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RECOVERY CURVES FOR PERMANENT HOUSES AFTER THE 2011 GREAT EAST JAPAN EARTHQUAKE

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Abstract

The Great East Japan Earthquake and Tsunami catastrophically struck the eastern part of Japan on March 11, 2011, especially the coastal areas of the Tohoku region. As of March 8, 2016, the number of casualty is 19,418, with 2,592 people still considered missing (FDMA, 2016). This paper aims to quantify the recovery processes of the 2011 Great East Japan Earthquake and Tsunami, and recovery curves are constructed based on disaster recovery public housing construction datasets. Firstly, it explains the background of housing reconstruction strategies conducted in the recovery phase and the importance of quantification of recovery processes. Secondly, the research method to construct recovery curves is described, followed by the data information used in this study. Thirdly, the recovery processes in Iwate, Miyagi, and Fukushima Prefecture, and recovery curves are demonstrated in terms of disaster recovery public housing construction conditions. Finally the processes and recovery curves are compared to understand regional different situations.

As a result, the recovery curves, which quantitatively demonstrate the commencement and the completion conditions of the disaster recovery public housing construction for Iwate, Miyagi, and Fukushima Prefecture, are obtained, as well as the three significant recovery curve parameters: Mean (λ), Standard deviation (ζ), and Coefficient of determination (R^2). Then the following findings were clarified.

(1) The coefficient of determination, which indicates level of relationship between the actual data and the obtained model, is more than 0.96 for all cases. This fact shows high adaptability of the cumulative normal distribution model to recovery processes represented by construction of permanent houses.

(2) The shortest time period that construction commencement ratio reached 50% was 48.88 months for Iwate; the longest was 55.50 months for Fukushima. The time difference between them was 6.63 months.

(3) With regard to the time period that the construction completed ratio becomes 50%, the shortest was of Miyagi with 57.84 months, followed by Iwate with 59.63 months and Fukushima with 60.28 months.

(4) The time difference for construction completion between the shortest and the longest became shortened compared with the construction commencement.

(5) The recovery ratio of the three prefectures is between 50% and 60% as of March 2011, five years since the disastrous event. It seems that the post-disaster recovery of the 2011 Great East Japan Earthquake and Tsunami, as a whole, takes more time than other recovery cases such as the 1999 Taiwan Earthquake or the 2004 Indian Ocean Tsunami.

Keywords: Reconstruction Agency; disaster recovery public housings; Iwate Pref.; Miyagi Pref.; and Fukushima Pref.

1. Introduction

1.1 Outline

This paper aims to quantify the recovery processes of the 2011 Great East Japan Earthquake and Tsunami, and recovery curves are constructed based on disaster recovery public housing construction datasets in this paper. Firstly, it explains the background of housing reconstruction strategies conducted in the recovery phase and the importance of quantification of recovery processes. Secondly, the research method to construct recovery curves is described, followed by the data information used in this study. Thirdly, the recovery processes in Iwate, Miyagi, and Fukushima Prefecture, and recovery curves are demonstrated in terms of disaster recovery public housing construction conditions. Finally the processes and recovery curves are compared to understand regional different situations.

1.2 Background

The Great East Japan Earthquake and Tsunami (the 2011 Off the Pacific Coast of Tohoku Earthquake) catastrophically struck the eastern part of Japan on March 11, 2011, especially the coastal areas of the Tohoku region. As of March 8, 2016, the number of casualty was 19,418, with 2,592 people still considered missing, and 121,809 buildings were heavily and 278,496 buildings were moderately destroyed (FDMA, 2016) [1]. As of March 2016, five years since the disastrous event, the long-term post-tsunami urban recovery has progressed according to the regional situations affected by the disaster. Although the post-tsunami urban recovery activities cover diverse strategies such as construction of levee or seawall, and land use planning as shown in Fig. 1 [2], which are managed by Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), one of the most important activities for the victims is construction of permanent housings. MLIT prepares urban recovery projects related to housing resettlement for the municipalities affected by the earthquake: (1) construction of disaster recovery public housings, (2) support for self-construction by the victims, (3) Promoting Group Relocation for Disaster Mitigation Projects, and (4) Land Readjustment Projects. This paper deals with (1) construction of disaster recovery public housings.

