin length by channel, existence of lakes, etc.)	Electric media
Land	Official announcement of land price/land price research	1983 – 2002	Publicly assessed land price/standard land price	Paper
	Land use area	1976, 1987, 1991, 1997	Land use area for 11 categories, including paddy fields, dry fields, orchards, other tree farms, forests and waste land	Electric media
Topography	Natural topography/mean gradient/topography/soil classification	1981	Altitude, gradient, surface geology, geological classification, etc.	Electric media
Natural environment	Basic research for natural environment conservation		Animals, vegetation distribution and condition, etc.	Electric media
Census	Census	1970, 1975, 1980, 1985, 1990, 1995, 2000	Population, population by age group, Number of employees by industry, Number of workers by industry, Number of students in schools and universities, Number of households by type, workplaces/places of schools (in or outside the local municipality)	Electric media

Figure 2 illustrates the increase/decrease in agricultural population from 1970 to 2000 in Yamagata Prefecture in mesh units of 1 km^2. Figure 3 shows the increase/decrease in managed arable land area in the same period in the same units. From these figures, it can be seen that the decrease in managed arable land area was smaller than the decrease in agricultural population in the 30 years between 1970 and 2000 in Yamagata Prefecture, indicating the progress of concentration of agriculture to large-scale farmers.

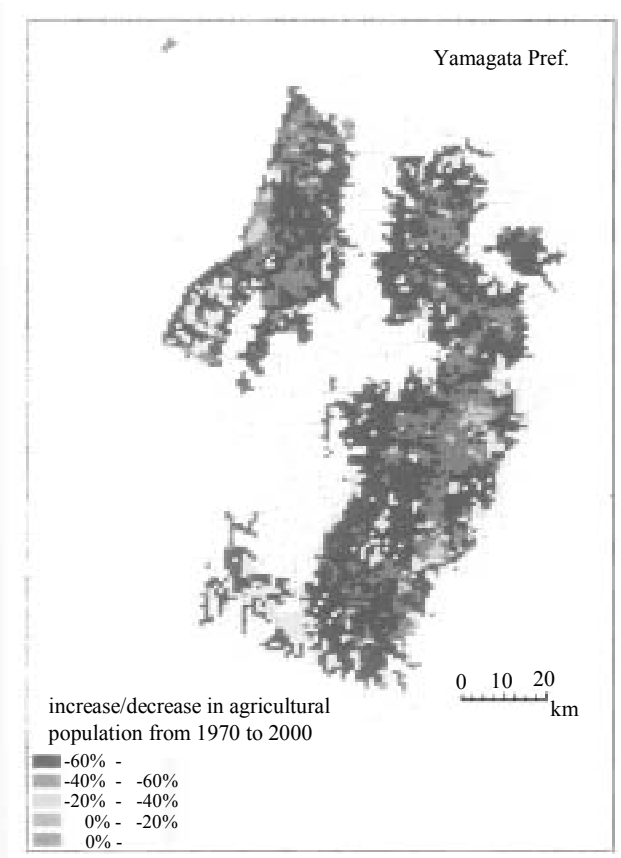


Figure 2.Increase / Decrease in Agricultural Population from 1970 to 2000 in Yamagata Prefecture in Mesh Units of 1 km^2

