Regional Difference on Road Recovery in Iwate Prefecture Following the 2011 Tohoku Earthquake

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***Abstract*—In a previous study, we have calculated the usable road distance in the southern coastal area of Iwate Prefecture following the 2011 Tohoku Earthquake. In this context, a usable road is one on which at least one vehicle has been probed during the observation period. If the accumulative usable distance up to September 30, 2011 is considered as 100%, then the percentage of the usable road distance determined by April 7, 2011 is 80% and 90% by April 29, 2011, respectively. In the current study, we have calculated the regional difference of the road recovery in Iwate Prefecture following the 2011 Tohoku Earthquake. Hence, we have divided Iwate Prefecture into four areas, in particular, the Northern Inland, Southern Inland, Northern Coastal, and Southern Coastal areas, respectively. The main results of our study are as follows. First, we have determined that, for the both Northern and Southern Inland areas, 80% of the road distance has been usable by April 15, 2011 and 90% by May 27, 2011, which indicates that the recovery speed in both the Northern and Southern Inland areas have been slightly slower than that in the Southern Coastal area. Second, we have found that, for the Northern Coastal area, 80% of the road distance has been usable by April 29, 2011 and 90% by June 24, 2011, which implies that the recovery speed in the Northern Coastal area has been extremely slower than that in the Southern Coastal area. Hence, we have concluded that these findings are sustained by the fact that the road recovery efforts have been focused more on the regions heavily affected by the earthquake and consequently by the tsunami.**

***Index Terms*—2011 Tohoku Earthquake; G-BOOK telematics data; vehicle-tracking map; Iwate Prefecture; big data analysis**

I. Introduction

A. The 2011 Tohoku Earthquake

The 2011 Tohoku Earthquake [Fig.1] struck the northeastern coast of Japan on March 11, 2011. Subsequently, the region was severely affected by the tsunami. Following these natural disasters, the electricity, water, and gas supplies were shut down in both coastal and inland areas. Furthermore, the road travel was disrupted in many parts of the region.

B. The purpose of the study

The purpose of our study was to evaluate the regional difference on the road recovery in Iwate Prefecture following the 2011 Tohoku Earthquake.

Therefore, we have divided Iwate Prefecture into four areas according to their geographic positions and features: the Northern Inland, Southern Inland, Northern Coastal, and Southern Coastal areas, respectively.

During the disaster, these four areas were affected differently. The strength of the earthquake in the southern areas was much stronger than that in the northern regions. Furthermore, the tsunami had struck the Southern Coastal area more heavily than the Northern Coastal area.

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Therefore, we assume that there were specific differences between the four studied regions during the road recovery process following the disaster.

II. Our previous studies

A. Previous study 1

Our previous study 1 [1] was focused on the use of the main roads in the Southern Coastal area of Iwate Prefecture [Fig.2]. The usable distances of the main roads following the 2011 Tohoku Earthquake have been calculated from the G-BOOK telematics data [3].

The main findings of this study are as follows:

1) The usable distance of the roads in a weekly period has continuously increased from March 18 to April 7, 2011, but it has fluctuated thereafter.

2) Defining the accumulative usable distance up to September 30, 2011 as 100%, it has been determined that 80% of the road distance has been usable by April 7, 2011 and 90% by April 29, 2011.

3) The use of the main road in the coastal area of Iwate Prefecture has been completely recovered by April 29, 2011.

B. Previous study 2

Our previous study 2 [2] was focused on the use of the main roads not only in the Southern but also in the Northern Coastal area of Iwate Prefecture.

The accumulative usable road distance ratio of the main roads has been precisely calculated for each city using the free and open source geographical information system software QGIS. The main findings in this study [2] are listed below.

(1) The change in the accumulative usable road distance ratio during the research period differed from one city to the next.

(2) The ratio increases in the usable distances of Kuji, Iwaizumi, and Noda were extremely delayed. In our study, we were able to determine related roads by analyzing the maps generated by the QGIS software. For Kuji and Iwaizumi, the delays were mostly dependent on the Iwate Prefectural Road number 7 (the Kuji-Iwaizumi line). For Noda, the delay was mostly dependent on the Iwate Prefectural Road number 273 (the Akka-Tamagawa line).