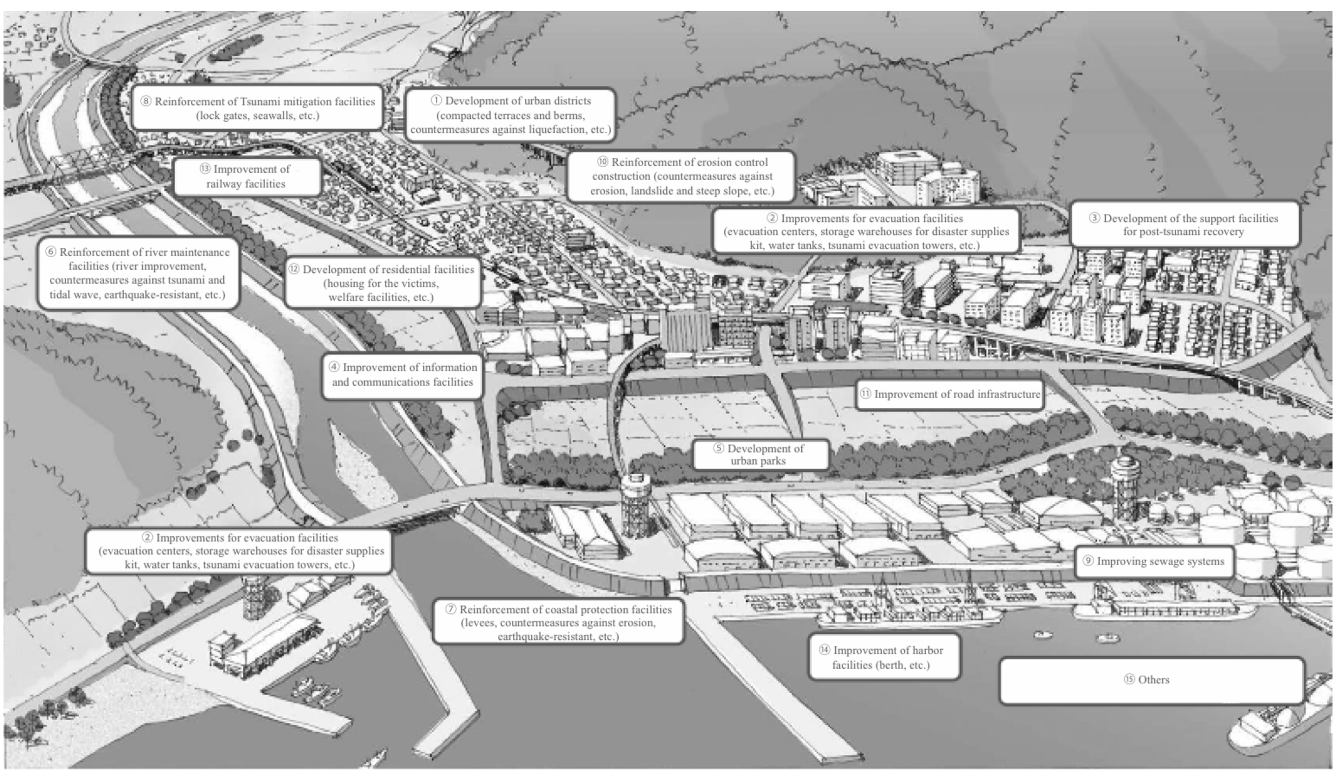

Fig. 1 –A glance at recovery projects conducted after the 2011 Great East Japan Earthquake and Tsunami [2]

1.3 Importance of quantitative evaluation for post-disaster recovery processes

We have to learn good practices and problems on urban recovery from the past great disasters. To this end, we have to monitor long-term recovery processes, such as how to provide living environment to the affected people. Comparative study of the post-disaster recovery processes is one way to understand similarities and differences on recovery policy and planning among past disasters. However, it is not easy to evaluate the recovery activities because they are comprehensive phenomenon and imply various aspects with historical, economical, religious, and social context. In order to make a comparative study of post-disaster recovery processes, a quantitative evaluation method that quantifies a lively post-disaster recovery process as a simple model is indispensable.

