Regional and Altitudinal Differences on Road Usage Recovery in Aomori Prefecture Following the 2011 Tohoku Earthquake

Shouyi Gao, Noriaki Endo, *Member, IAENG,* and Mitsugu Saito

***Abstract*—We evaluate regional and altitudinal differences in road recovery in Aomori Prefecture following the 2011 Tohoku Earthquake. We divided Aomori Prefecture into six regions, i.e., Shimokita, Kamikita, Sannpachi, Tosei, Chunan, and Seihoku regions. Next, we divided Aomori Prefecture into two areas, namely Low Altitude Area and High Altitude Area. In this context, altitude means the height above sea level. Low Altitude Area is under 50 meters above sea level. And, High Altitude Area is over 50 meters above sea level. The cumulative usable road distance ratio of the main roads both for the Low Altitude Area and for the High Altitude Area had been precisely calculated for each city from telematics data using the open source geographical information software. Defining the cumulative usable distance up to September 30, 2011 as 100%, the percentages of usable road distances were calculated. According to the results of our study, we conclude that the recovery conditions of regional roads in different altitude areas of Aomori Prefecture following the 2011 Tohoku Earthquake differed. Furthermore, we also conclude that the land shape of the regions is closely related to road usage recovery.**

***Index Terms*—2011 Tohoku Earthquake; Aomori Prefecture; regional and altitudinal differences; road usage recovery; telematics data; vehicle-tracking map**

I. Introduction

A. The 2011 Tohoku Earthquake

The 2011 Tohoku Earthquake struck the northeastern coast of Japan on March 11, 2011 [1]. The epicenter of the earthquake [Fig. 1] was located about 80 miles (130 km) east of Sendai City, Miyagi Prefecture, and the focus occurred 18.6 miles (about 30 km) below the floor of the western Pacific Ocean. The subsequent tsunami severely affected the region. Following these natural disasters, electricity, water, and gas supplies were shut down in both coastal and inland areas. Road travel was also disrupted in many parts of the region [2]–[16].

B. Purpose

The purpose of our study was to evaluate the regional and the altitudinal differences in road recovery in Aomori Prefecture following the 2011 Tohoku Earthquake.

Manuscript received September 3, 2024; revised September 27, 2024.

Shouyi Gao is a PhD candidate of the Design and Media Technology, Graduate School of Engineering, Iwate University, Morioka, Iwate, Japan (Email: gaoshouyi888@yahoo.co.jp).

N. Endo is a Professor in the Faculty of Sport Science, Department of Sport Intelligence and Mass Media, Sendai University, Shibata, Miyagi, Japan (formerly a professor in the Department of Regional Innovation and Management, Graduate School of Arts and Sciences, Iwate University; corresponding author, Email: endo@iwate-u.ac.jp).

M. Saito is a Professor in the Department of Design and Media Technology, Graduate School of Engineering, Iwate University, Morioka, Iwate, Japan (Email: mitsugu@iwate-u.ac.jp).

Therefore, based on geographic position and features, we divided Aomori Prefecture into six regions, i.e., Shimokita, Kamikita, Sanpachi, Tosei, Chunan, and Seihoku regions. Next, we divided Aomori Prefecture into two areas, namely Low Altitude Area and High Altitude Area. In this context, altitude means the height above sea level. Low Altitude Area is under 50 meters above sea level. And, High Altitude Area is over 50 meters above sea level.

During the disaster, these regions and areas were affected differently [17]. For example, the Low Altitude Area of Hachinohe City in Sanpachi Region was especially affected by the tsunami following the 2011 earthquake [18]. Therefore, we assumed that there were specific differences among the studied regions and areas during the road recovery process following the disaster. This paper is the revised and extended version of [19].

II. 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. [20] 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 [Fig.2].

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.

As a mater of fact, because of the obsolescence, G-Book Telematics Service of Toyota has been expired on March 31, 2022 [21]. Currently, T-Connect Telematics Service of Toyota is still available for Telematics Service users. Additionally, some probe-car data products of Toyota have been available by ESRI Japan since 2021 [22] .