(3) In our previous study 1 [1], we determined that the use of the main road in the Southern Coastal area of Iwate Prefecture was completely recovered by April 29, 2011.

However, in this study, when we have precisely observed the change in the usable road distance ratio during the research period for each city, the ratio increase in the usable road distance of Kamaishi has been delayed compared with other Southern Coastal cities.

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For Kamaishi City, the delay was mostly dependent on the Iwate Prefectural Road number 249 (the Sakuratoge-Heita line).

III. Telematics Data and Vehicle-Tracking Map

Telematics is a general term encompassing telecommunications and informatics. A telematics service provides various personalized information for users, especially for drivers of automobiles. G-BOOK is a telematics service provided by Toyota Motor Corporation.

To calculate the usable distance of the main roads, we applied the vehicle tracking map originally created by Hada et al. [4] after the 2007 Niigataken Chuetsu-oki earthquake.

That vehicle tracking map was based on telematics data provided by Honda Motor Company. Similarly, in our study, we used the vehicle tracking map based on telematics data provided by Toyota's G-BOOK system [Figs. 3 and 4].

Registered members of G-BOOK can access telematics services to acquire GPS data for car navigation systems and interactive driving data, such as traffic jam points, road closures, and weather reports.

Such comprehensive data acquisition is possible because the telematics system server receives accurate location data (geographic coordinates) from its registered members.

Telematics services are extremely useful to drivers. Because the accurate driving routes of registered users remain in the system server, they are accessible to traffic researchers in various fields.

IV. Research Methods

The current study used the research methods of our previous study 2 [2]; only the research area was different.

A. Research area

Our previous study 1 [1] was focused only on the Southern Coastal area of Iwate Prefecture [Fig.4], and our previous study 2 [2] was focused on the entire coastal area of Iwate Prefecture (i.e., both Southern and Northern Coastal areas)[Fig.4].

The current study was focused on the entire area of Iwate Prefecture (i.e., Southern and Northern Coastal areas as well as Southern and Northern Inland areas) [Fig.4].

B. Research materials

In our current study, we have used the vehicle tracking maps built from the G-BOOK telematics data that is available on the Internet on March 18, 2011 following the 2011 Tohoku Earthquake [3].

The data used in this study have been collected between March 18 and September 30, 2011 (i.e., approximately six months following the 2011 Tohoku Earthquake).

C. System

Hardware:

The computations have been performed on a standard PC laptop with a Core i5-4200U CPU (1.6 GHz) and 4 GB memory (SONY VAIO PRO 11).

Software:

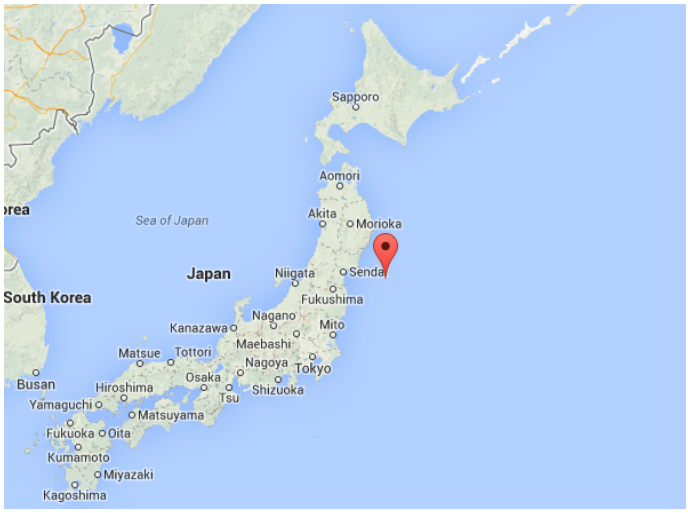

Fig. 1. The center of the 2011 Tohoku Earthquake on March 11, 2011 (https://www.google.co.jp/maps/).