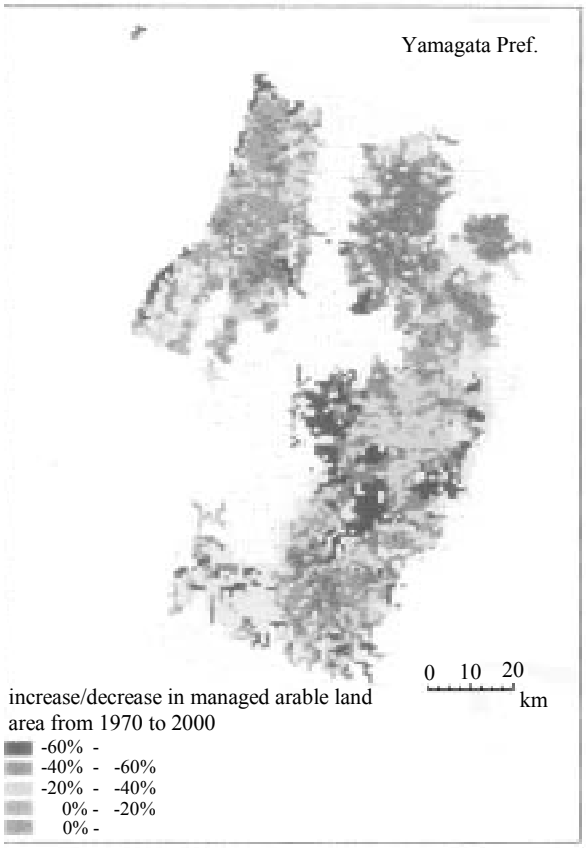


Figure 3.Increase / Decrease in Managed Arable Land Area from 1970 to 2000 in Yamagata Prefecture in Mesh Units of 1 km^2

The Ministry of Land, Infrastructure and Transport developed NITAS, a comprehensive traffic analysis system that can analyze roads 5.5 m or greater in width throughout Japan in mesh units of 1 km^2. Because it also enables analysis by setting new random links, it is possible to evaluate the transportation network when roads that are being planned or those constructed are placed in service.

By combining these 1-km^2-mesh unit data and results of traffic analysis obtained by NITAS and overlaying them on a GIS, it is possible to properly understand the effects of road maintenance or those of changes in future conditions (e.g., decreases in population). It is also effective when the effect of investment into infrastructure is explained to the citizens.

In the next section, the transportation network of Hokkaido that supports people's daily lives will be evaluated using 1-km^2-mesh unit population distribution data and regional traffic conditions clarified by NITAS.

3. EVALUATION OF THE TRANSPORTATION NETWORK THAT SUPPORTS PEOPLE'S DAILY LIVES

3.1. Purpose of Evaluation

Table 2 shows the populations, areas, number of emergency medical care centers and road lengths in Hokkaido and Bavaria. It can be seen from the table that: 1) both the population distribution and road network of Hokkaido have a low density compared with Bavaria, and 2) the ratio of local road length to the total road length is 95% in Bavaria and 92% in Hokkaido, indicating that the effect of lower improvement level of local roads on daily lives is significant.

Table 2.Comparison of Hokkaido with Bavaria

	Population (10,000 peoples)	Area (10,000 km^2)	Number of the emergency medical center	The total road length (km)	The express way length (km)	The national road length (km)	The regional road length (km)
Hokkaido	570	8.34	8	87,803	562	6,438	80,803
Bavaria	1,233	7.05	46	181,142	2,283	6,550	172,309

Figure 4 shows the result of estimating the access time to the emergency medical center in the sphere of area communities using NITAS, and tabulating it for each regional bloc by weighting with the population in each mesh unit of 1 km^2. It includes the result of analysis of Bavaria (Germany). It can be seen from the figure that the access time to the emergency medical care center was longer in regional blocs than in Germany (excluding Kanto), indicating an insufficiency in emergency medical care systems.