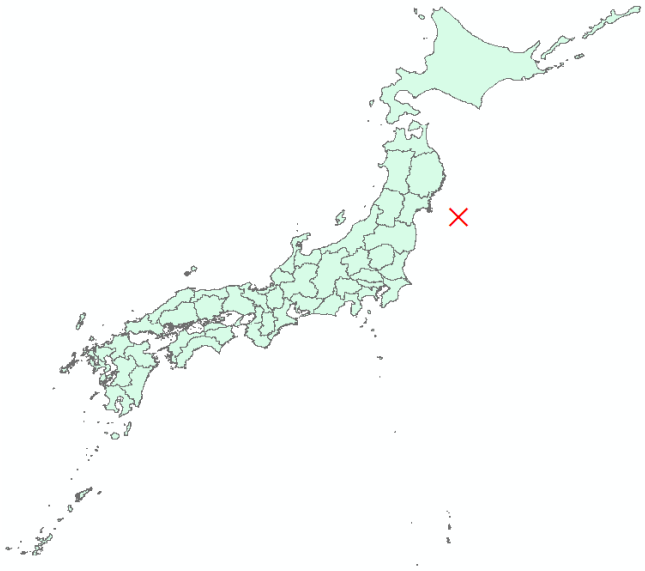

Fig. 1. The epicenter of the 2011 Tohoku Earthquake occurred on March 11, 2011 (created by authors).

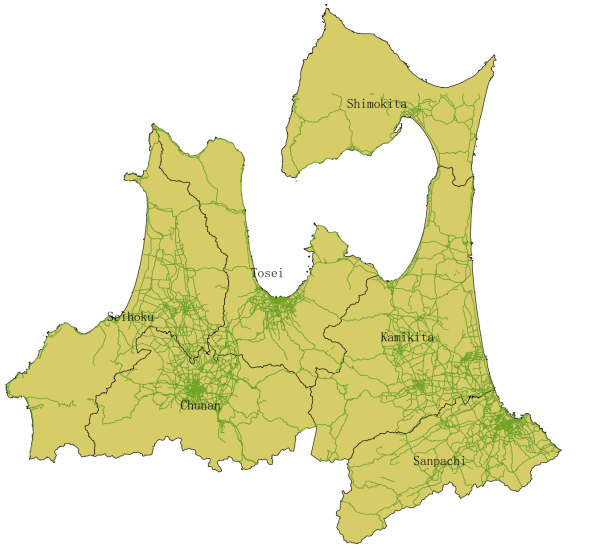

Fig. 2. Vehicle tracking map of Aomori Prefecture. Aomori Prefecture is divided into six regions, i.e., Shimokita, Kamikita, Sannpachi, Tosei, Chunan, and Seihoku regions. The perimeter of a region is shown by a gray polygon (created by authors).

III. Research Methods

A. Research area

The current study was focused on the entire area of Aomori Prefecture (i.e., Shimokita, Kamikita, Sannpachi, Tosei, Chunan, and Seihoku regions) [Fig.2].

Next, we divided Aomori Prefecture into two areas, namely Low Altitude Area and High Altitude Area. In this context, altitude means the height above sea level. Low Altitude Area is under 50 meters above sea level. And, High Altitude Area is over 50 meters above sea level.

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 [23].

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

1) Hardware: The computations have been performed on a standard PC laptop, SONY VAIO-Z with an Intel Core i5-2450M CPU @ 2.50 GHz, 8 GB memory, and a 128 GB RAID-0 SSD.

2) Software: The software QGIS version 2.18.20 [24], and LibreOffice Calc 4.2.7 spreadsheet software [25], running on the Windows 10 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 [26] on the Linux operating system along with Vine Linux 4.2 [27], which is a Linux distribution developed by a Japanese Linux community.

Note that QGIS, LibreOffice Calc, ogr2ogr, and Vine Linux are open source software 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.

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 cumulative distance up to the specified date. Note that the cumulative distance up to September 30, 2011 was considered 100%.

IV. Results

A. Regional road recovery differences in Low Altitude Areas

Defining the cumulative usable distance up to September 30, 2011 as 100%, the percentages of usable road distances are given in Table.II. In Table.II, the upper lines indicate the cumulative usable road distances (in kilometers), and the lower lines represent the ratio of cumulative usable road distance.

1) Shimokita region of Low Altitude Area: It was determined that 80% of the road distance was usable by April 15, 2011 and 90% was usable by April 29, 2011.