Fig. 2. Main roads in the Southern Coastal area of Iwate Prefecture.

The software QGIS version 2.6.1 (the latest version available) [6] and LibreOffice Calc 4.2.7 spreadsheet software (the most stable version available) [7] running on the Windows 7 Professional operating system have been used in this study. It is well-known that QGIS is one of the most popular geographic information systems used worldwide.

Prior to the abovementioned applications for geographical data processing, we have used the ogr2ogr software [8] on the Linux operating system along with Vine Linux 4.2 [9], which is a Linux distribution developed by a Japanese Linux community.

Note that QGIS, LibreOffice Calc, ogr2ogr, and Vine Linux are open source softwares freely available on the Internet.

D. Data Processing

1) The vehicle tracking maps constructed from the G-BOOK telematics data have been provided in the Google map KMZ format. For our analysis, we have first converted the KMZ files to SHP files (i.e., shape-files), which are compatible with ArcGIS using the ogr2ogr software.

2) Next, the data coordinates have been converted from the terrestrial latitude and longitude to the x and y coordinates in a rectangular coordinate system.

3) To reduce the computation time, the data file has been clipped to small files containing only the research area.

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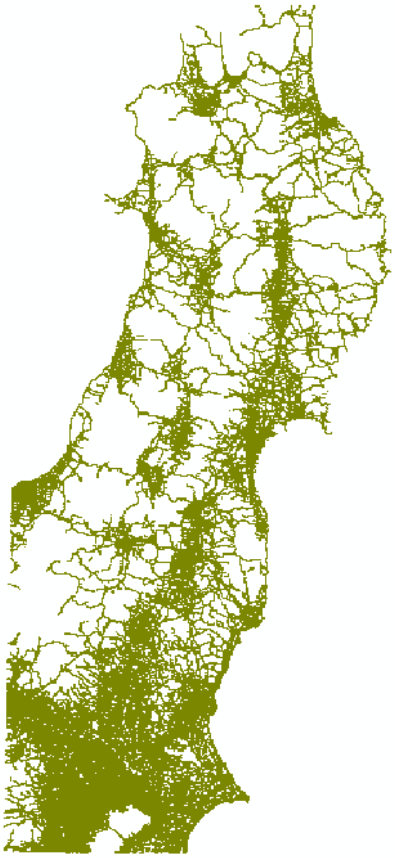

Fig. 3. The vehicle-tracking map of eastern Japan.

