Convenience Rating of Post-disaster Recovery Housing Complexes Constructed in Fukushima Prefecture Following the 2011 Tohoku Earthquake

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***Abstract*—This study evaluated the convenience of post-disaster recovery housing complexes constructed in Japan's Fukushima Prefecture following the 2011 Tohoku Earthquake. We assumed that the convenience of daily facilities was very important especially for elder evacuees. Because the elder people often access them on foot. The study targeted three municipalities in the coastal area of Fukushima Prefecture that were most heavily struck by the earthquake-triggered tsunami: Soma, Minamisoma, and Iwaki. Using geographical information system software, we conducted a network analysis of the coordinate data on the locations of crucial infrastructure. Housing complexes within the defined service area of each infrastructure facility were assigned a score of 10, while those within two and three times the defined service area were assigned scores of 5.0 and 3.3, respectively. These scores were used to rate the convenience of each housing complex. In Minamisoma City, the post-disaster recovery housing complexes were found to offer better access to key infrastructure than ordinary housing complexes. In Soma City, however, the post-disaster recovery housing complexes had poorer access to key infrastructure than the ordinary complexes. And in Iwaki City, the two types had comparable access.**

***Index Terms*—2011 Tohoku Earthquake; convenience; network analysis; ordinary housing complexes; post-disaster recovery housing complexes**

I. Introduction

Following the 2011 Tohoku Earthquake [1], many people were relocated to temporary housing. These were people who had lost their homes in the disaster and who lacked the financial means to rebuild. In Iwate Prefecture, which was seriously damaged by the earthquake-triggered tsunami, 94.6% of the temporary dwellings were occupied in December 2011. However, not all of these temporary complexes are conveniently located. For example, daily shopping and banking are problematic for residents located beyond a certain distance from the precincts.

Therefore, our previous studies [2] compared the convenience of temporary housing complexes in the southern coastal area of Iwate Prefecture that were constructed after the 2011 Tohoku Earthquake. The three target cities, Kamaishi, Ofunato, and Rikuzentakata, were the ones impacted most severely by the tsunami that followed the earthquake.

The convenience of a living environment is often evaluated by considering the distance between the dwelling and surrounding infrastructure [3]. So, to evaluate the usability of a housing complex, we also created a scoring index that increases as the distance from the key infrastructure decreases.

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Note that temporary housing complexes are not designed for permanent occupation. For this reason, many post-disaster recovery housing complexes, which are intended to be permanent, are built in stricken areas. We assume that evacuees will live in them for an extended period. In a previous study, therefore, we compared the convenience of post-disaster recovery housing complexes with that of ordinary housing complexes [4], [5].

In the present study, we changed the target field from Iwate Prefecture to Fukushima Prefecture, which the tsunami following the earthquake had also impacted most severely. Therefore, the purpose of this study is to evaluate the convenience of post-disaster recovery housing complexes constructed in Japan's Fukushima Prefecture following the 2011 Tohoku Earthquake.

II. Methodology

A. Research area and materials

The research focused on three cities in the coastal area of Fukushima Prefecture [Fig. 1], Soma, Minamisoma, and Iwaki, that were inundated by the tsunami that struck after the Tohoku Earthquake of 2011. The data used in the study were the coordinates of post-disaster recovery housing complexes, of ordinary housing complexes [Figs. 2 to 4], and of the infrastructure supporting daily life in December 2016 for Iwaki and in November 2020 for Soma and Minamisoma. Post-disaster recovery housing complexes are permanent public housing sites built after the disaster. On the other hand, ordinary housing complexes are permanent public housing sites built before the disaster.

B. Daily life infrastructures

The types of infrastructure evaluated in this study include the facilities listed below. The area assumed to be serviced by each facility type is given in parentheses. These service areas were defined as those that could be accessed easily on foot by elder people.