The trial to explain a post-disaster recovery process with a “model of recovery activity” launched in the 1970s. Haas et al. [3] classifies the post-disaster recovery process into four stages: (1) emergency response, (2) restoration of the restorable, (3) reconstruction of the destroyed for functional replacement, and (4) reconstruction for commemoration, betterment and development. Then he made a recovery model based on the dataset of the1906 San Francisco Earthquake. Vale regards the case study of the San Francisco Earthquake as the best comparative study in his book *The Resilient City* [4], but he suggests that “it is not enough to pose general models for urban recovery,” and “we can only conceptualize the pattern of recovery if we delve into what drives the variation.”

Now that we have accumulated a huge amount of disaster and recovery records since twentieth century, we can extract good practices and future problems by making post-disaster models of the past experiences with profound understanding of the context behind the models.

In this context, our research group proposed a method to construct recovery curves to demonstrate recovery processes of a disaster based on building reconstruction data. Among various parameters to evaluate recovery processes such as population or economic conditions, building reconstruction datasets are used to construct recovery curves because the housing reconstruction is recognized as the most crucial element for the affected people. The first case we constructed recovery curves was for the recovery process of Chi-Chi Township, seriously damaged by the 1999 Chi-Chi Earthquake in Taiwan [5]. The second case was for Sri Lanka affected by the 2004 Indian Ocean Tsunami, in which Murao and Nakazato [6] developed recovery curves for temporary (transitional) and permanent housings for 11 districts in the country and compared. By this study, it was found that the Compertz distribution is the best fit for temporary housing construction conditions, while the cumulative normal distribution most closely matches the distribution of constructed permanent housings. Following Sri Lankan case, recovery curves for Thailand (Murao et al. [7]) and for Aceh, Indonesia (Sugiyasu and Murao [8]), were constructed. Based on these studies, the recovery processes of the three countries damaged by the 2004 Indian Ocean Tsunami were quantitatively compared by Murao [9].

As for the recovery from the 2011 Great East Japan Earthquake and Tsunami, Murao [10] developed recovery curves based on temporary housing construction data and clarified regional differences between Iwate, Miyagi, and Fukushima Prefecture, as shown in Fig. 2 and Fig. 3. This paper focuses on recovery conditions based on the disaster recovery public housing construction data.

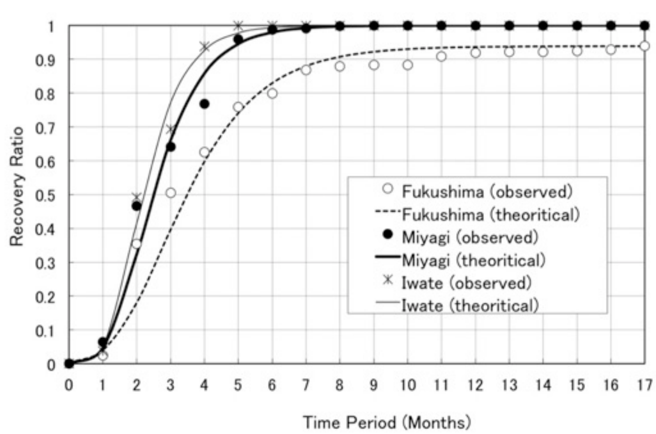

Fig. 2 – Recovery curves for temporary housing in Iwate, Miyagi, and Fukushima Prefecture [10]