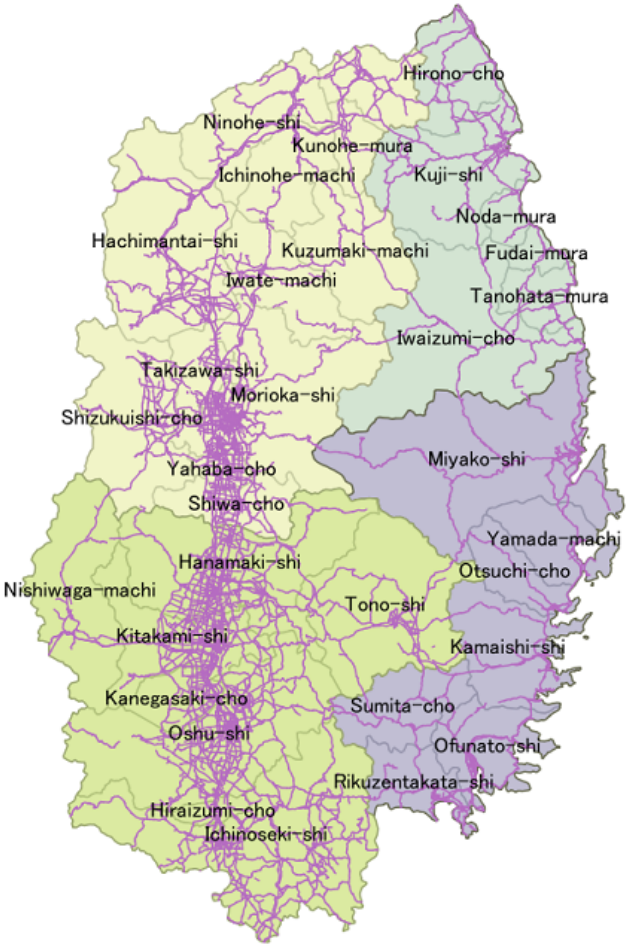

Fig. 4. The vehicle-tracking map of Iwate Prefecture is shown by the violet lines. The perimeter of a city is shown by a gray polygon. Iwate Prefecture has been divided into four areas: the Northern Costal, Southern Coastal, Northern Inland, and Southern Inland areas.

4) After merging daily data into weekly data and removing duplicate data, we have been able to calculate the exact usable road distance available for a given week.

In this context, a usable road is one on which at least one vehicle has been probed during the observation period.

The purpose of converting the daily data to weekly data was to smooth the daily fluctuations in the traffic flows.

5) Next, we have calculated the proportion of the accumulative distance up to the specified date. Note that the accumulative distance up to September 30, 2011 was considered 100%.

V. Results

A. Regional difference of road recovery

Defining the accumulative usable distance up to September 30, 2011 as 100%, the percentages of the usable road distances have the values given in Table. I. In this table [Table.I], the upper lines indicate the accumulative usable road distances (in meters) and the lower lines represent the accumulative usable road distance ratios.

1) The Northern Inland area

It was determined that 80% of the road distance has been usable by April 15, 2011 and 90% by May 27, 2011.

2) The Southern Inland area

It was determined that 80% of the road distance has been usable by April 15, 2011 and 90% by May 27, 2011.

The recovery speed in both the Northern and Southern Inland areas have been slightly slower than that in the Southern Coastal area.

3) The Northern Coastal area

It was determined that 80% of the road distance has been usable by April 29, 2011 and 90% by June 24, 2011.

The recovery speed in the Northern Coastal area has been extremely slower compared with that in the Southern Coastal area.

4) The Southern Coastal area

As we have already described in our previous study 1 [1], 80% of the road distance has been usable by April 7, 2011 and 90% by April 29, 2011.

B. Cities whose road recovery was extremely delayed

1) The Northern Inland area [Fig.6]

The ratio increases in the usable distance of Iwate Town, Kunohe, and Ichinohe have been extremely delayed.

We were able to determine related roads by analyzing the maps generated by the QGIS software.

For Iwate Town, the delay has been mostly dependent on the Iwate Prefectural Road number 158 (the Yabukawa-Kawaguchi line).

