🏆 *reviewed paper*

# Walkability Assessment of Elderly People in Collective Relocation after the Great East Japan Earthquake – a Case Study in Kesennuma City, Japan

*Takahiro Kanamori, Wanglin Yan*

(Takahiro Kanamori, Keio University, 5322 Endo, Fujisawa, Kanagawa, Japan, leonis@sfc.keio.ac.jp)
(Prof. Wanglin Yan, Keio University, 5322 Endo, Fujisawa, Kanagawa, Japan, yan@sfc.keio.ac.jp)

## 1 ABSTRACT

Ten years have passed since the Great East Japan Earthquake, and collective relocation has been completed in the tsunami-affected areas. While collective relocation has ensured safety from the tsunami, the lives of elderly residents after relocation are expected to change drastically due to the distance from the highly convenient coastal areas. This paper clarifies how, in the midst of population decline and aging community, the collective relocation to areas with rugged terrain had an impact on the living conditions of elderly residents, particularly regarding daily movement on foot, and how these conditions have changed since the collective relocation. Specifically, the amount of walking load from each collective relocation complex to the nearest living facilities was calculated for the 5th and 10th year after the earthquake. The analysis revealed that while an increasing number of complexes improved their walking accessibility due to the increase in local living facilities, 15 of the 103 complexes in Kesennuma City required a very large amount of physical effort to reach all living facilities.

Keywords: Elderly People, Walkability, Aging, Collective Relocation, Post-Disaster Reconstruction

## 2 INTRODUCTION

The Great East Japan Earthquake that occurred on March 11, 2011, caused extensive damage to the Tohoku and other coastal areas of the Pacific Ocean by the tsunami. In the tsunami-affected areas, the Collective Relocation Projects (hereinafter "CRP") and Disaster Recovery Public Housing Projects (hereinafter "DPP") were executed as collective relocation, relocating residents from low-lying coastal areas to higher ground and other locations with less tsunami risk. Most of the sites for collective relocation were decided within five years since the earthquake, and these projects were implemented at an unprecedented scale.

Among the tsunami-affected areas, the Sanriku coastal area is characterized by a rias coastline with steep terrain extending close to the shore. The intricate topography forms inner bays, and many areas have a thriving aquaculture industry due to the tranquil environment, and fishing has flourished in the offshore areas. Given such background, urban areas have been formed in low-lying coastal areas for its convenience. However, in the reconstruction from the earthquake, lowland coastal areas that remain at risk of L2 tsunamis (the largest class of tsunami), even with seawalls and land raising, were designated as disaster hazard area under Article 39 of the Building Standards Act, and restrictions were placed on the location and structure of residential buildings. As a result, housing reconstruction was mainly carried out outside the disaster hazard area, and the coastal areas, which had been the center of livelihood and daily services, were spatially separated from the inland and highland areas, which were the new residential areas. In other words, the reconstruction of housing after this earthquake may have prioritized the reduction of tsunami disaster risk at the expense of the increase in livelihood risk.

This earthquake occurred in the midst of a rapidly shrinking and aging population, and many of the residents who participated in the collective relocation project can be assumed to be elderly. As mentioned above, within the Sanriku coastal area, many small and dispersed housing complexes were built in steep terrain areas due to topographical constraint. Combined with the difficulty of developing convenient living facilities, many housing complexes are considered to have poor living convenience. Ten years have passed since the earthquake, and the collective relocation projects and land readjustment projects have been completed, and new roads have generally been laid out. The structure of the city has changed significantly compared to five years ago, when the sites for collective relocations were largely determined, as new public transportation networks and commercial areas have been formed. The demand for reconstruction has also changed, and the living environment seems to have changed drastically, with stores closing and some districts failing to reach their planned population due to delays in reconstruction projects. This may have resulted in a gap between the lifestyle and what was initially envisioned. In addition, the combination of these demographic changes, disaster reconstruction projects, and topography are expected to have a significant impact on the lives of the elderly in the collective relocation complex. In particular, problems in terms of walking mobility for the elderly are likely to become apparent in the near future, and mobility will become difficult in the area with its rugged terrain.

This paper focuses on Kesennuma City, Miyagi Prefecture, where a large-scale collective relocation project was implemented as a result of the tsunami. The purpose is to examine how, in the midst of population decline and aging community, the collective relocation to areas with rugged terrain had an impact on the living conditions of elderly resident, particularly regarding daily movement on foot, and how these conditions have changed since the collective relocation. Specifically, this paper calculates the amount of physical load calculated based on the effect of inclination on the body and physical functions, and conduct a walking accessibility assessment from each collective relocation complex to the nearest living facilities. The target focus of these assessments is mainly on the 5th and 10th year after the earthquake.

## 3 LITERATURE REVIEW

Many studies have addressed and provided insights into issues related to lifestyles and the aging society. One such study, particularly focusing on the understanding of aging population and its walking mobility, is the study by Hasegawa, who studies the differences in housing attitudes in relation to the aging population in detached housing complexes (Hasegawa et al., 2011). This study revealed that the older the members in the elderly households are, and the less convenient housing complexes are, the stronger residents show anxiousness over their daily transportation means. In particular, the study points out that the inconveniences experienced in regard to hospital visits and daily shopping are major factors resulting in residents changing their residence. Considering the increase in the number of elderly residents who will be unable to drive in the near future, taking into account residents' lifestyle from the perspective of walking mobility will be crucial for elderly residents. In this context, the concept of walkability is important when focusing on walking mobility. A study of walking accessibility for the elderly conducted by Hara et al. (2009) revealed that the area reachable on foot is significantly smaller than that in plain areas. This study considers the effects of physical ability and topography, and this paper believes that it is important to consider walkability from these perspectives.