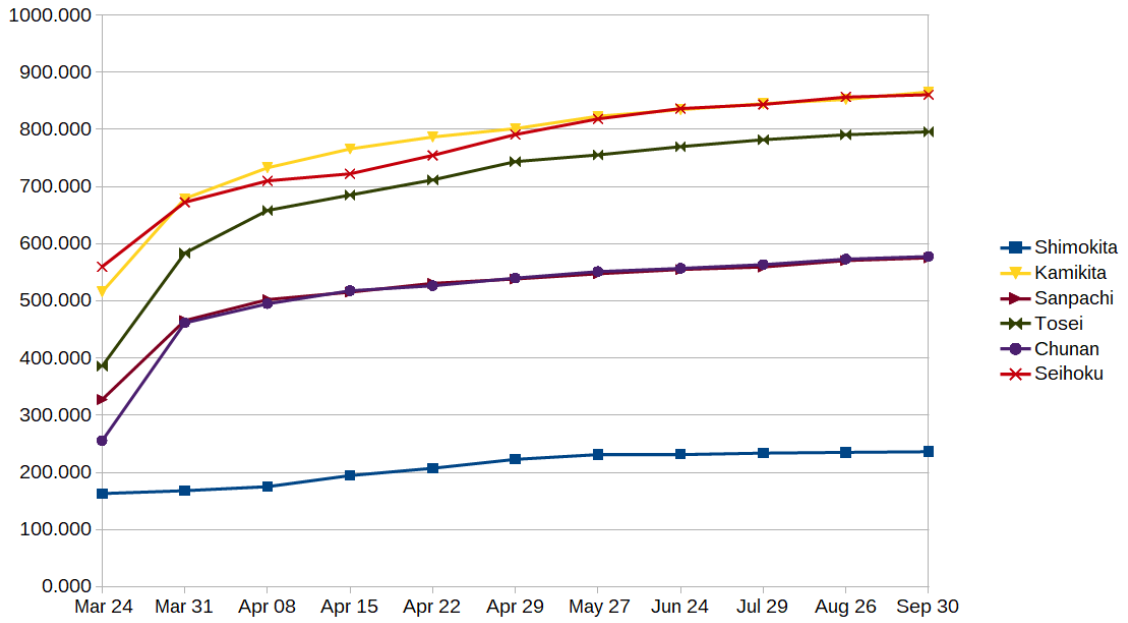

Fig. 3. Usable road distance for Aomori Prefecture's Low Altitude Areas. The vertical scale displays the distance of the usable roads (kilometers) for each date.