1) Retail
   a. Supermarkets (0.5 km)
   b. Convenience stores (0.5 km)
2) Financial services
   a. Post offices and banks (0.5 km)
3)Medical services
   a. Clinics (emergency department: internal medicine, pediatrics, or surgery) (0.5 km)

ISBN: 978-988-14049-3-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

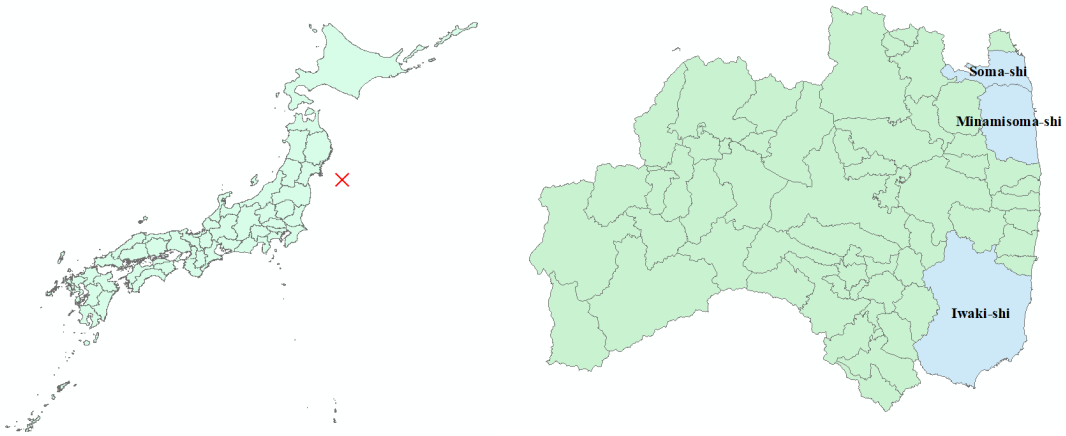

Fig. 1. Left: The epicenter of the 2011 Tohoku Earthquake on March 11, 2011. Right: Fukushima Prefecture's Soma, Minamisoma, and Iwaki City.

Fig. 2. Soma City: Post-disaster recovery housing complexes (permanent public housing sites built after the disaster) are denoted by red circles and ordinaly housing complexes (permanent public housing sites built before the disaster) by blue squares.

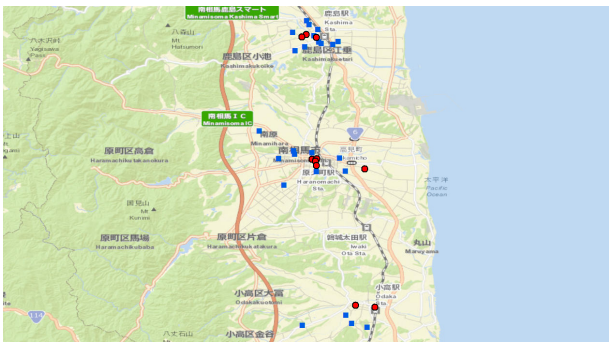

Fig. 3. MinamiSoma City: Post-disaster recovery housing complexes (permanent public housing sites built after the disaster) are denoted by red circles and ordinaly housing complexes (permanent public housing sites built before the disaster) by blue squares.

C. Data sources

The post-disaster recovery housing data were retrieved from the website of each city [6]. Data on infrastructures were obtained from NTT i Town Pages (a searchable telephone directory available on the Internet) [7]. The correct infrastructure coordinates and states of the services were confirmed from Internet maps and websites.

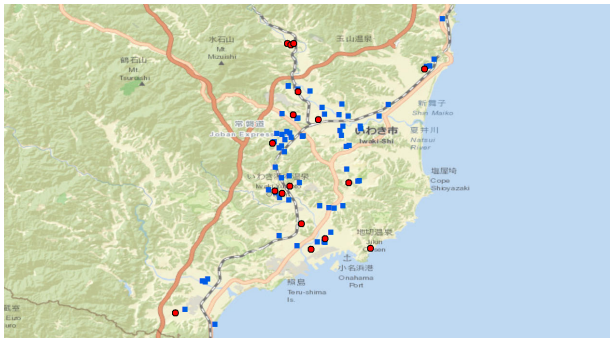

Fig. 4. Iwaki City: Post-disaster recovery housing complexes (permanent public housing sites built after the disaster) are denoted by red circles and ordinaly housing complexes (permanent public housing sites built before the disaster) by blue squares.

