The convenience of temporary housing complexes in Iwate Prefecture constructed after the 2011 Tohoku Earthquake

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Abstract. This study compares the convenience of temporary housing complexes in the Iwate Prefecture following the 2011 Tohoku Earthquake. The study was targeted at three major cities in the southern coastal area of Iwate Prefecture, namely, Kamaishi, Ofunato, and Rikuzen-Takata, that were most heavily struck by the earthquake-triggered tsunami.

We conducted a network analysis in geographical information system software using the coordinate data of several daily infrastructures. Temporary housing complexes within the defined service area of each infrastructure were assigned a score of 1.00. The main findings are summarized below:

1) The temporary housing complexes in Rikuzen-Takata City were less accessible to infrastructures (as evidenced by the low coverage area of 1.00 scores) than the other investigated cities.

2) The scores of Kamaishi City and Ofunato City were statistically similar, but complexes in Ofunato City were surrounded by slightly more infrastructures (greater coverage area of 1.00 scores) than Kamaishi City.

3) We identified more than the predicted number of blank areas in the targeted areas. Thus, we consider that support services for people living in such areas are urgently required, especially in the realms of daily shopping, banking, and healthcare.

1. Introduction
Following the 2011 Tohoku Earthquake [1], many people were relocated to temporary housings [2]. These housings were assigned to persons who had lost their homes in the disaster and lacked the financial means to rebuild. In the Iwate Prefecture, which was seriously damaged by the earthquake-triggered tsunami, 94.6% of the temporary dwellings were occupied in December 2011.

However, temporary housing complexes are not always conveniently located for everyday living. For example, daily shopping and banking becomes problematic for residents located beyond a certain distance of the precincts.

Therefore, this study compared the convenience of temporary housing complexes in the southern coastal area of the Iwate Prefecture, constructed after the 2011 Tohoku Earthquake. The three target cities, Kamaishi, Ofunato and Rikuzen-Takata, had been most severely stricken by the tsunami that followed the earthquake.

The convenience of living environments is frequently evaluated by the distance between the dwelling and surrounding infrastructures [3]. Similarly, we found that the usability score for a
The research focuses on three cities in the southern coastal area of the Iwate Prefecture [Fig. 1], [Table. 1], namely, Kamaishi City, Ofunato City and Rikuzen-Takata City, all of which were inundated by the tsunami that struck after the Tohoku earthquake in 2011.

| Populaions | Temporary housings | Occupied | Occupied Ratio(%) |
|------------|--------------------|----------|-------------------|
| Kamaishi City | 39,574 | 3,164 | 2,865 | 90.5 |
| Ofunato City | 40,737 | 1,811 | 1,784 | 98.5 |
| Rikuzen-Takata City | 23,300 | 2,168 | 2,141 | 98.8 |
| Iwate Prefecture | 1,330,147 | 13,984 | 13,233 | 94.6 |

complex increases with decreasing distance from the infrastructures.

2. Methodology
2.1. Research area
The research focuses on three cities in the southern coastal area of the Iwate Prefecture [Fig. 1], [Table. 1], namely, Kamaishi City, Ofunato City and Rikuzen-Takata City, all of which were inundated by the tsunami that struck after the Tohoku earthquake in 2011.

2.2. Research materials
The data used in the study were the coordinate data of the temporary housing complexes [Fig. 2] and the infrastructures of daily life in December 2011.

2.3. Daily life infrastructures
The daily life infrastructures evaluated in this study are listed below. The assumed service areas are given in parentheses.
1) Commerce field
   a. Large supermarkets (3 km)
   b. Middle-sized supermarkets (1 km)
2) Service field
   a. post offices and banks (1 km)
3) Medical field
   a. large hospitals (3 km)
   b. private clinics (1 km)
4) Transport field
   a. bus stops (0.5 km)

2.4. Obtaining the research data
The temporary housing data were retrieved from the Iwate Prefecture website [4].
Data on the daily life infrastructures were obtained from NTT i Town Pages (a telephone number search service available on the Internet) [5].
Bus stop coordinates were available from digital maps compiled by the National Land and Traffic Agency of Japan.
The real infrastructure coordinates and states of the services were confirmed from Internet sites and maps.

2.5. Analysis
After plotting the infrastructures on the map, we conducted a network analysis using the ArcGIS Network Analyst function. This software enables the measurements of actual road distances in addition to linear distances between two features.
In this study, we created network datasets from simple road distances, neglecting road bends and speed limit data. From the network data sets, we determined the service areas of the infrastructures, representing individual features by polygons.
Based on the distance from the infrastructures and the service area covered by the infrastructure, we then assigned a usability score to each temporary housing complex.

3. Results 1: Comparizon of the characteristics of three cities
The infrastructures of the three target cities are compared in Figure 3.
Temporary housing complexes located within the defined service area of each infrastructure are assigned a usability score of 1.00. Complexes located within twice and thrice the defined service area are assigned scores of 0.66 and 0.33, respectively. Complexes located beyond three times the infrastructure service coverage score 0.00.

3.1. Kamaishi City
In Kamaishi City (as in the other target cities), the 1.00-score area coverage for convenience stores was small, and was also relatively low for small supermarkets. In contrast, the 1.00-score area for large supermarkets and clinics was relatively wide.

3.2. Ofunato City
The 1.00-score area coverage for almost all infrastructures was larger in Ofunato City than in Kamaishi and Rikuzen-Takata. Especially, buses, clinics, and large supermarkets were accessible to many temporary housing dwellers, while hospitals covered a relatively small accessible area.
3.3. Rikuzen-Takata City
The 1.00-score area coverage for almost all infrastructures was smaller in Rikuzen-Takata City than in Kamaishi and Ofunato. There is no large supermarket in this city, and no temporary housing complexes exist within the service area of convenience stores. The 1.00-score area coverage for small supermarkets, clinics, and buses are also comparatively small.