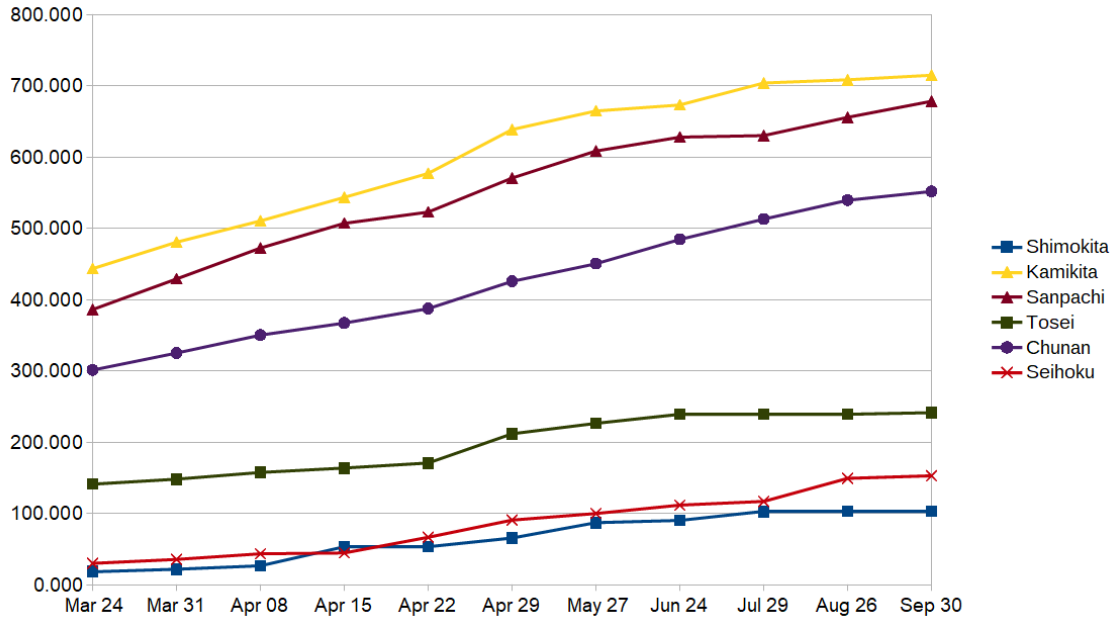

Fig. 4. Usable road distance for Aomori Prefecture's High Altitude Areas. The vertical scale displays the distance of the usable roads (kilometers) for each date.

2) Kamikita region of Low Altitude Area: It was determined that 80% of the road distance was usable by April 8, 2011 and 90% was usable by April 22, 2011.

3) Sanpachi region of Low Altitude Area : It was determined that 80% of the road distance was usable by March 31, 2011 and 90% was usable by April 22, 2011.

The recovery speed in Sanpachi region was almost the same as that in Kamikita region.

4) Tosei region of Low Altitude Area: It was determined that 80% of the road distance was usable by April 8, 2011 and 90% was usable by April 29, 2011.

5) Chunan region of Low Altitude Area: It was determined that 80% of the road distance was usable by April 8, 2011 and 90% was usable by April 22, 2011.

The recovery speed in Chunan region was almost the same as that in Sanpachi region.

6) Seihoku region of Low Altitude Area: It was determined that 80% of the road distance was usable by April 8, 2011 and 90% was usable by April 29, 2011.

B. As a whole in Low Altitude Areas

In Low Altitude Areas, road usage recovery speed in Kamikita, Sanpachi, and Chunan regions was slightly faster than that in Shimokita, Tosei, and Seihoku regions.

TABLE I
REGIONAL DIFFERENCE FOR ROAD RECOVERY IN AOMORI PREFECTURE (CUMULATIVE USABLE ROAD DISTANCES (KILOMETERS) AND RATIOS)

	Mar 24	Mar 31	Apr 08	Apr 15	Apr 22	Apr 29	May 27	Jun 24	Jul 29	Aug 26	Sep 30
Shimokita	181.078	189.664	201.503	247.838	260.652	288.315	318.224	322.108	336.084	337.928	339.096
	53.4	55.9	59.4	73.1	76.9	85.0	93.8	95.0	99.1	99.7	100.0
Kamikita	959.292	1159.550	1243.268	1309.422	1363.893	1440.071	1487.709	1507.609	1549.090	1560.852	1580.338
	60.7	73.4	78.7	82.9	86.3	91.1	94.1	95.4	98.0	98.8	100.0
Sanpachi	713.567	894.579	974.673	1022.458	1053.589	1108.952	1156.057	1182.891	1189.534	1226.347	1253.628
	56.9	71.4	77.7	81.6	84.0	88.5	92.2	94.4	94.9	97.8	100.0
Tosei	526.824	731.694	815.687	848.855	882.378	955.402	981.788	1008.837	1021.059	1030.012	1037.237
	50.8	70.5	78.6	81.8	85.1	92.1	94.7	97.3	98.4	99.3	100.0
Chunan	556.567	786.529	845.162	884.930	913.809	965.573	1001.610	1041.253	1076.455	1112.416	1129.560
	49.3	69.6	74.8	78.3	80.9	85.5	88.7	92.2	95.3	98.5	100.0
Seihoku	589.784	708.056	753.308	766.876	821.054	881.691	918.240	948.102	960.571	1005.656	1013.563
	58.2	69.9	74.3	75.7	81.0	87.0	90.6	93.5	94.8	99.2	100.0
All	3527.115	4470.076	4833.604	5080.382	5295.379	5640.007	5863.633	6010.805	6132.797	6273.217	6353.42
	55.5	70.4	76.1	80.0	83.3	88.8	92.3	94.6	96.5	98.7	100.0

TABLE II
REGIONAL DIFFERENCE FOR ROAD RECOVERY IN AOMORI PREFECTURE'S LOW ALTITUDE AREAS (CUMULATIVE USABLE ROAD DISTANCES (KILOMETERS) AND RATIOS)