D. Analysis

First we performed a geocoding procedure (address matching) using a building-level geocoding system that could be operated on the Internet [8]. After plotting the infrastructure sites on a map, we conducted a network analysis using ArcGIS 10.2.2 software with the Network Analyst function (Esri Inc., Redlands, CA, USA). This software enables the true measurement of road distances as well as the linear distances between two features. The software was run on a standard desktop PC.

We first created network datasets from simple road distances, neglecting bends and speed limit data. These network data sets were used to determine the service areas of the infrastructure, with individual features represented by polygons.

Based on the distance between the infrastructure and the area serviced, we then assigned a usability score to each housing complex. Post-disaster recovery housing complexes within the radius of a defined service area were assigned a score of 10, complexes within twice the defined service area were assigned a score of 5.0, and those within three times the service area were assigned a score of 3.3. These scores were used to assign convenience ratings to the housing complexes.

III. Results

Figures 5 to 7 compare the scores of the housing complexes of each city, while Tables I to III show the average

ISBN: 978-988-14049-3-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

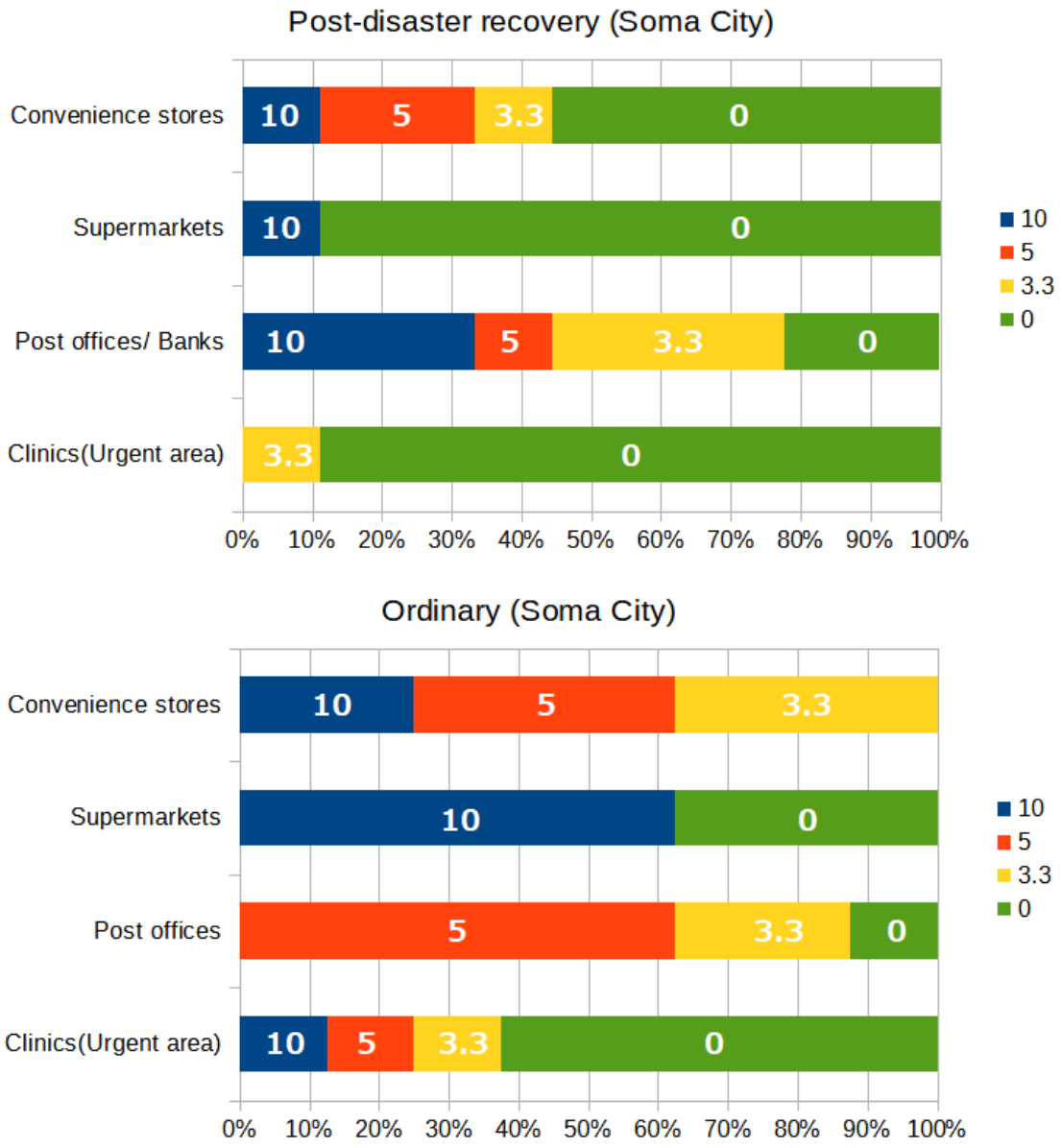

Fig. 5. Comparison of scores for Soma's two kinds of housing complex (Upper: post-disaster recovery housing complexes. Lower: ordinary public housing complexes). Blue (a score of 10) regions indicate the percentage of housing complexes located within the defined service area of each infrastructure facility. Red (a score of 5) and yellow (a score of 3.3) regions denote the percentage of temporary dwellings within two and three times the distance from the defined service area, respectively. Green (a score of 0) regions indicate the percentage of housing complexes more than three times the distance from the defined service area.

TABLE I
SCORES FOR SOMA

	Post-disaster complexes (n=9)	Ordinary complexes (n=8)	rank sum test
Convenience stores	2.59	5.61	
Supermarkets	1.11	6.25	$p<0.05$
Post offices Banks	4.99	3.95	
Clinics	0.37	2.29	
Averages	2.26	4.53	

TABLE II
SCORES FOR MINAMISOMA

	Post-disaster complexes (n=11)	Ordinary complexes (n=24)	rank sum test
Convenience stores	7.73	5.76	
Supermarkets	7.27	2.50	
Post offices Banks	8.18	4.78	$p<0.01$
Clinics	8.03	4.58	$p<0.05$
Averages	7.80	4.40	