On the other hand, the elderly nowadays often drive cars, and such a tendency is prominent in rural cities, as cars are significant means in maintaining livelihood (NPA, 2022). However, research indicates that elderly drivers perceive their driving ability to decrease due to their declining physical ability (Nihei et al., 2012) and this indicates high likelihood of inducing traffic accidents. Therefore, studies such as by Yamamoto et al. (2012), have argued that accessibility improvements that do not rely on automobiles are necessary to encourage elderly drivers to return their licenses. In conclusion, debating on the walking mobility of elderly residents is significant from the standpoint of promoting self-supportive and independent life for the future of the elderly.

Many studies addressing the impact of collective relocation on livelihoods have focused on uncovering the situation of residents/participants in the collective relocation (Tanaka, 2011) or on the situation concerning the divisive collective relocation (Tanaka et al., 2010). Most of these studies analyze disaster reconstruction based on non-tsunami disasters such as the Niigata Chuetsu Earthquake, which was a landslide disaster, and not many have addressed large-scale collective relocation for the reconstruction from tsunami disasters. Although there are a few studies on the Great East Japan Earthquake, few of them discuss the impact of collective relocation as regards population decline and aging society, and none of them discuss the impact of collective relocation on the walking environment of the elderly residents, nor provide quantitative evaluation of the relocation and comprehensively take into account these factors in their studies.

## 4 STUDY AREA

### 4.1 Study Area

Kesennuma City, located in the northeastern tip of Miyagi Prefecture, about 400 km north of Tokyo, is one of the cities that was severely damaged by the tsunami. The city has a particularly large number of collective relocation complexes among the affected areas. According to a tsunami trace survey conducted by Miyagi Prefecture, the maximum inundation depth in the city was 15 to 19 meters and the maximum run-up height was over 20 meters (Miyagi Prefecture, 2012). The inundated area covered 18.65 km², or 5.6% of the city area (Kesennuma City, 2011). The tsunami also caused fires, and as a result of these damages, more than 1,400 people were killed or missing (as of April 30, 2022), and more than 10,000 buildings were completely or partially destroyed (Miyagi Pref, 2022).

Kesennuma City geographically consists of areas stretching along from north to south, and include a remote island, Oshima, at its bay port. The city has a 30 kilometer stretch of inlets and a steep terrain characteristic of a rias-coastline, and the elevation rises sharply as one moves slightly away from the coast. Most of the city's urban areas and settlements are concentrated in a limited number of low-lying coastal plains, hills, and inlets. The city has a total population of 61,147 (2020 Census), but the population has decreased by 12,342 in the 10 years since 2010, the year before the earthquake. The aging rate of the population is 38.3% (2020 Census), an increase of 7.5% since 2010.

### 4.2 Collective Relocation Projects

CRP is a project that allows five or more households to relocate to a higher ground or other safe area while maintaining their communities, with purchase of the land from which they are relocating to and the cost of relocating their homes being subsidized. DPP provides inexpensive rental housing to disaster victims who cannot or do not wish to build their own houses. In the study area, about 30% of the 9,130 affected households participated in the CRP and DPP (Kesennuma City, 2018).

Collective relocation complexes in the city can be broadly classified into three types: collective relocation complexes (hereinafter "CRC"), disaster recovery public housing complexes (hereinafter "DPC"), and mixed-use complexes with a mixture of CRC and DPC (hereinafter "MRC"). In the study area, 2,994 units in 103 housing complexes, including 60 CRC, 33 DPC, and 10 MRC (September 2021) have been completed and the affected people have started living in their new homes.

These collective relocation complexes vary in location from those developed in coastal areas to inland areas (Figure 1), and the number of relocated units in each complex varies from 5 to 67 units in CRC and from 7 to 320 units in DPC (RA, 2021). The reasons behind the 5 units minimum relocation requirement and the decentralization of complexes include the relaxation of the minimum relocation requirement for CRP from 10 to 5 units and the difficulty of acquiring land for relocation sites, which has resulted in the creation of many very small complexes.

### 4.3 Target Living Facilities

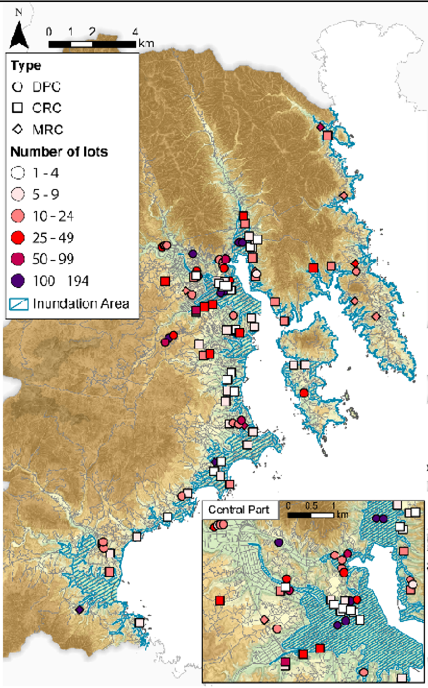
A study by Sato et al. (2013) focused on leisure, safety, daily living affairs, purchasing, transportation, and medical care as the minimum necessary living facilities from the perspective of continued residence of the elderly in a regional core city. In addition, a national survey on the living conditions of the elderly (MLIT, 2005) revealed that the frequency of daily shopping and hospital visits was higher than other daily activity purposes. Based on these findings, public transportation, commercial facilities, and medical facilities are defined as living facilities that are considered to be minimally necessary for people to live on foot in the study area. Table 1 shows the number of living facilities under each facility categories in each year.