	Mar 24	Mar 31	Apr 08	Apr 15	Apr 22	Apr 29	May 27	Jun 24	Jul 29	Aug 26	Sep 30
Shimokita	163.026	168.013	175.042	194.463	207.277	222.870	231.233	231.964	233.748	235.091	236.259
	69.0	71.1	74.1	82.3	87.7	94.3	97.9	98.2	98.9	99.5	100.0
Kamikita	515.913	679.019	732.879	765.978	786.851	801.486	823.066	834.519	845.189	852.478	865.556
	59.6	78.4	84.7	88.5	90.9	92.6	95.1	96.4	97.6	98.5	100.0
Sanpachi	327.536	465.607	502.369	515.421	530.822	538.417	547.593	554.955	559.397	570.647	575.362
	56.9	80.9	87.3	89.6	92.3	93.6	95.2	96.5	97.2	99.2	100.0
Tosei	385.818	583.686	658.268	685.273	711.719	743.703	755.430	769.869	782.043	790.770	795.949
	48.5	73.3	82.7	86.1	89.4	93.4	94.9	96.7	98.3	99.3	100.0
Chunan	255.468	461.584	495.052	517.887	526.504	539.978	551.306	556.887	563.519	573.079	577.795
	44.2	79.9	85.7	89.6	91.1	93.5	95.4	96.4	97.5	99.2	100.0
Seihoku	559.912	672.634	710.020	722.405	754.624	791.109	818.438	836.508	843.767	856.511	860.809
	65.0	78.1	82.5	83.9	87.7	91.9	95.1	97.2	98.0	99.5	100.0
All	2207.673	3030.544	3273.629	3401.427	3517.797	3637.562	3727.066	3784.702	3827.662	3878.577	3911.729
	56.4	77.5	83.7	87.0	89.9	93.0	95.3	96.8	97.9	99.2	100.0

C. Regional road recovery differences in High Altitude Areas

Defining the cumulative usable distance up to September 30, 2011 as 100%, the percentages of usable road distances are given in Table.III. In Table.III, the upper lines indicate the cumulative usable road distances (in kilometers), and the lower lines represent the ratio of cumulative usable road distance.

1) Shimokita region of High Altitude Area: It was determined that 80% of the road distance was usable by May 27, 2011, and 90% was usable by July 29, 2011.

2) Kamikita region of High Altitude Area: It was determined that 80% of the road distance was usable by April 22, 2011, and 90% was usable by May 27, 2011.

The recovery speed in Kamikita region was faster than that in Shimokita region.

3) Sanpachi region of High Altitude Area : It was determined that 80% of the road distance was usable by April 29, 2011, and 90% was usable by June 24, 2011.

The recovery speed in Sanpachi region was slightly slower than that in Kamikita region according to the values in Table.III.

4) Tosei region of High Altitude Area: It was determined that 80% of the road distance was usable by April 29, 2011, and 90% was usable by May 27, 2011.

5) Chunan region of High Altitude Area: It was determined that 80% of the road distance was usable by May 27, 2011, and 90% was usable by July 29, 2011.

The recovery speed in Chunan region was almost the same as that in Shimokita region.

6) Seihoku region of High Altitude Area: It was determined that 80% of the road distance was usable by August 26, 2011, and 90% was usable also by August 26, 2011.

The recovery speed in Seihoku region was about a month slower than that in Shimokita and Chunan regions.

D. As a whole in High Altitude Areas

In High Altitude Areas, road usage recovery speed in Kamikita, Sanpachi, and Tosei regions was faster than that in Shimokita and Chunan regions.

V. DISCUSSION

A. Low Altitude Areas

In Low Altitude Areas, road usage recovery speed in Kamikita, Sanpachi, and Chunan regions was slightly faster than that in Shimokita, Tosei, and Seihoku regions. Low Altitude Areas in Kamikita, Sanpachi, and Chunan regions mainly consist of the plateau. On the other hand, Low Altitude Areas in Shimokita, Tosei, and Seihoku regions mainly consist of the alluvial plain. Therefore we suppose that road usage recovery speed in Low Altitude Areas was affected by these differences in land shape.