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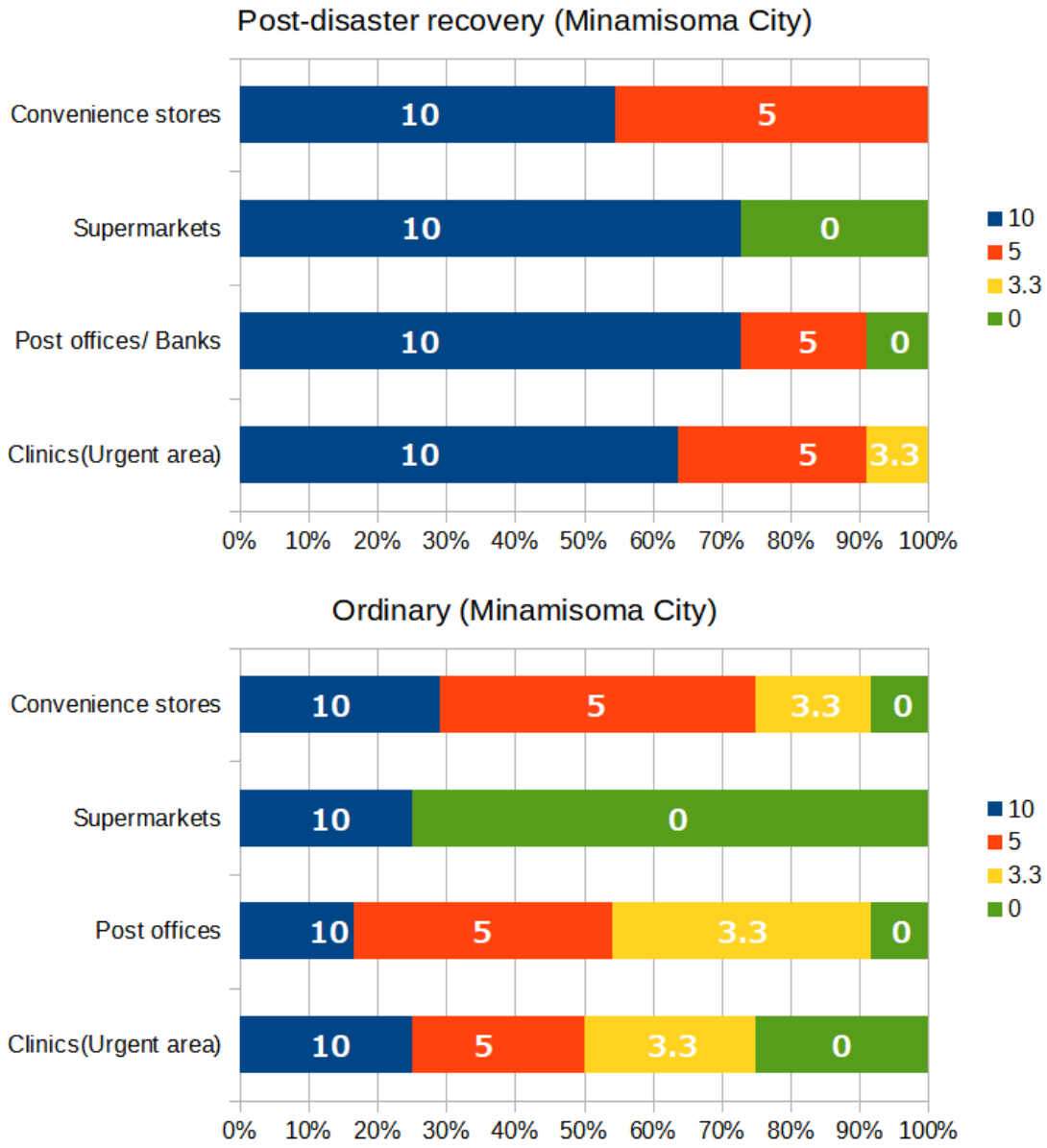

Fig. 6. Comparison of scores for Minamisoma's two kinds of housing complex (Upper: post-disaster recovery housing complexes. Lower: ordinary public housing complexes). Blue (a score of 10) regions indicate the percentage of housing complexes located within the defined service area of each infrastructure facility. Red (a score of 5) and yellow (a score of 3.3) regions denote the percentage of temporary dwellings within two and three times the distance from the defined service area, respectively. Green (a score of 0) regions indicate the percentage of housing complexes more than three times the distance from the defined service area.

TABLE III
SCORES FOR IWAKI

	Post-disaster complexes (n=17)	Ordinary complexes (n=65)	rank sum test
Convenience stores	7.35	6.33	
Supermarkets	4.90	4.35	
Post offices Banks	5.39	5.23	
Clinics	5.00	6.30	
Averages	5.66	5.55	