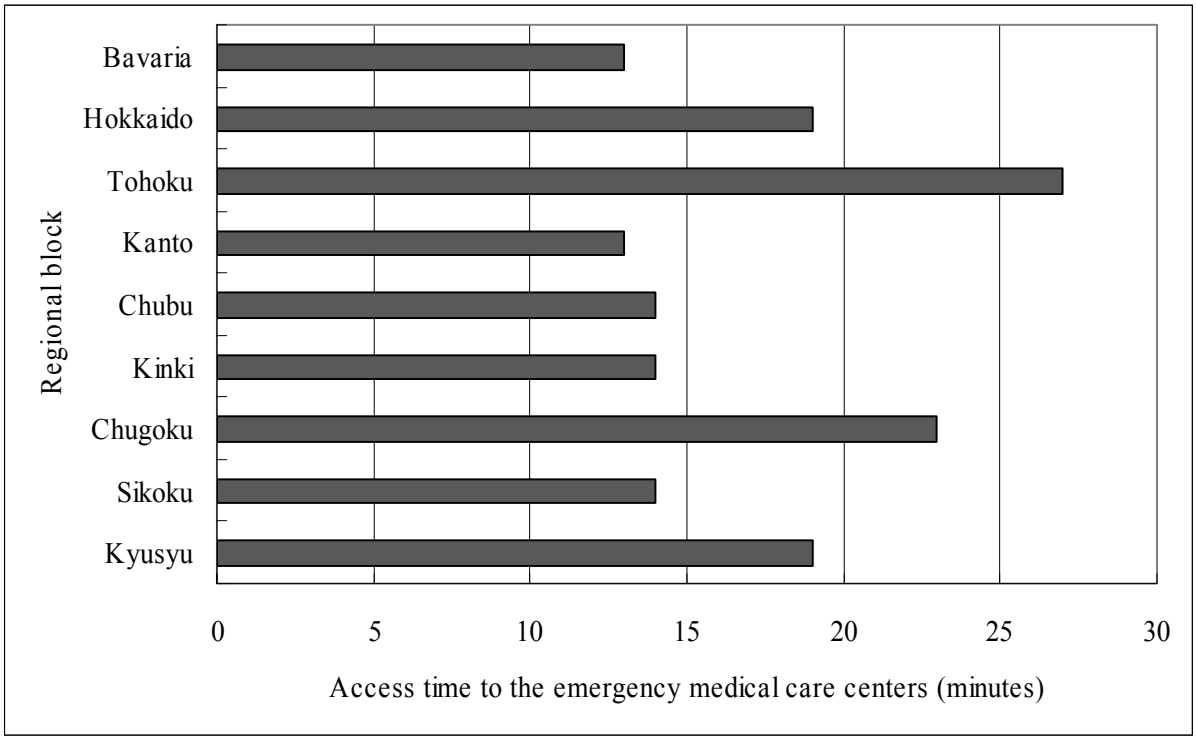


Figure 4.Access Time to the Emergency Medical Care Center

Table 2 and Figure 4 reveal that both the placement of emergency medical care centers and

establishment of transportation networks to support access to facilities were insufficient in Japan when compared with Germany.

In this study, the transportation network supporting the daily lives of the residents is evaluated for the case of Hokkaido, where the population is dispersed over a wide area. When conducting the evaluation, it is necessary to consider the decrease in road maintenance costs due to aggravation of financial conditions. Aggravation of financial conditions is especially remarkable in Hokkaido (a local government), and it has already been decided to reduce public works expenditures by 19% in the five years between 2003 and 2007 to regain fiscal stability. It is therefore expected that there will be a marked difference in maintenance level between roads managed by the central government and those by the local government. While people use community roads, highways and expressways as a network for commuting, shopping, visiting hospitals and other daily activities, the service level of community roads managed by local government will become worse. It is thus becoming necessary to evaluate road service within spheres of area communities, taking into account the difference in road management bodies, such as national, prefectural and municipal governments.

Taking the above into consideration, the access time to the emergency medical care center will be estimated in Section 3.3 and the usage rate of local roads in the access to the emergency medical care center will be estimated in Section 3.4 to analyze how the deterioration of maintenance level of local roads would affect the traffic in the sphere of area communities.

3.2. Subject Area

The subject area to be analyzed was a region centered on Obihiro, Hokkaido. Figure 5 indicates the one-hour sphere of automobile traffic from the Obihiro City Hall, which was estimated using NITAS. The population in this sphere is approximately 300,000.