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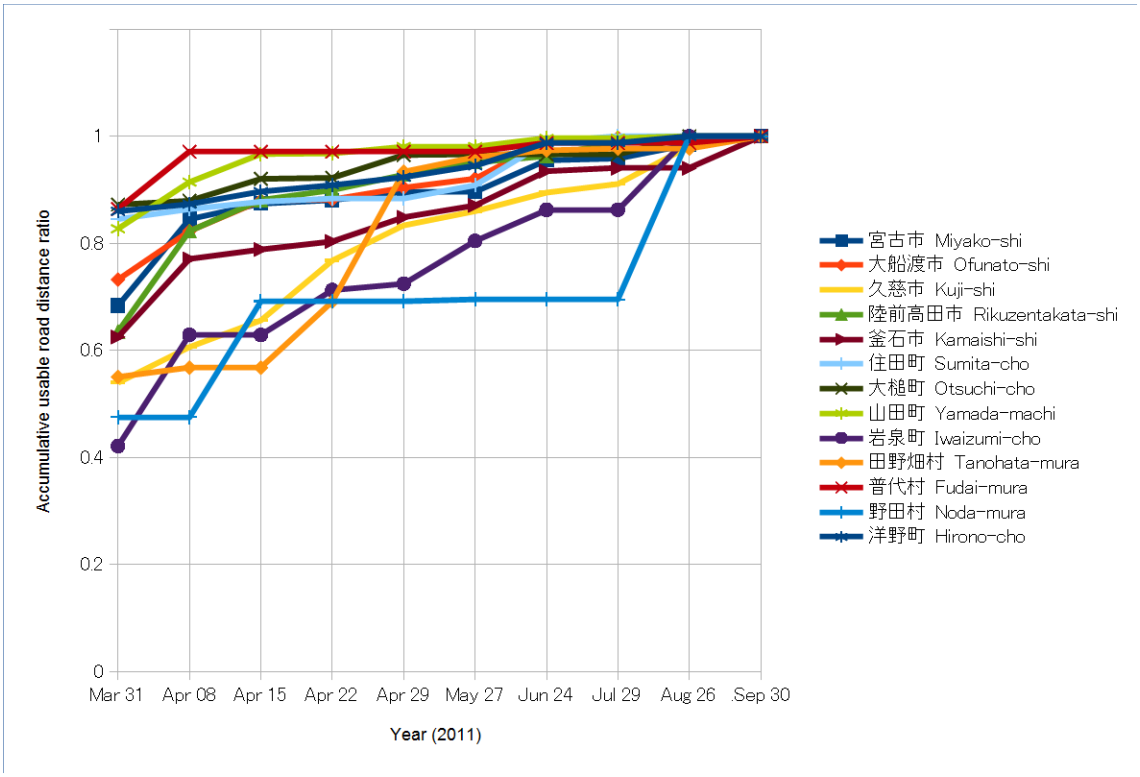

Fig. 5. The accumulative usable road distance ratio for the coastal area [2]. The vertical scale displays the accumulative distance proportion of the usable roads (the relative to accumulative distance on September 30, 2011) for each date.