#### 4.3.1 Public Transportation

Public transportation in the city includes local buses and Bus Rapid Transit (BRT). Before the earthquake, the JR Kesennuma Line and JR Ofunato Line had been in operation but were inoperable immediately after the earthquake due to the damage caused by the tsunami. Currently, all of the city's railroads have resumed service with the introduction of BRT. Some routes have been drastically changed in accordance with the status of reconstruction of coastal areas and housing. Based on the above, this paper defines bus routes and BRT as public transportation.

| **Living Facility** | | **2016** | **2021** |
|---|---|---|---|
| Public Transportation | Bus Stops, BRT Stations | 259 | 270 |
| Commercial Facility | Supermarkets | 14 | 13 |
| | Pharmacies | 8 | 12 |
| | Convenience Stores | 33 | 41 |
| Medical Facility | Hospitals (Internal Medicine) | 19 | 20 |

Table 1: Number of Facilities under Each Category of Living Facility (July 2018)



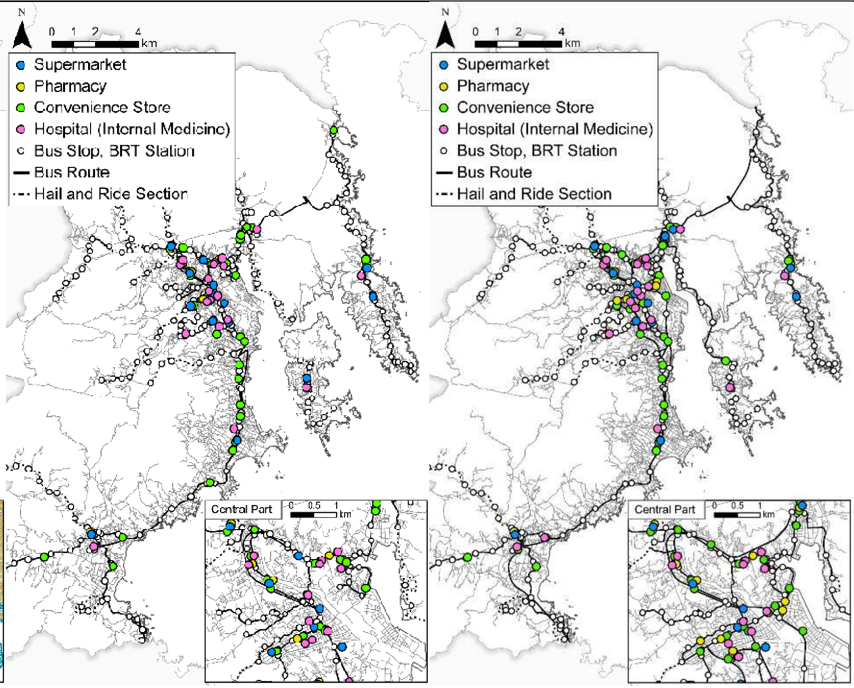




Fig. 1: Location and scale of collective relocation complex (left). Fig. 2: Location of living facilities in 2016 (middle) and 2021 (right)

### 4.3.2 Commercial Facilities

There is a wide variety of commercial facilities in the city, ranging from a commercial complex to supermarkets, pharmacies, convenience stores, and local stores. Given that the local stores are known to have only a limited range and number of products which they handle, and studies have shown that the frequency of elderly purchasing at such stores is significantly lower than that of other commercial facilities, this paper limits its focus of commercial facilities to supermarkets, convenience stores, and pharmacies, excluding local stores. However, in some areas, the local stores are relatively larger than in other areas and are serving as supermarkets and convenience stores provided that there are no other commercial facilities in the vicinity. Therefore, in each area of Karakuwa and Oshima some among such stores were treated as commercial facilities and classified as supermarkets or convenience stores based on the national categorization (METI, 2005). Pharmacies are classified under commercial establishments, as pharmacies offer a wide range of food products as well as medical supplies and a similar classification has been given in other existing studies (Suzuki et al., 2014).

### 4.3.3 Medical Facilities

General hospitals and clinics with internal medicine departments, which are considered to be frequently used by the elderly based on previous studies (Sato et al., 2013) are the focus of this study.

## 5 METHODOLOGY

This paper assesses the walking accessibility of the elderly on the shortest one-way road route from each collective relocation complex to the nearest living facilities (public transportation, supermarkets, pharmacies, convenience stores, hospitals (general hospitals and clinics including internal medicine) throughout Kesennuma City.

### 5.1 Definition of Walking Accessibility

This paper defines the evaluation method of walking accessibility based on a previous study (Hara et al., 2009). Hara et al. developed a walking accessibility index based on the evaluation method suggested by Sato et al. (2006), while improving it by using metabolic conversion walking distance, which takes into account physical ability and topographical conditions.