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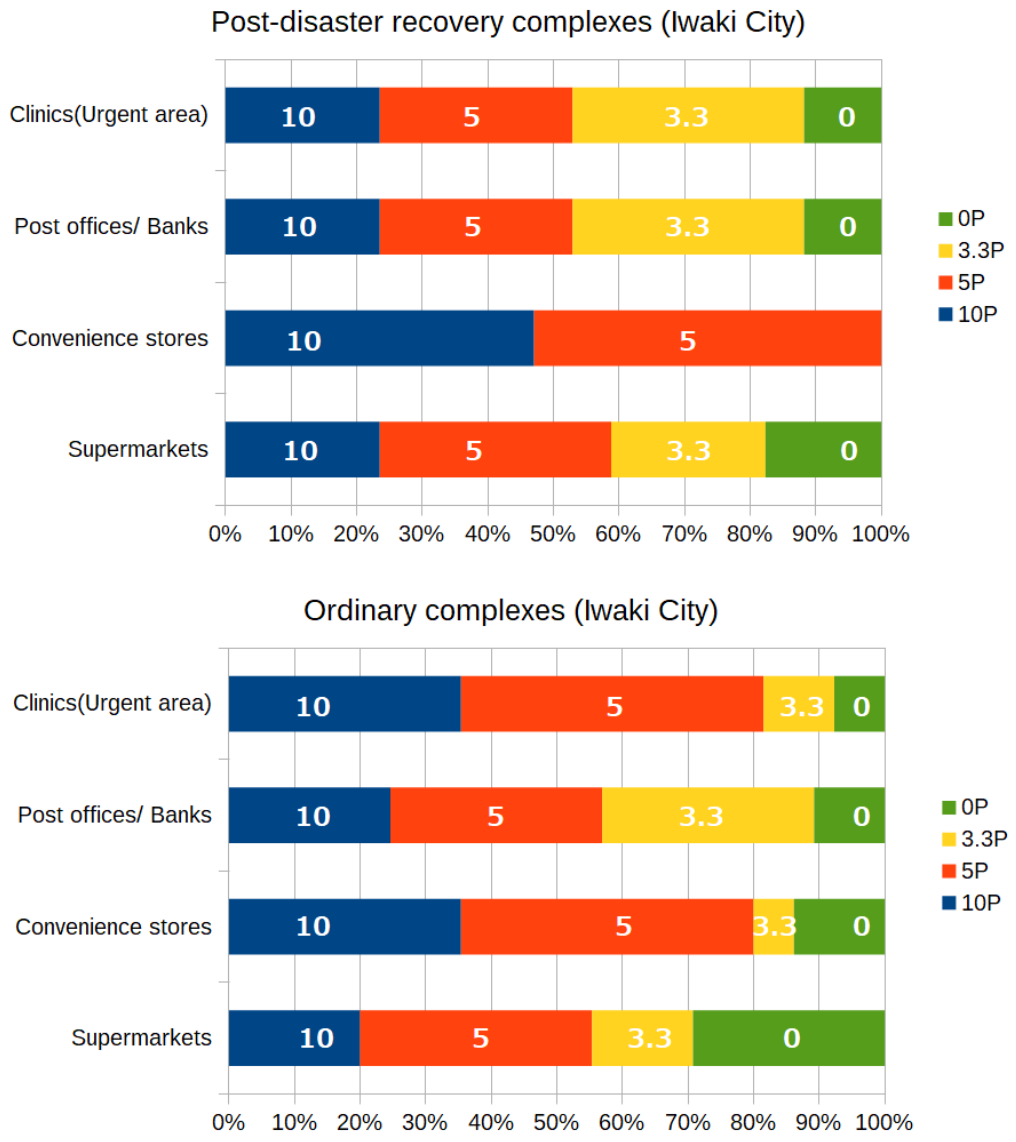

Fig. 7. Comparison of scores for Iwaki's two kinds of housing complex (Upper: post-disaster recovery housing complexes. Lower: ordinary public housing complexes). Blue (a score of 10) regions indicate the percentage of housing complexes located within the defined service area of each infrastructure facility. Red (a score of 5) and yellow (a score of 3.3) regions denote the percentage of temporary dwellings within two and three times the distance from the defined service area, respectively. Green (a score of 0) regions indicate the percentage of housing complexes more than three times the distance from the defined service area.

scores given to the facilities of each city. The average scores of the post-disaster recovery housing complexes and the ordinary housing complex were evaluated using Wilcoxon rank sum test operated on R statistical System [9]. Based on these figure and tables, the findings were as follows:

A. *Convenience of facilities*

For Minamisoma, post offices and banks were significantly more convenient to residents of the post-disaster housing complexes than to residents of the ordinary housing complexes ($p<0.01$).