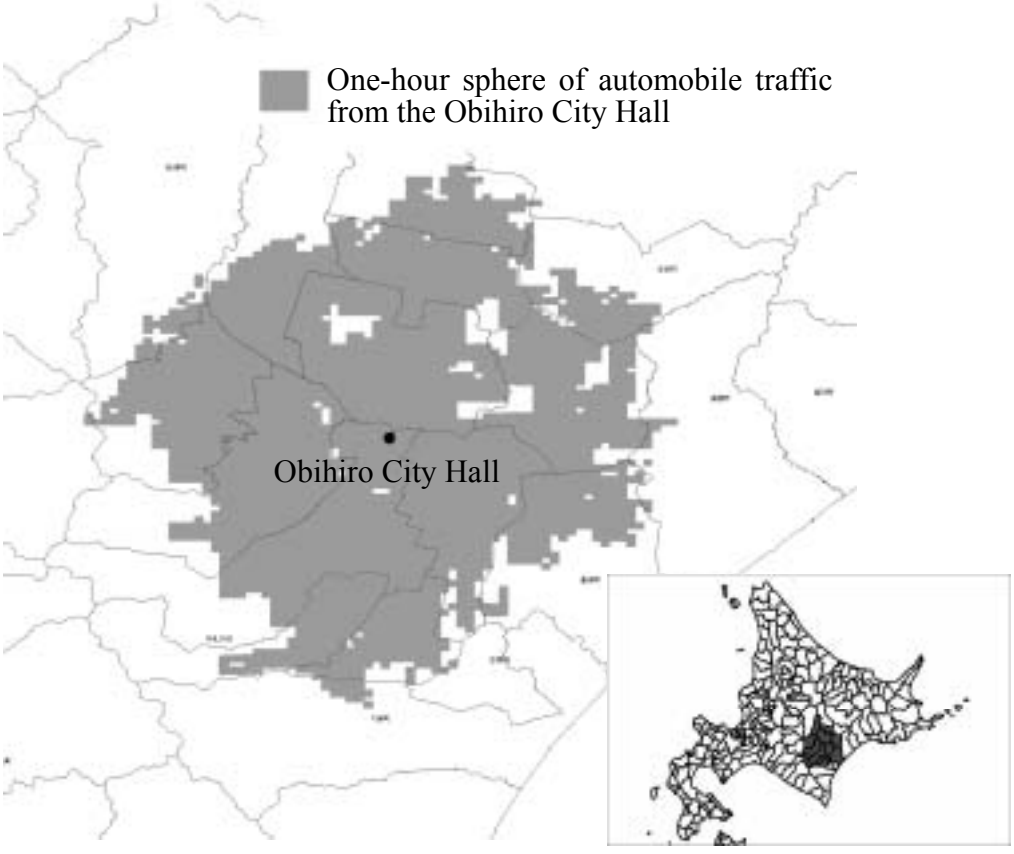


Figure 5.One-hour Sphere of Automobile Traffic From the Obihiro City Hall

Figure 6 shows the population distribution in the sphere. It can be seen from the figure that the population is dispersed over a wide area.