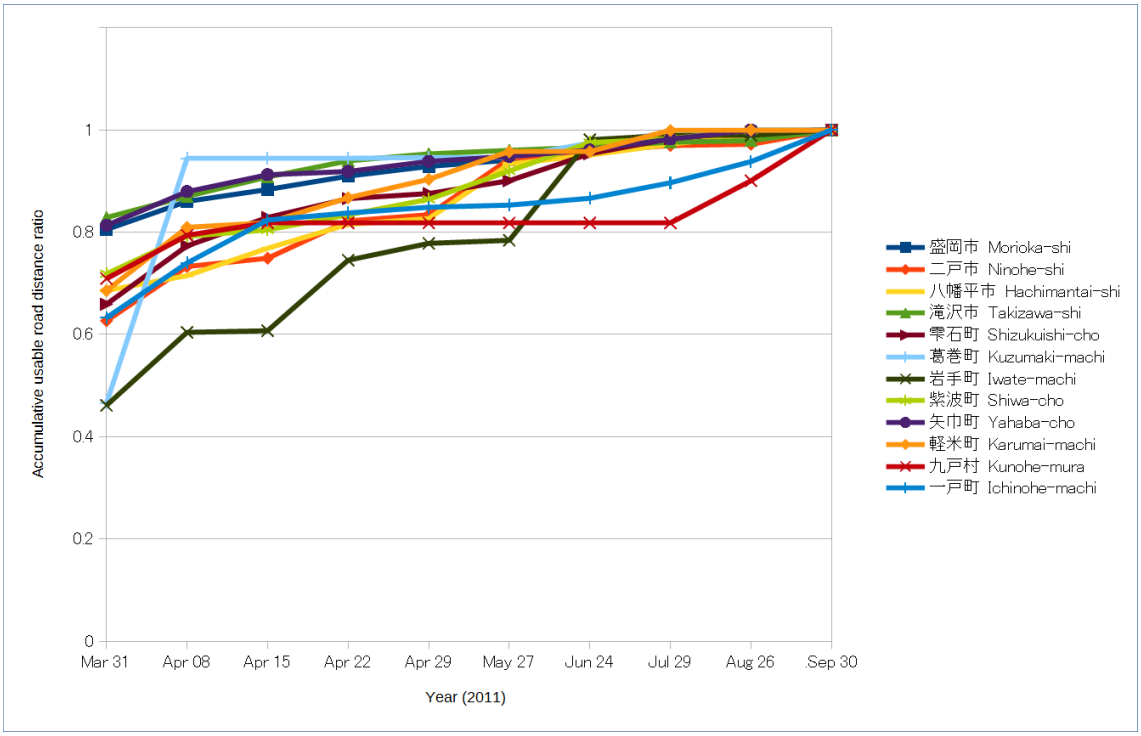

Fig. 6. The accumulative usable road distance ratio for the Northern Inland area. The vertical scale displays the accumulative distance proportion of the usable roads (the relative to accumulative distance on September 30, 2011) for each date.

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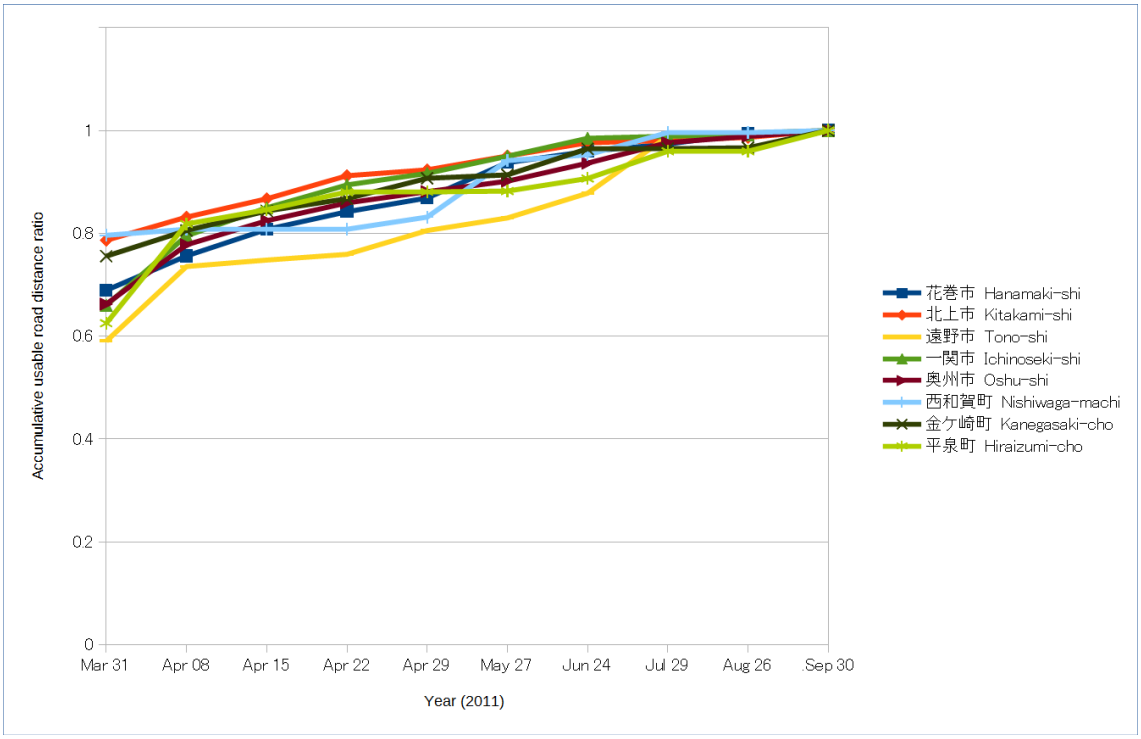

Fig. 7. The accumulative usable road distance ratio for the Southern Inland area. The vertical scale displays the accumulative distance proportion of the usable roads (the relative to accumulative distance on September 30, 2011) for each date.

TABLE I
REGIONAL DIFFERENCE ON ROAD RECOVERY (ACCUMULATIVE USABLE ROAD DISTANCES (IN METERS) AND RATIOS).