In addition, clinics were also significantly more convenient to residents of the post-disaster housing complexes than to residents of the ordinary housing complexes ($p<0.05$).

For Soma, supermarkets were significantly less convenient to residents of post-disaster housing complexes than to residents of the ordinary housing complexes ($p<0.05$).

B. *Overall convenience*

In Minamisoma City, the post-disaster recovery housing complex residents had quicker access to convenience stores than did residents of ordinary housing. This means that the residents of post-disaster complexes had easier access to essential facilities compared to residents of ordinary housing complexes.

In Soma City, however, the post-disaster complexes had lower convenience scores than the ordinary housing complexes. This means that in Soma City, essential infrastructure was less accessible to residents of the post-disaster recovery housing complexes than to those of the ordinary housing complexes.

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In Iwaki City, meanwhile, post-disaster complexes and ordinary housing complexes had almost the same convenience scores, suggesting that they offered the same accessibility to essential facilities.

IV. Discussion

A. Overall convenience

The results suggest that, in Soma, the daily life of evacuees has still not been convenient. This was not in line with our expectations. For Minamisoma, convenience to facilities may have been the first priority when the locations of post-disaster housing complexes were chosen, whereas in the case of Soma, we assumed that the key consideration was connection to the local community. We assumed that the criteria for the locations of housing complexes in Iwaki City was intermediate between those applied to the other two municipalities.

B. Retail facilities evaluated in this study

The retail facilities evaluated in this study were supermarkets and convenience stores. These days in Japan, most retail stores are either of those two types, even in rural areas. But other types of retail stores exist, such as small stores that deal with only daily food items, and necessities. In this context, daily food items mean the ones such as rice balls, boxed lunches, breads, and drinks. We must not forget this fact, even if it may not affect the results of this study statistically.

C. Evaluation of road conditions such as road slope and width

When people decide whether to visit a facility or not, they often consider not only the road distance but also the road conditions such as road slope and width; for example, people might avoid roads with steep hills or narrow roads where walking is unpleasant because of proximity to motor vehicles. Both of these conditions affect road usability, but we could not evaluate them in this study. In future studies, we would like to create some parameters to evaluate such factors for daily facilities.

D. Data on infrastructure

In this study, data on infrastructure were obtained from NTT i Town Pages. Using this database, we have to retrieve the data every ten infrastructures. Therefore, if we need to retrieve a large dataset, we need to perform some complicated operations. To decrease the number of manipulations, we created and used an original utility program in the Perl language for this study. This program makes it possible to retrieve large datasets from NTT i Town Pages with fewer manipulations.

E. Mobile grocery stores and mobile convenience stores

In Fukushima Prefecture's Soma City, a supermarket started a small mobile delivery service by truck on January 8, 2014 [10]. We assume that this service is very useful for lightening the difficulty of shopping in that area.

In Fukushima Prefecture's Minamisoma City, Family Mart started a mobile convenience store delivery service using 2-ton trucks on June 27, 2013 [11].

In Miyagi Prefecture, next to Fukushima Prefecture, 7-Eleven Japan started mobile convenience store service using 2-ton trucks just one month after the 2011 Tohoku Earthquake [12]. Renovated, refrigerated 2-ton trucks carried many daily food items such as rice balls, boxed lunch, breads, and drinks. In addition, they started a mobile ATM service in May 2011.

If such mobile services were available in areas that are not so convenient not only for daily shopping and banking, but also for medical services, the residents would appreciate them very much.

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ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)