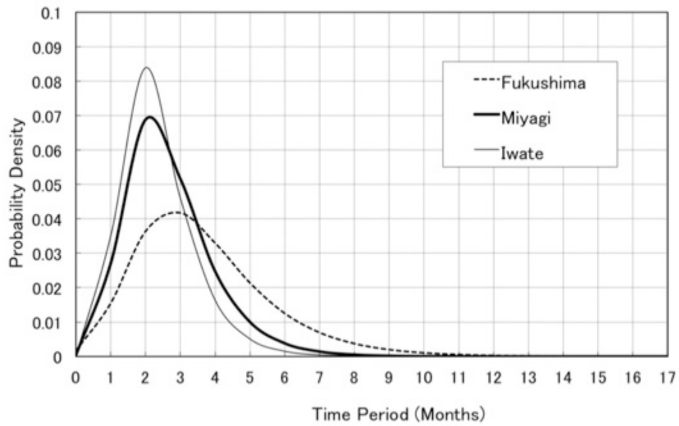

Fig. 3 – Probability density functions for temporary housing in Iwate, Miyagi, and Fukushima Prefecture [10]

2. Method

In order to construct recovery curves after the 2011 Great East Japan Earthquake and Tsunami, the following procedure was taken.

2.1 Data collection

The Reconstruction Agency, the principal agency of the Government of Japan, tasks with leading and managing the reconstruction process following the 2011 Great East Japan Earthquake. The agency periodically provides the road map for housing reconstruction [11]. The disaster recovery public housing construction dataset is collected and used to develop the recovery curves in this research.

2.2 Data arrangement

The dataset is categorized according to construction site and construction period, specifying either construction is completed or in progress.

2.3 Understanding the change in the number of scheduled necessary houses

Each prefecture often estimated and determined the number of necessary houses for construction depending on victims' inconstant demands or environmental changes of construction sites. The change in the number of scheduled necessary houses for each prefecture is illustrated by the dataset, and differences between three prefectures are clarified. Then the denominators to calculate the recovery ratio for the prefectures are determined.

2.4 Understanding of construction conditions

Chronological construction conditions in the recovery processes are clarified, from the viewpoints of construction in progress (commenced) or completed, based on the dataset.

2.5 Development of the recovery curves

For the period until the completion estimated by each prefecture, the cumulative ratio of actual building construction is assumed to be fitted for the cumulative normal distribution curve according to the previous research for Sri Lanka conducted by Murao and Nakazato [6]. Then recovery curves for construction in progress and for completed are developed.

2.6 Comparison of the recovery curves

Finally, these recovery curves for Iwate, Miyagi, and Fukushima Prefecture, are quantitatively compared to clarify the regional characteristics.

3. Data Used

3.1 Disaster recovery public housings

The 2011 Great East Japan Earthquake and Tsunami gave us a number of difficulties for housing reconstruction, such as the following nine challenges listed by Otake [12]: (1) Ensuring safety, (2) High volume supply, (3) Convenient living, (4) Consideration for the elderly, (5) Harmony with the environment, (6) Maintaining the history and culture of the region, (7) Guaranteeing employment, (8) Procuring funds, and (9) Shortness of time.

The disaster recovery public housing construction, which supports affected people who do not have enough money to reconstruct or purchase houses, is one of the important strategies for housing reconstruction to overcome the challenges. This study deals with a dataset of the disaster recovery public housings constructed by Iwate, Miyagi, and Fukushima Prefecture.

3.2 The road map for housing reconstruction

The information of disaster recovery public housings had been released as "the road map for housing reconstruction" since December 2012 on the website of the Reconstruction Agency [11]. The latest information as of April 2016 is of September 2015, and the construction data from December 2012 and September 2015 is used in this study.

The inventory includes the number of scheduled necessary houses, the number of houses under construction, and the number of completed houses for each construction site in all municipalities in which disaster recovery public housings are provided in Iwate, Miyagi, and Fukushima Prefectures. Fig. 4 shows houses recently completed in Ishinomaki City (left) and Onagawa Town (right) in Miyagi Prefecture.