The Walking Energy Consumption (E) is calculated using the following equation (1). The Relative Metabolic Rate (RMR) represents the activity intensity of walking up a gradient along the pathway, and their relative load is expressed as (RMR + 1.2). Basal Metabolic Rate per Unit Weight and Time (BMR) × Weight (W), represents the basal metabolic rate per unit of time. The Volume of Basal Metabolic Rate represents the minimum amount of energy required for basic life functions, and the Basal Metabolic Rate (BMR) and Weight (W) vary with age. Walking Time (T) is the value obtained by dividing the Road Distance to the Destination Facility (l) by the Walking Speed (v).

Walking load (R) is expressed by equation (2), and Walking Accessibility to the Destination Facility (A) is expressed by equation (3). The Estimated Daily Energy Requirement per Unit Body Weight (a) ×Weight (W) represents the estimated daily energy requirement. The estimated daily energy requirement is the average daily value of habitual energy intake that is estimated to have the highest probability of zero energy balance (MHLW, 2010). This value is determined by the physical activity level, which is determined by the content of daily activities in addition to the Volume of Basal Metabolic Rate. In this paper, the physical activity level is set in "Level II (moderate)", representing the activity level in sedentary lifestyle with some light exercise involved. The Amount of Walking Load to the Destination Facility (R) is the Energy Consumption (E) of walking from the starting point to the destination, divided by the estimated daily energy requirement. The Walking Accessibility to the Destination Facility (A) is the walking load (R) minus 1. In other words, walking accessibility in this study refers to the ratio of the amount of energy that can be consumed other than by walking to the nearest living facilities out of the daily energy requirement. The closer the value of walkability (A) is to 1, the better the walkability from the relocation site to the nearest living facilities.

The Relative Metabolic Rate (RMR) are calculated as shown in equation (4), as it differs depending on the gradient (s). The Relative Metabolic Rate (RMR) increases as the gradient becomes steeper and decreases as the gradient becomes more gradual. However, even on a gradual gradient, it becomes a heavy load on the body of an elderly person when climbing a hill, and similarly with a steep gradient, it becomes a heavy load

$$E = (RMR + 1.2) \times BMR \times W \times T \quad (1)$$

$$R = E/(a \times W) \quad (2)$$

$$= (RMR + 1.2) \times BMR \times W \times T \times \{1/(a \times W)\}$$

$$= (RMR + 1.2) \times BMR \times W \times (l/v) \times \{1/(a \times W)\}$$

$$A = 1 - R \quad (3)$$

when v = 80 (4)

$$RMR = 10.0 \quad (s \leq -0.25)$$

$$RMR = -58.07s - 4.52 \quad (-0.25 \leq s \leq -0.11)$$

$$RMR = 3.113e^{4.614s} \quad (-0.11 \leq s \leq 0.25)$$

$$RMR = 10.0 \quad (0.25 \leq s)$$

| **Age** | ***v*** **(m/min)** | ***BMR*** **(kcal/kg/min)** | ***a*** **(kcal/day)** | ***W*** **(kg)** |
|---|---|---|---|---|
| 65 to 74 | 47 | 0.01367 | 34.46 | 58.71 |

Table 2: Parameters

| **Variable** | **Description** | **Units** |
|---|---|---|
| *A* | Walking Accessibility to the Destination Facility | - |
| *R* | Amount of Walking Load to the Destination Facility | - |
| *E* | Energy Consumption | kcal |
| *RMR* | Relative Metabolic Rate | - |
| *BMR* | Basal Metabolic Rate per Unit Weight and Time | kcal / kg / min |
| *W* | Weight | kg |
| *T* | Walking Time | min |
| *a* | Estimated Daily Energy Requirement per Unit Body Weight | kcal / kg / day |
| *l* | Road Distance to the Destination Facility | m |
| *v* | Walking Speed | m / min |
| *s* | Gradient | % |

Table 3: Abbreviations and Meaning


ISBN 978-3-9504945-1-8. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

As mentioned above, the Basal Metabolic Rate per Unit Weight and Time (BMR) and Weight (W) vary with the age of the walker. The Estimated Daily Energy Requirement per Unit Body Weight (a) and Walking Speed (v) also differ. This paper focuses on elderly in the early stage of life (65 to 74 years old) who are expected to commute by foot, using the values in Table 2 as parameters. For parameters other than that of Walking Speed (v), various parameters are obtained from the results of the daily life area needs survey conducted by Kesennuma City (Kesennuma City, 2014), using the average values for men and women. While the data referred to by Hara et al. (2009) are national averages, this paper did not adopt the same methodology given that physical conditions may differ by region. On the other hand, the same values were adopted in this paper from the previous study by Hara et al. (2009). Since the Relative Metabolic Rate (RMR) for walking up a gradient at a speed other than 80 m/min is unavailable, the same value, as the previous study (Sato et al., 2006), of moving at 80 m/min is used, while reflecting decrease in physical ability and walking speed due to aging in Walking Time (T). The interpolation is performed by reflecting the decline in physical ability and walking speed due to aging in the walking time (T). The abbreviation and meaning of each component described in this section are shown in Table 3.