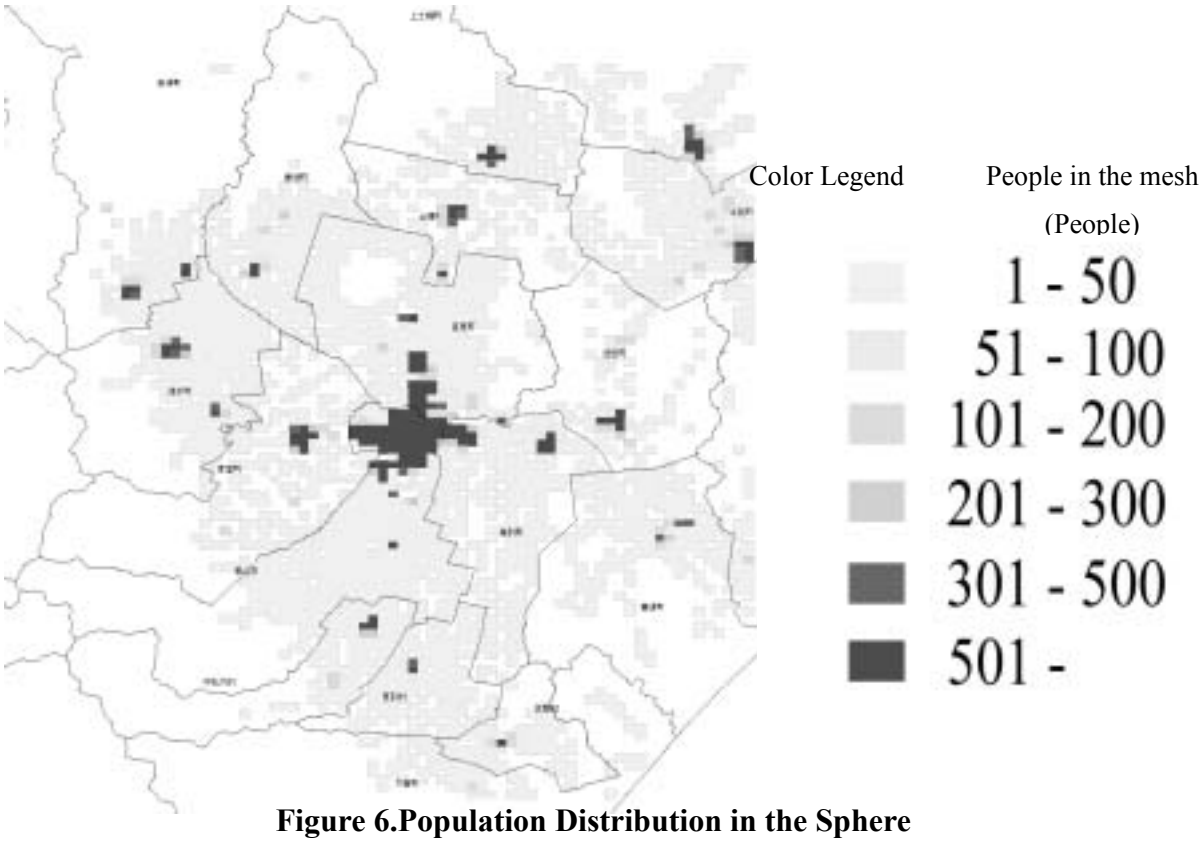


Figure 6.Population Distribution in the Sphere

3.3. Estimation of Access Time to the Emergency Medical Care Center

a) Estimation Method

In this study, the access time to the emergency medical care center from municipalities in the sphere of area communities was defined as follows, with the population in each mesh unit as the weight.

Entire population of *j*-City P_j is as follows since p_{jk} is the population in each mesh unit what is comprised in *j*-City:

$$P_j = \sum_k p_{jk} \tag{1}$$

Where, *j* is the Number of municipalities where have been comprised in a sphere of area communities and *k* is the Number of 1km^2 meshes what have been comprised in *j*-City.

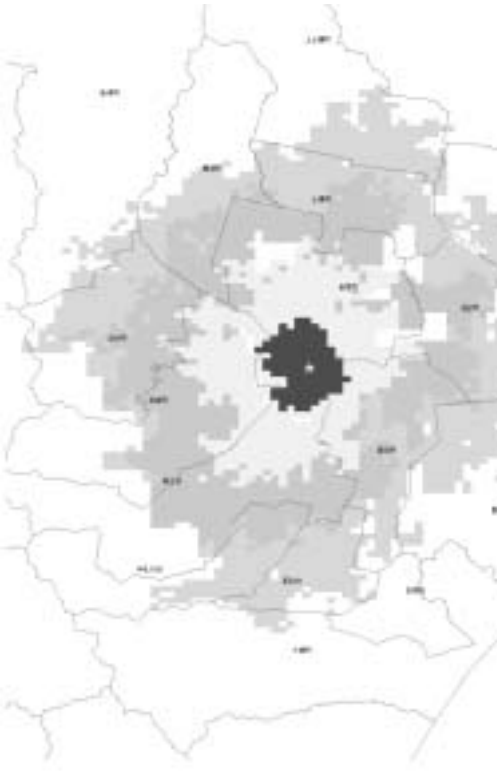
Mean access time from j-City to the emergency medical care center $\overline{T}_j$ is as follows:

$$\overline{T}_j = \frac{\sum_k t_{jk} \cdot p_{jk}}{P_j} \tag{2}$$

Where, t_{jk} is access time from 1km^2 meshes have been comprised in *j*-City to the emergency medical care center.

b) Results

The access time from all 1-km^2 mesh units in the sphere to the emergency medical care center was estimated using NITAS. The calculation conditions are: 1) use of expressways and 2) driving at an average cruising speed. Figure 7 shows the result of estimations of access times to the emergency medical care center. As can be seen, the access time to the emergency medical care center exceeded 30 minutes for 21% of the residents, even if they fall within the sphere.



Color Legend	Time to the emergency medical care center	Number of people who included the sphere (Ten thousand people)
	0 - 15 minutes	17.6
	15 - 30 minutes	6.4
	30 - 45 minutes	3.5
	45 - 60 minutes	3.0

Figure 7.Access Times to the Emergency Medical Care Center

Figure 8 illustrates the access time to the emergency medical center in the sphere of area communities using NITAS, and tabulating it for each regional bloc by weighting with the population in each mesh unit of 1 km^2. Generally speaking, the desirable access time to the emergency medical care center is 30 minutes. However, only 3 towns of Obihiro, Otohuke, and Memuro are satisfying it.

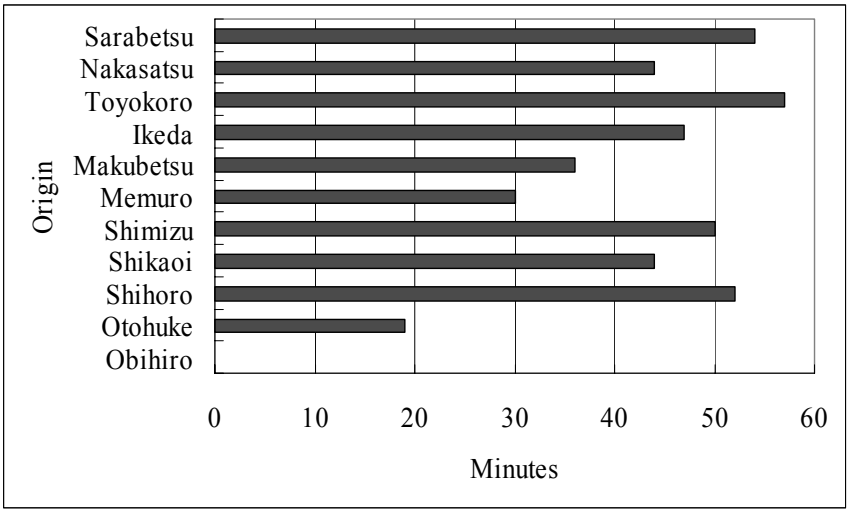


Figure 8.The Access Time to the Emergency Medical Care Center from Municipal Offices in the Sphere

3.4. Estimation of the Usage Rate of Local Roads

a) Estimation Method

The following process was used to estimate the usage rate of local roads while traveling to the emergency medical care center in the sphere of area communities:

1) One-hour sphere of automobile traffic from the municipal office of the central city was estimated using NITAS and designated as the target area to be analyzed.
2) The shortest route from each municipal office in the sphere was estimated using NITAS.
3) Driving routes were divided into national highways, expressways and local roads, and the driving distance for each type of road was measured using GIS software that incorporates a digital map.

b) Results

Figure 9 shows the result of estimating the traveling distance on local roads en route to the emergency medical care center from municipal offices in the sphere. It can be seen from the figure that the usage rate of local roads en route to the emergency medical care center exceeded 90% in large municipalities and nearly 40% on the average, even for urban areas.