Fig. 4 – Disaster recovery public housings completed in Ishinomaki City (left) and Onagawa Town (right) in Miyagi Prefecture

4. Transition of Disaster Recovery Public Housing Construction

4.1 Transition of the number of scheduled necessary houses

According to the data used, the number of scheduled necessary houses in the three prefectures had been changed respectively since the first announcement of December 2012 as shown in Fig. 5.

The number of scheduled necessary houses in Iwate was increased from 5,154 in December 2012 to 6,097 in June 2013 and was slightly decreased to 5,771 in September 2015. However, the change ratio is very small compared with the ones of Miyagi and Fukushima.

In Miyagi Prefecture, the number of scheduled necessary houses was rapidly increased for six months from 11,038 in December 2012 to 15,442 in June 2013. Then, it gradually increased to approximately 16,000 houses in September 2015.

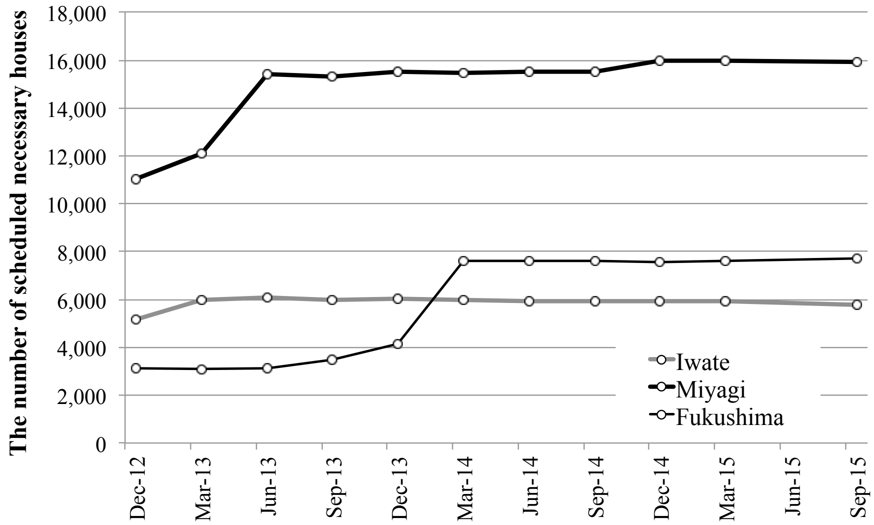

Fig. 5 – Transition of the number of scheduled necessary houses in Iwate, Miyagi, and Fukushima

In Fukushima, 3,132 houses, less than in Iwate, were estimated as of December 2012, but it becomes 7,609, an increase of 70%, by March 2014. The increasing tendency in Fukushima is seen nine months after the Miyagi Prefecture's case, which was influenced by the release of restricted areas around Fukushima Daiichi Nuclear Power Plant in 2013.

4.2 The completed ratio of disaster recovery public housings as of September 2015

Table 1 shows the construction conditions of the disaster recovery public housings in the prefectures affected by the 2011 Great East Japan Earthquake and Tsunami as of September 2015. It contains the number of completed houses, scheduled houses, and the construction-completed ratio. Hereafter, the number of scheduled houses in Table 1 is used as the denominator for the recovery ratio in Iwate, Miyagi, and Fukushima Prefecture.

Table 1 – Construction conditions of the disaster recovery public housings in the prefectures affected by the 2011 Great East Japan Earthquake and Tsunami as of September 2015 [11]

Prefecture	Iwate	Miyagi	Fukushima	Aomori	Ibaraki	Chiba	Nagano	Niigata	Total
Completed	2,216	7,422	2,855	67	240	49	28	6	12,883
Scheduled	5,771	15,924	7,701	67	274	49	28	6	29,820
Completed ratio	38.4%	46.6%	37.1%	100%	87.6%	100%	100%	100%	43.2%

Although 34 houses were in progress in Ibaraki Prefecture, the construction in the four prefectures moderately damaged, Aomori, Chiba, Nagano, and Niigata, had been already completed. On the other hand, the completed ratio of the severely damaged three prefectures, Iwate, Miyagi, and Fukushima Prefecture, was less than half: 38.4%, 46.6%, and 37.1%, respectively. It implies difficulties in recovery in these severely affected areas.