### 5.2 Data Management

The data of collective relocation complexes were based on the “Land-Use Plan Map” (March 2016) and the " Overall Picture of Restoration and Reconstruction " (September 2021). The collective relocation complexes include several large complexes that are more than 500 m wide, and in these complexes, walking accessibility differs significantly at both ends of the complex. Therefore, for these large housing complexes, the data will be divided by construction zone and residential groupings as appropriate to enable a more detailed evaluation.

### 5.3 Method of Analysis

Network analysis is used for this analysis. First, a 5-meter mesh is used for the elevation data, and all road data are divided into 10-meter segments. Slope angle is reflected to each segment while the value of the walking load is stored per segments. Next, after finding the focal point of the relocation complexes, using the nearest road from the focal point as the starting point, the shortest road route to the nearest living facilities is extracted and walking accessibility of the route is analyzed. The walking accessibility value is calculated as a round-trip and then divided by 2 to obtain an average value per one-way trip. For public transportation, since some bus routes have hail and ride sections, only such sections are used as the routes to the nearest bus route.

## 6 RESEARCH FINDINGS

In the assessment of walking accessibility, collective relocation complexes are classified using the “walkable area” as criterion. Given the difficulty to assess relative walkability in absolute values, this paper defines the existing concept of walkable area as "an area where people can walk on a flat road with no gradient”. Furthermore, the threshold is set as the amount of walking load when a person aged 65 to 74 walks in a walkable area and the amount of walking load when walking twice as far. The assessment is conducted after classification of results into three classes (Table 4).

| Classification | Transportation Walking Accessibility | Commercial/Medical Facility Walking Accessibility |
|---|---|---|
| Complex A (Within Walkable Distance) | 0.9854～1 (0～400 m) | 0.9818～1 (0～500 m) |
| Complex B (Outside Walkable Distance) | 0.9709～0.9854 (400～800 m) | 0.9636～0.9818 (500～1,000 m) |
| Complex C (Outside Walkable Distance) | ～0.9709 (800m～) | ～0.9636 (1,000 m～) |

Table 4: Classification of Collective Relocation Complexes

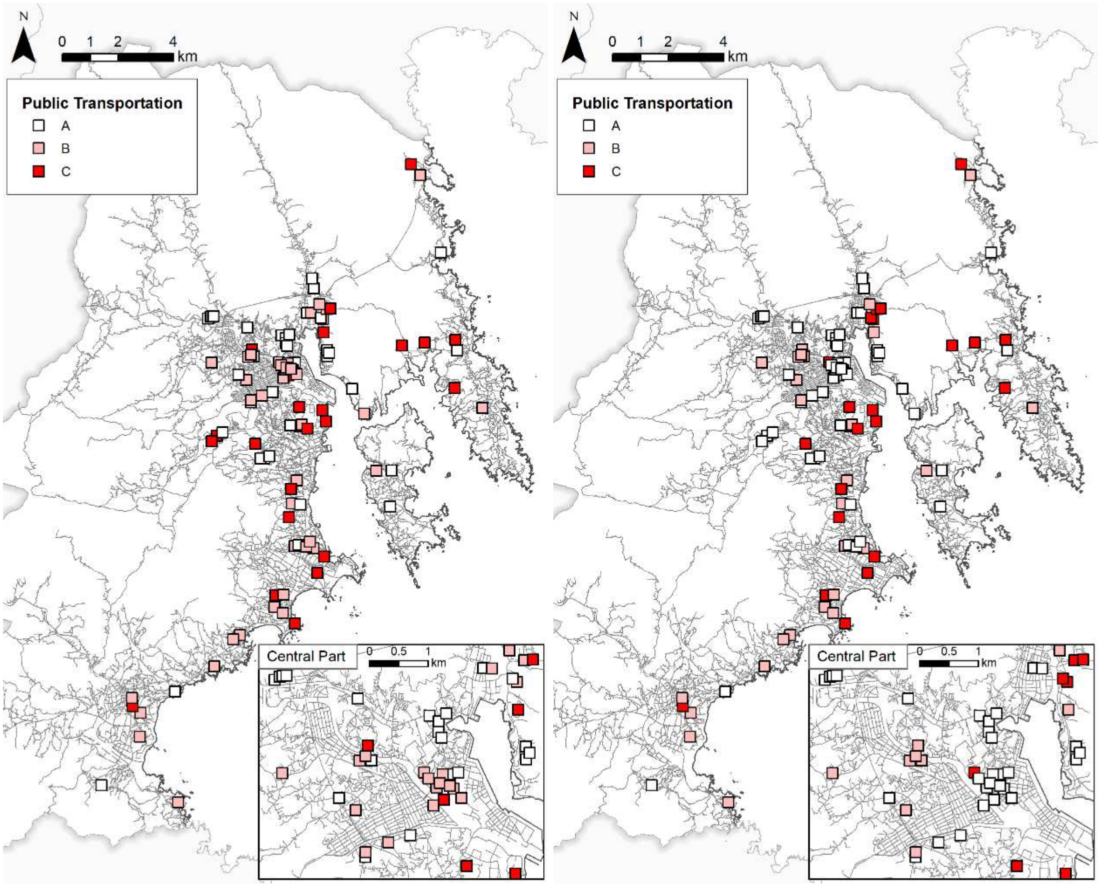



Fig. 3: Accessibility of public transportation in 2016 (left) and 2021 (right)