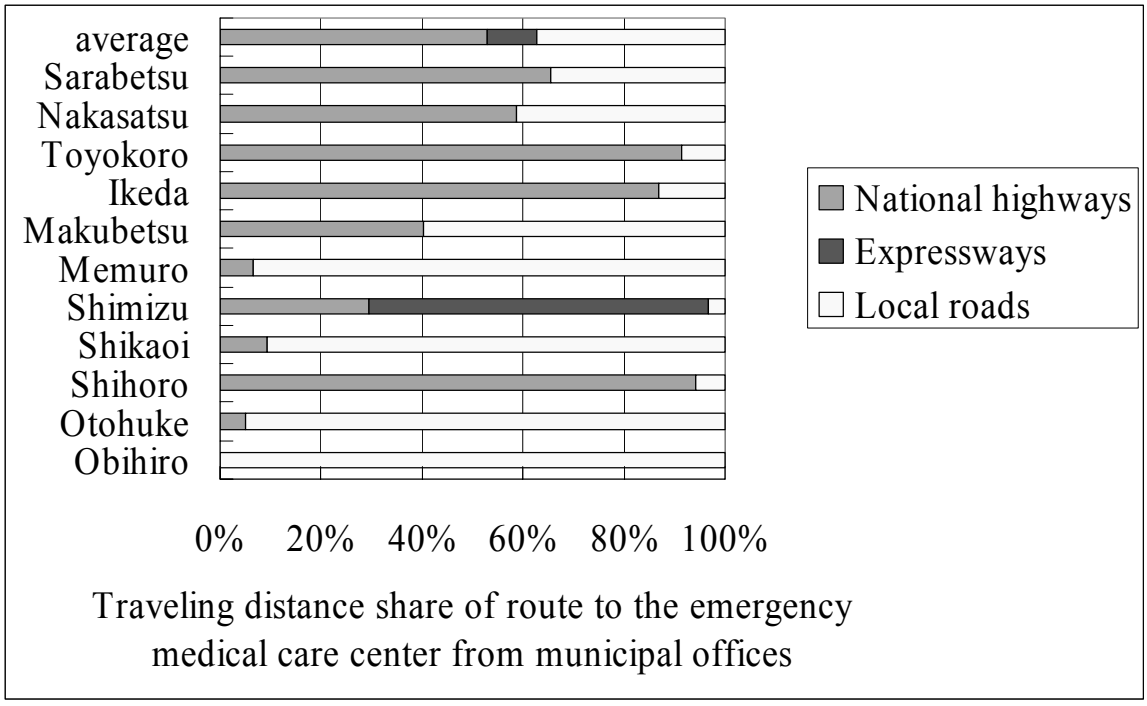


Figure 9.Traveling Distance Share of Route to the Emergency Medical Care Center from Municipal Offices

4. CONCLUSIONS

The following three points were clarified by this study:

1) It takes 16 minutes to the emergency medical care center in the sphere of are communities in Japan. In the meanwhile, it takes 13 minutes in Bavaria, Germany. This difference results from rich infrastructures based on the space improvement been promoted for “equal living conditions,” for many years in Germany.
2) In Hokkaido, where the population is dispersed over a wide area, local roads used for transportation within the sphere of area communities accounted for approximately 38% of

all routes. It is necessary to control the deterioration of service level of community roads under the local government.

3) Lower maintenance levels of roads cause significant problems that the access time to the emergency medical care center is longer.

From now on, to establish an environment to be able to compete with other regions will be needed to realization of regional formation with diversity. However, it is difficult under the current budgetary conditions. Therefore, we should make better use of information technology. In addition, we should discuss the reorganization of communities.

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