4.3 Disaster Recovery Public Housing Construction Processes

The dataset used in this study contains the number of houses under construction and the number of completed houses. Fig. 6 and Fig. 7 demonstrate the transition of disaster recovery public housing construction in progress and completed in Iwate, Miyagi, and Fukushima Prefecture. The unit of time axis in the figures represents quarters of the Japanese fiscal year. The values after September 2015 are based on the data expected by the governments.

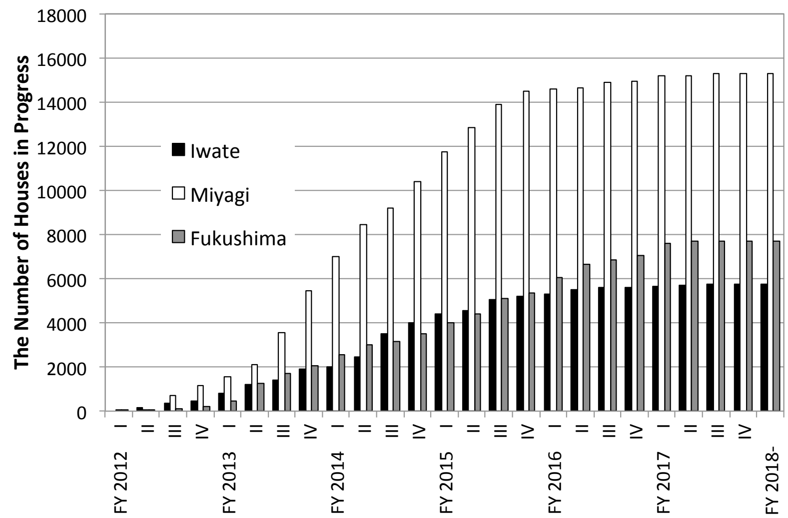

Fig. 6 – Transition of disaster recovery public housing construction in progress in Iwate, Miyagi, and Fukushima

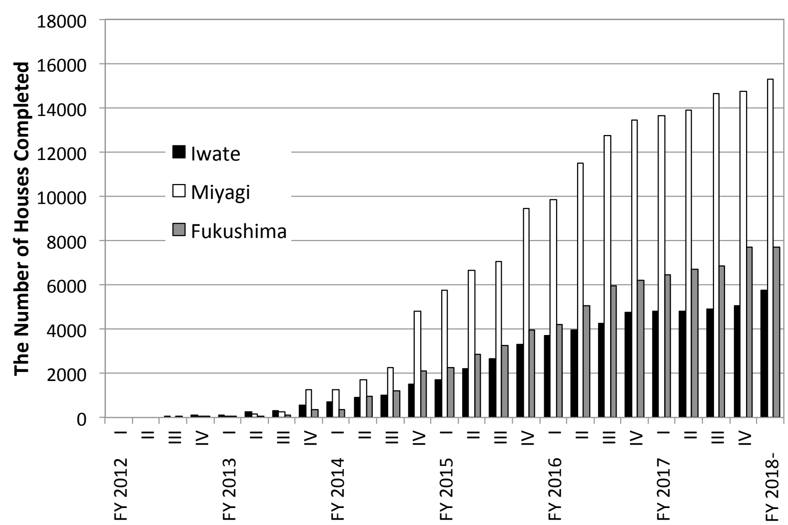

Fig. 7 – Transition of disaster recovery public housing construction completed in Iwate, Miyagi, and Fukushima

5. Development of the Recovery Curves

As mentioned in 1.3, the cumulative normal distribution most closely matched the distribution of constructed permanent housings in the previous research [6]. Therefore, the cumulative normal distribution is adopted to construct recovery curves based on the data of disaster recovery public housing construction in this study. According to the dataset, two types of recovery curves, for commenced construction and for completed construction, are constructed in this chapter.