According to a survey on public transportation conducted by the Cabinet Office (CAO, 2016), the largest number of respondents thought 5 to 10 minutes as an acceptable time range between their home to the nearest station/bus stop, 235 m to 470 m in distance. Furthermore, bus stops are located every 400 m in many sections in the study area. Based on these factors, this paper defines the walkable distance for public transportation as 400 m. For commercial/medical facilities, walkable distance is based on the survey result conducted by the Cabinet Office (CAO, 2009). In this survey, the largest number of respondents in their 60s answered 501 to 1,000 m as the "walkable range", while the largest number of respondents in their 70s and above answered 500 m. Thus, the walking range is defined as 500 m in this paper. The complexes that can be reached within above walkable distance load are defined as "A complexes," those that can be reached with up to twice the load are "B complexes," and those with significantly greater load are defined as "C complexes".

### 6.1 Public Transportation

Walking accessibility of public transportation is shown in Figure 3. The classifications resulted in 38 complexes falling under complex A, 42 in B, and 23 in C, in 2016, while 53 were classified under complex A, 28 in B, and 22 in C in 2021. Given the infrastructural role of public transportation, bus stops and BRT stations are laid out throughout the city, thus many of the collective relocation complexes have better walking accessibility than other living facilities. In terms of changes over time, as of 2016, less than 40% of all collective relocation complexes were able to reach the nearest public transportation facility with the amount of load within walkable distance, but by 2021 this had improved to 50%. Most of the collective relocation complexes' walking accessibility has improved due to the extension of bus routes to the complexes and the detouring of bus routes given the completion of land readjustment projects in low-lying areas. On the other hand, 20% fall under C and there is no change seen between 2016 and 2021. In terms of location, in both 2016 and 2021, A were mostly found in densely populated areas with good public transportation in the center of the city, while complex C were found to be distributed not only on the fringes but also in areas close to the center.


ISBN 978-3-9504945-1-8. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

## 6.2 Commercial Facilities

First, for supermarkets, there were 8 complexes falling under complex A, 19 in B, and 76 in C, in 2016, while 11 in A, 18 in B, and 74 in C in 2021. While the number of complexes with improved walkability increased, only about 10% of the complexes could be reached by walking load in both 2016 and 2021, and C had over 70%, resulting in overall poor walking accessibility. Compared to public transportation, supermarkets have generally poor walking accessibility outside the center of the city, as the location of facilities are concentrated in the central area. In Oshima, the only supermarket on the island closed due to a new bridge being built in 2019 as part of a reconstruction project, and a supermarket operated by a local company near Kesennuma Station closed, indicating the withdrawal of facilities.

Next, for pharmacies, there were 7 under complex A, 4 in B, and 89 in C, in 2016, while 21 in A, 14 in B, and 68 in C in 2021. Note that since there are no pharmacies on Oshima, the three complexes on the island were excluded for 2016 because there are no facilities that can be reached on foot, and were included for 2021 because a bridge connecting Oshima to the mainland has since been built. The number of pharmacies decreased significantly in C and doubled in A, as four pharmacies were opened in the center of the city after the land readjustment projects was completed.

Convenience stores had 20 under complex A, 34 in B, and 46 in C complexes in 2016, while 31 in A, 27 in B, and 45 in C complexes in 2021. Note that as of 2016, there were no convenience stores on Oshima, so the three complexes on the island were excluded because there were no facilities that could be reached on foot. Convenience stores are scattered over a wide area of the city, resulting in A being second only to public transportation. In terms of temporal changes, B decreased, and A increased significantly. This was contributed by the increase in the number of convenience stores, which increased by eight over the five years since 2016, with many opening in the center of the city. There are 10 complexes (as of 2021) where there are no supermarkets and pharmacies within walkable area and only convenience stores are within walkable area, indicating that convenience stores may have become an important living facility to support daily life.