	Mar 31	Apr 08	Apr 15	Apr 22	Apr 29	May 27	Jun 24	Jul 29	Aug 26	Sep 30
Northern	1850873.51	2070475.04	2152283.40	2251706.55	2296780.33	2403134.24	2483876.38	2532471.47	2571798.73	2603629.91
inland	0.711	0.795	*0.827*	0.865	0.882	*0.923*	0.954	0.973	0.988	1.000
Southern	2386739.37	2722218.13	2870724.95	2991566.34	3074037.86	3201569.09	3310978.41	3396994.03	3429255.89	3465835.57
inland	0.689	0.785	*0.828*	0.863	0.887	*0.924*	0.955	0.980	0.989	1.000
Northern	394082.91	449373.30	471389.15	524694.94	564884.21	589275.55	614317.97	618734.27	668603.07	675390.65
coastal	0.583	0.665	0.698	0.777	*0.836*	0.872	*0.910*	0.916	0.990	1.000
Southern	666655.53	779216.76	814157.35	821573.46	843427.24	855066.71	903310.83	910464.22	920120.72	934580.47
coastal	0.713	*0.834*	0.871	0.879	*0.902*	0.915	0.967	0.974	0.985	1.000

For Kunohe, the delay has been mostly dependent on the Iwate Prefectural Road number 5 (the Ichinohe-Yamagata line).

For Ichinohe, the delay has been mostly dependent on the road forward to the Okunakayama Ski Field.

2) The Southern Inland area [Fig.7]

The ratio increases in the usable distance of Iwate Town, Kunohe, and Ichinohe have been extremely delayed.

We were able to determine related roads by analyzing the maps generated by the QGIS software.

For Tono, the delay has been mostly dependent on Iwate Prefectural Road number 160 (Tsuchibuchi-Tatsusobe line).

For Hiraizumi (the town of National Heritage), the delay has been mostly dependent on the roads forward to the Motsuji Temple, Hiraizumi Kominkan, and Satoyama.

3) The Northern Coastal area

According to our previous study [2], the ratio increases in the usable distance of Kuji, Iwaizumi, and Noda have been extremely delayed compared with other northern coastal cities.

4) The Southern Coastal area

As it has been shown in [2] that the ratio increase in the usable distance of Kamaishi has been extremely delayed compared with other Southern Coastal cities.

VI. DISCUSSION

In our previous study 2 [2] and the current study, we have used free and open source software programs that were extremely efficient in analyzing the collected data.

In the current study, we have evaluated the regional difference on the road recovery in Iwate Prefecture following the 2011 Tohoku Earthquake. Iwate Prefecture has been divided into four areas, in particular, the Northern Inland, Southern Inland, Northern Coastal, and Southern Coastal areas, respectively.

According to results of our study, we have concluded that the recovery conditions of the regional roads following the 2011 Tohoku Earthquake differed on the basis of area.

For the Southern Coastal area, as we have shown in the previous study 1 [1], it was determined that 80% of the road distance has been usable by April 7, 2011 and 90% by April 29, 2011.

According to our findings, for both the Northern and Southern Inland areas, 80% of the road distance has been usable by April 15, 2011 and 90% by May 27, 2011, i.e., the recovery speed in both the Northern and Southern

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Inland areas was slightly slower compared with the Southern Coastal area.

For the Northern Coastal area, 80% of the road distance has been usable by April 29, 2011 and 90% by June 24, 2011, which means that the recovery speed in the Northern Coastal area was extremely slower than that in the Southern Coastal area.

We consider that our findings are supported by the reasonable fact that the road recovery efforts have been focused more on the regions that are heavily affected by the earthquake and subsequently by the tsunami, in particular, the Southern Coastal area. In fact, the road recovery process had to be intensified in the Southern Coastal area to accelerate the rescue operations, provide temporary housing for citizens, and rebuild the infrastructure of the region.

ACKNOWLEDGMENTS

We would like to thank all the people worldwide who assisted the people of Japan following the 2011 Tohoku Earthquake.

In addition, we would like to thank the people who created and maintained the useful software and telematics archives used in this study.

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