Time (months) and the completion ratio of housing construction are important factors to make recovery curves. The time period starts in March 2011, with April being regarded as month "1," and extends over 100 months until July 2019. The completion ratio of housing construction for a given time period is calculated based on the total amount of scheduled houses as shown in Table 1. For a time period of t (months), the cumulative construction ratio of disaster recovery public housings R (t) can be described by the cumulative normal distribution, using equation (1):

$$R\,(t) = \Phi\;((t - \lambda) / \zeta) \tag{1}$$

where Φ represents the standard normal distribution, and λ and ζ are the mean and standard deviation of t, respectively. The two parameters λ and ζ are determined using the least squares method on log-normal probability paper as exemplified in Fig. 8.

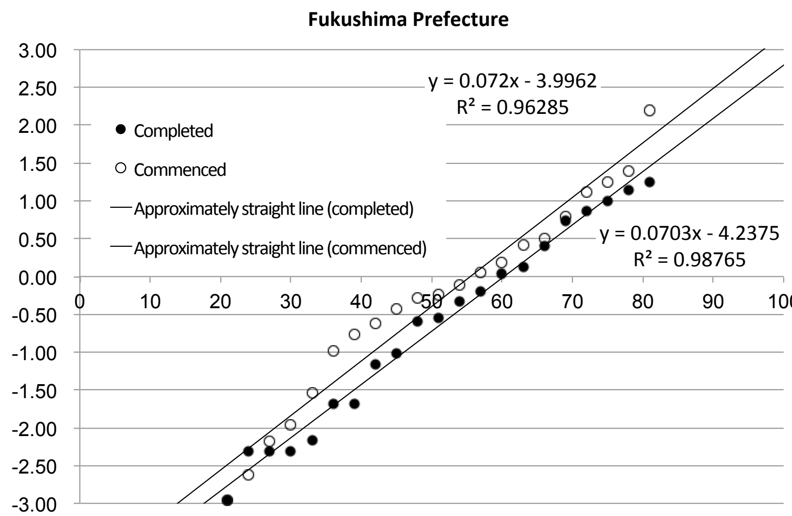

Fig. 8 – Relationship between a time period and the cumulative construction ratio of disaster recovery public housings in Fukushima Prefecture plotted on log-normal probability paper

The parameters and recovery curves obtained by the procedure above are shown in Table 2, Fig. 9, and Fig. 10. The recovery ratio calculated by actual data is plotted on the figures.

The coefficient of determination, which indicates level of relationship between the actual data and the obtained model, is more than 0.96 for all cases. This fact shows high adaptability of the cumulative normal distribution model to quantify the recovery processes represented by the disaster recovery public housing construction as well as the previous researches [5] [6] [7] [8].

Table 2 – Recovery curve parameters for Iwate, Miyagi, and Fukushima Prefectures

	Parameters	**Iwate**	**Miyagi**	**Fukushima**
Commenced	Mean (λ)	48.88	49.74	55.50
	Standard deviation (ζ)	14.35	11.68	13.89
	Coefficient of determination (R^2)	0.99	0.96	0.96
Completed	Mean (λ)	59.63	57.84	60.28
	Standard deviation (ζ)	17.15	13.02	14.22
	Coefficient of determination (R^2)	0.99	0.99	0.99