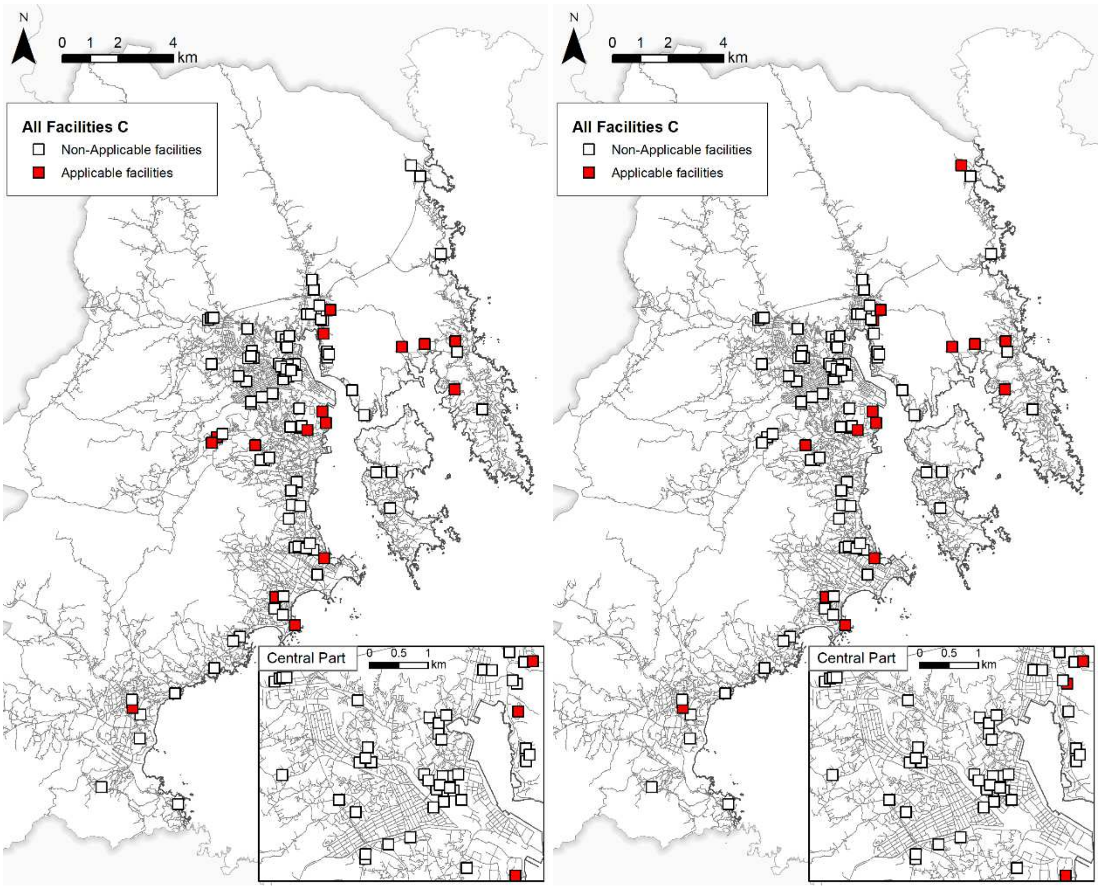



Fig. 4: Accessibility of all living facilities C in 2016 (left) and 2021 (right)

### 6.3 Medical Facilities

In 2016, there were 8 complexes classified as complex A, 25 in B, and 70 in C. In 2021, there were 16 in A, 21 in B, 66 in C. The number of the complexes within walkable distance was about 10% in 2016, while complexes classified as complex A has doubled due to the construction of a hospital in an area where a land readjustment project was completed. On the other hand, even in the central area, many complexes are outside of walkable area.

### 6.4 Multiple Living Facilities

The results of walking accessibility to each living facilities, classified into the three classifications in the previous section, indicated there were 46 complexes with 845 units (as of 2021) classified as complex B or C, where all living facilities were not within walkable distance. In particular, there were 499 units in 16 complexes in 2016 and 341 units in 15 complexes in 2021 which fell under complex C in terms of all living facilities (Figure 4), indicating that there are still a number of complexes that may be in a serious situation, with no significant change in their numbers. In terms of location, several are located in areas close to the center of the city, as well as in areas away from the city center. In addition, there are 40 complexes with 1,075 units (as of 2021) that have become C complexes in terms of all living facilities except public transportation. In such complexes, the continuation of public transportation may determine the continuation of residence, and the maintenance of local bus routes may become a major focus.

## 7 DISCUSSION

The results of the analysis revealed that in many of the collective relocation complexes are strongly affected by gradients, which places a heavy burden on the physical condition of elderly residents when traveling on foot to the nearest living facilities. Although public transportation, with its large number of facilities and distribution in mid-mountainous areas, made more complexes more accessible compared to walking accessibility to commercial and medical facilities, still only about 50% of the complexes were reachable within walkable distance load. Most of the commercial and medical facilities are located in central areas, with the exception of convenience stores, and due to this influence, it was found that only a small number of facilities can be reached within walkable distance load. In particular, 15% of the complexes require more than twice the load to reach all facilities within walkable distance, indicating that there is a certain number of complexes in serious condition. Many of these complexes are relatively small, which may make public transportation more difficult. In addition, these small-scale complexes are also arranged by council-type, in which residents themselves, discuss and decide where to relocate. Given that public aid will become more and more difficult with the decline in population, developing a system in which it considers livelihood risks from the perspective of self-aid and mutual aid is crucial. From the perspective of self-aid, it is necessary to present to residents the risks of living after relocation when selecting a new location, and from the perspective of mutual aid, it is necessary to consider whether residents can support each other.

In regard to changes seen overtime, the number of the complexes which saw an increase in walking accessibility has increased overtime since 2016, as reconstruction projects have increased the number of different living facilities, with the exception of supermarkets, as these have especially increased in many central areas. On the other hand, on a micro level, some complexes were affected by the withdrawal or relocation of facilities due to reconstruction projects and population decline, which worsened walkability in a few of these complexes. In such complexes, there is a possibility that a gap has emerged between the lifestyle envisioned before the relocation, and it is necessary to clarify the actual situation to see if residents are able to adapt to the changes in their lifestyles. In addition, such commercial facilities, which are strongly influenced by market principles, could easily be withdrawn as the population declines. Therefore, ensuring safety while also ensuring livelihood convenience through self-aid, mutual aid, and public aid will be an issue, including for future disaster reconstruction.