4. Results 2: Convenience of each infrastructure in the three cities
In each of the evaluated cities, infrastructures were generally located along main roads. Since the tsunami stricken areas were largely coastal, the temporary housing complexes tended to be located outside of the original downtown areas.

Of particular importance in this section is the blank area (0.00-scoring area) of each service. The coverage of the infrastructures in each city are described below.

4.1. Large supermarket (3 km) [Fig.4]
1) Kamaishi City: Large supermarkets are located from the coastal area to the internal area nearby national route 283 and the JR Kamaishi railway line. A temporary shop was constructed near Hirata following the disaster in December 07, 2011.
2) Ofunato City: Ofunato City hosts a shop in Takkon and a temporary shop in Ofunato Town.
3) Rikuzen-Takata City: No large supermarket currently exists in this city.

4.2. Middle-sized supermarket (1 km) [Fig.5]
1) Kamaishi City: Several service areas are located in the internal area close to national route 283. Two areas reside in Unosumai and Hirata.
2) Ofunato City: Most of the service areas are located near the Ofunato railway station, which is close to national route 45. Other service areas are near the Sanriku, Ryori, and Hosoura railway stations.
3) Rikuzen-Takata City: Several service areas reside in the downtown, Takekoma, and Otomo areas.

4.3. Convenience stores (0.5 km) [Fig.6]
1) Kamaishi City: Several service areas are located in the internal area close to national route 283. Two areas reside in Unosumai and Hirata.
2) Ofunato City: Most of the service areas are located near the Ofunato railway station, which is close to national route 45. Some service areas reside near the Sanriku, Ryori, and Hosoura railway stations.
3) Rikuzen-Takata City: Several service areas are located at Takekoma and Yahagi in the downtown area.

4.4. Post offices and banks (1 km) [Fig.7]
In Japan, post offices offer standard banking services. Hence, we treated both services as a single group.
1) Kamaishi City: This city hosts 7 banks and 15 post offices.
2) Ofunato City: This city hosts 4 banks and 8 post offices.
3) Rikuzen-Takata City: This city hosts 2 banks and 7 post offices.
Figure 2. Locations of temporary housing complexes (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City).

Figure 3. Comparisons of infrastructures of three targeted cities. Blue regions indicate the percentage of temporary housing complexes located WITHIN the defined service area of each infrastructure. Red and green regions denote the percentage of temporary dwellings within TWO and THREE times the defined service area, respectively. Violet regions indicate the percentage of temporary dwellings outside three times of the defined service area.
Figure 4. Locations of large supermarkets (Upper: Kamaishi City, Lower: Ofunato City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively.

4.5. Large hospitals (3km) [Fig.8]

1) Kamaishi City: Four large hospitals lie along national route 283.
2) Ofunato City: A single large hospital exists in Ofunato Town.
3) Rikuzen-Takata City: There is a single large hospital in Yonesaki Town. This temporary hospital replaces the former hospital that was damaged by the tsunami.

4.6. Private clinics (1 km) [Fig.9]

1) Kamaishi City: Kamaishi City contains 29 private clinics. Several private clinics are located along national route 283; others are located in Kuribayashi, Unosumai, and the Hirata area.
2) Ofunato City: This city accommodates 32 private clinics. Most of these are located near the Ofunato railway station, which is close to national route 45. Some service areas exist near the Yoshihama, Ryori, and Sanriku railway stations.
3) Rikuzen-Takata City: The 12 private clinics in Rikuzen-Takata City are more separated than in the other investigated cities.
Figure 5. Location of middle-sized supermarkets (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas (where the score for each infrastructure = 0.00) are delineated by red ovals.

Figure 6. Location of convenience stores (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas are delineated by red ovals.
Figure 7. Location of post offices and banks (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas are delineated by red ovals.

Figure 8. Location of large hospitals (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas are delineated by red ovals.
Figure 9. Location of private clinics (Upper: Kamaishi City, Center: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas are delineated by red ovals.

Figure 10. Bus stop locations (Upper: Kamaishi City, Middle: Ofunato City, Lower: Rikuzen-Takata City). Green and red points indicate the infrastructures and the temporary housing complexes, respectively. Blank areas are delineated by red ovals.
4.7. Bus stops (0.5Km) [Fig.10]
1) Kamaishi City: Most of the bus stops are located along national routes 45 and 283 near the residential areas.
2) Ofunato City: Most of the bus stops are located along national routes 9, 45, and 107 near the residential areas.
3) Rikuzen-Takata City: Most of the bus stops have been shifted from the tsunami-stricken national routes to the internal prefectural and city roads near the residential areas.

5. Discussion
5.1. City population and proportion of stricken urban area
Of the three investigated cities, Rikuzen-Takata City hosts the smallest population [Table. 1], and the proportion of its urban area struck by the tsunami was much larger. We link these factors to the low 1.00-scoring areas of the housing complexes in this city, that is, infrastructures are far less accessible to temporary housing dwellers in Rikuzen-Takata City than to the temporary housing occupants in the other cities.

5.2. Shape of the main city area
Although the populations of Kamaishi City and Ofunato City are statistically the same [Table. 1], the main urban areas are very differently shaped. Kamaishi City is narrower and longer than Ofunato City, and its urban area is much less intensive. This different topography probably explains the higher 1.00-scoring area of the temporary housing complexes in Ofunato City than in Kamaishi City, for almost all infrastructures.

5.3. Blank areas of the daily infrastructures
We identified more than the predicted number of blank areas (where temporary dwellings were not covered by daily infrastructures) in the targeted areas. Thus, we consider that support services for people living in such areas are urgently required, especially in the realms of daily shopping, banking, and healthcare.

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