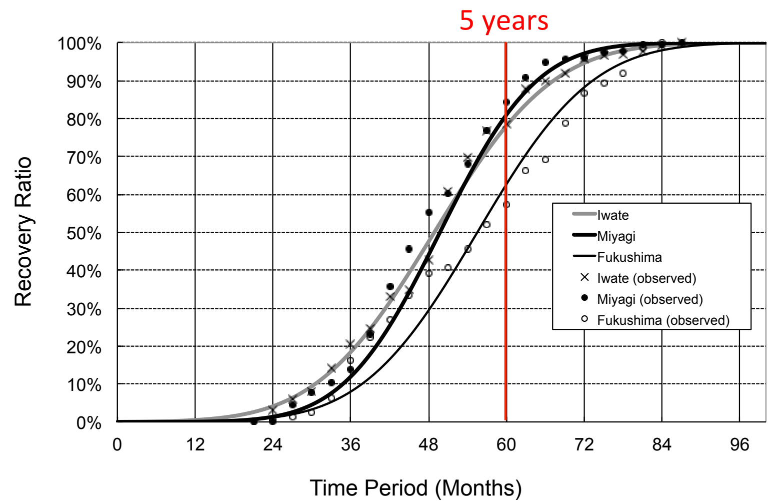

Fig. 9 – Recovery curves based on disaster recovery public housing construction commenced

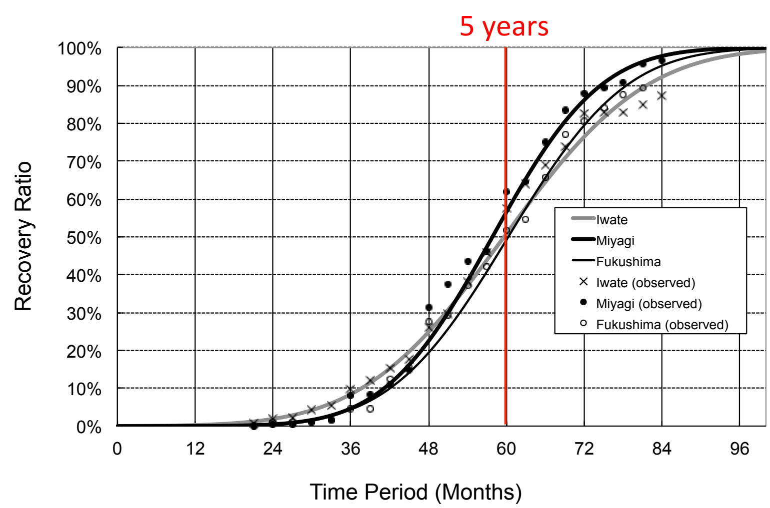

Fig. 10 – Recovery curves based on disaster recovery public housing construction completed

The shortest time period that the construction commencement ratio reached 50% was 48.88 months for Iwate; the longest was 55.50 months for Fukushima. The time difference between them was 6.63 months. On the other hand, with regard to the time period that the construction completed ratio becomes 50%, the shortest was of Miyagi with 57.84 months, followed by Iwate with 59.63 months and Fukushima with 60.28 months. The time difference between Miyagi and Fukushima is 2.44 months. As shown in Fig. 9 and Fig. 10, the time difference for construction completion between the shortest and the longest became shortened compared with construction commencement.

Now that five years have passed since the occurrence of the event, a large number of recovery activities are being conducted in the areas affected by the disaster. However, the recovery ratio of the three prefectures is between 50% and 60%. It seems that the post-disaster recovery, as a whole, of the 2011 Great East Japan Earthquake and Tsunami takes more time than other recovery cases such as the 1999 Taiwan Earthquake or the 2004 Indian Ocean Tsunami.

6. Conclusion

This paper aims to quantify the recovery processes of the 2011 Great East Japan Earthquake and Tsunami, and recovery curves are constructed based on disaster recovery public housing construction datasets. Firstly, it explains the background of housing reconstruction strategies conducted in the recovery phase and the importance of quantification of recovery processes. Secondly, the research method to construct recovery curves is described, followed by the data information used in this study. Thirdly, the recovery processes in Iwate, Miyagi, and Fukushima Prefecture and recovery curves are demonstrated in terms of disaster recovery public housing construction conditions using the cumulative normal distribution. Finally the processes and recovery curves are compared to understand regional different situations.

As a result, the recovery curves, which quantitatively demonstrate the commencement and the completion conditions of the disaster recovery public housing construction for Iwate, Miyagi, and Fukushima Prefecture, are obtained, as well as the three significant recovery curve parameters: Mean (λ), Standard deviation (ζ), and Coefficient of determination (R^2). Then the following findings were clarified.

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