## 8 CONCLUSIONS

This paper focused on collective relocation as a post-disaster reconstruction project in the midst of a declining and aging population. We used objective indicators to identify issues in walking accessibility to the nearest living facilities for the elderly in the collective relocation complexes in an aging society. The results showed that many of the collective relocation complexes were affected by gradients and that they were relocated to locations where there were no nearby living facilities, resulting in poor walking accessibility. In terms of changes over time, as infrastructure improvements in coastal areas were completed, living facilities were also increasing, which improved the walking accessibility of many of the complexes. On the other hand, a small number of complexes experienced a deterioration in walkability, as some of the facilities were withdrawn or relocated due to the reconstruction projects and population decline. This may have resulted in a gap between the lifestyle and what was initially envisioned.

In Japan, where cities have developed in low-lying coastal areas, there is a major dilemma as to which countermeasures should be prioritized, disaster risk or livelihood risk. This study is expected to provide fundamental knowledge from the viewpoint of advance reconstruction from the Nankai Trough Mega Earthquake, which is predicted to cause a tsunami with a high probability of occurrence in the near future.

## 9 ACKNOWLEDGEMENT

This research was supported by the Ushioda Grant 2021 and Taikichiro Mori Memorial Research Grants 2021 from Keio University.

## 10 REFERENCES

HASEGAWA, Naoki, SUZUKI, Hiroshi: A study on the situation of living consideration in detached housing estates by aging and location - A case study in Kani city -, Journal of Architecture and Planning, Vol76, Issue 663, pp.965-971. 2011.

HARA, Takuya, ISHIZAKA, Koichi, OHASHI, Yoshiko: Evaluation of residential area from a point of elderly people's walking accessibility in local center city, Journal of Architecture and Planning, Vol74, Issue 635, pp.129-135. 2009.

National Police Agency: Driver's license statistics -Supplementary material 2-. 2020.

NIHEI, Misato, KAMATA, Minoru: A survey of the elderly in regional cities on their attitudes toward driving and giving up driving, Journal of Mechanical Systems for Transportation and Logistics, Vol. 5, Issue. 1, pp. 98–109. 2012.

YAMAMOTO, Kazuo, HASHIMOTO, Seiji: A study on the structure about the consciousness of relinquishment of the driver's license - Comparison of who have driver's license and who relinquishment of the driver's license -, Journal of the City Planning Institute of Japan, Vol.47, Issue 3, pp.763-768. 2012.

MIYAZAKI, Kosuke, TOKUNAGA, Yoshiyuki, KIKUCHI, Takehiro, KOEDA Akira, TANIMOTO, Keishi, KITA, Hideyuki: An analysis of activity of elderly people in rural area, Infrastructure planning review, Vol.22, Issue 3, pp.583-591. 2005.

TANAKA, Masato: The realities and background of the moving of residents by the collective relocation project after the Niigata ken chuetsu earthquake - Cases of Nishidani district and Kotaka district, Nagaoka city -, Journal of Architecture and Planning, Vol.76, Issue 665, pp.1251-1257. 2011.

TANAKA, Masato, NAKAKITA, Emi: The Realities of Separation of Disaster-stricken Villages by the Collective Relocation Project and Its Impact on Residents - Case of Nishidani district, Nagaoka City, Niigata Prefecture -, Journal of Social Safety Science, Vol.13, pp.463-470. 2010.

Miyagi Prefecture: First Year Record of The Great East Japan Earthquake (in Japanese). 2012.

Kesennuma City: Disaster Reconstruction Plan (in Japanese). 2011.

Miyagi Prefecture: Evacuation Situation and Damage to the Great East Japan Earthquake. 2022.

Kesennuma City: Results and Future Responses to the Intention Survey for the Project for Relocation of Houses at Risk Due to Proximity to Cliffs and Septic Tank Subsidy (in Japanese). 2018.

Kesennuma City: Progress of Collective Relocation Project (in Japanese). 2021.

Kesennuma City: Progress of Disaster Recovery Public Housing Project (in Japanese). 2021.

Reconstruction Agency: Housing Reconstruction Schedule (in Japanese). 2021.

SATOH, Eiji, MITSUHASHI, Nobuo: A study on residential sustainability for the elderly in the local city - Case study of evaluation on residential environment at Utsunomiya city -, Journal of Architecture and Planning, Vol.78, Issue 691, pp.1965-1972. 2013.

Ministry of Land, Infrastructure, Transport and Tourism: Survey on sustainable community development in an aging society (in Japanese). 2005.

SUZUKI, Yu, KIMURA, Kazuhiro, HINO, Satoru, KANEKO, Yuki: Shopping status of elderly and support measures from the view point of various of shopping, Journal of Japan Society of Civil Engineers, Ser. D3(Infrastructure Planning and Management), Vol.70, Issue 5, pp.I_371-I_382. 2014.

Ministry of Economy, Trade and Industry: 2005 Commerce in our country (in Japanese). 2005.

Ministry of Health, Labour and Welfare: Dietary Reference Intakes for Japanese (2010), 2010.

Kesennuma City: Daily living area needs assessment (in Japanese). 2014.

SATOH, Eiji, YOSHIKAWA, Tohru, YAMADA, Asuka: Investigation of converted walking distance considering resistance of topographical features and changes in physical strength by age - Model for location planning of regional facilities considering topographical condition and aging society Part 1 -, Journal of Architecture and Planning, Vol.71, Issue 610, pp.133-139. 2006.

Cabinet Office: Public Opinion Poll on Public Transportation (in Japanese). 2016.

Cabinet Office: Public Opinion Poll on Walkable Community Development (in Japanese). 2009.