TABLE III
REGIONAL DIFFERENCE FOR ROAD RECOVERY IN AOMORI PREFECTURE'S HIGH ALTITUDE AREAS (CUMULATIVE USABLE ROAD DISTANCES (KILOMETERS) AND RATIOS)

	Mar 24	Mar 31	Apr 08	Apr 15	Apr 22	Apr 29	May 27	Jun 24	Jul 29	Aug 26	Sep 30
Shimokita	18.052	21.651	26.461	53.375	53.375	65.445	86.991	90.144	102.336	102.837	102.837
	17.6	21.1	25.7	51.9	51.9	63.6	84.6	87.7	99.5	100.0	100.0
Kamikita	443.379	480.531	510.389	543.444	577.042	638.585	664.643	673.090	703.901	708.374	714.782
	62.0	67.2	71.4	76.0	80.7	89.3	93.0	94.2	98.5	99.1	100.0
Sanpachi	386.031	428.972	472.304	507.037	522.767	570.535	608.464	627.936	630.137	655.700	678.266
	56.9	63.2	69.6	74.8	77.1	84.1	89.7	92.6	92.9	96.7	100.0
Tosei	141.006	148.008	157.419	163.582	170.659	211.699	226.358	238.968	239.016	239.242	241.288
	58.4	61.3	65.2	67.8	70.7	87.7	93.8	99.0	99.1	99.2	100.0
Chunan	301.099	324.945	350.110	367.043	387.305	425.595	450.304	484.366	512.936	539.337	551.765
	54.6	58.9	63.5	66.5	70.2	77.1	81.6	87.8	93.0	97.7	100.0
Seihoku	29.872	35.422	43.288	44.471	66.430	90.582	99.802	111.594	116.804	149.145	152.754
	19.6	23.2	28.3	29.1	43.5	59.3	65.3	73.1	76.5	97.6	100.0
All	1319.439	1439.528	1559.973	1678.951	1777.578	2002.442	2136.561	2226.099	2305.129	2394.634	2441.693
	54.0	59.0	63.9	68.8	72.8	82.0	87.5	91.2	94.4	98.1	100.0

B. High Altitude Areas

In High Altitude Areas, road usage recovery speed in Kamikita, Sanpachi, and Tosei regions was faster than that in Shimokita and Chunan regions. High Altitude Areas in Kamikita, Sanpachi, and Tosei mainly consist of Mountains (equal to "Sanchi" in the Japanese word for a group of not so very high mountains). On the other hand, High Altitude Areas in Shimokita and Chunan mainly consist of the mountain range (equal to "Sanmyaku" in the Japanese word for a group of very high mountains). Therefore we suppose that road usage recovery speed in High Altitude Areas was also affected by these differences in land shape.

C. Land shape is closely related to road usage recovery

According to the results of this research, we conclude that the land shape of the regions is closely related to road usage recovery. For more precise evaluation, we have to use land shape classification figures for the analysis. Therefore, we would like to conduct that kind of analysis in the near future.

REFERENCES

[1] Britannica, Japan earthquake and tsunami of 2011 (accessed on August 31, 2024) https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011

[2] Hayato Komori and Noriaki Endo, "Road Distance Traveled by Vehicles Following the 2011 Tohoku Earthquake, Calculated by G-BOOK Telematics Data," *Proceedings of the 9th International Conference on Signal-Image Technology & Internet-Based Systems*, SITIS 9, Dec.2-5, 2013, Kyoto, Japan, 870-874. https://doi.org/10.1109/SITIS.2013.142

[3] Noriaki Endo and Hayato Komori, "Analysis of Vehicle Tracking Maps in Iwate Prefecture Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of the International MultiConference of Engineers and Computer Scientists 2015*, IMECS 2015, Mar.18-20, 2015, Hong Kong, 124-128. Available at http://www.iaeng.org/publication/IMECS2015/IMECS2015_pp124-128.pdf

[4] Noriaki Endo and Hayato Komori, "Municipal Difference on Road Recovery in Iwate Prefecture Following the 2011 Tohoku Earthquake," IAENG Transactions on Engineering Sciences - Special Issue for the International Association of Engineers Conferences 2015, World Scientific, 2016, 226-235. https://doi.org/10.1142/9789813142725_0018

[5] Noriaki Endo and Hayato Komori, "Regional Difference on Road Recovery in Iwate Prefecture Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of the World Congress on Engineering and Computer Science 2015*, WCECS 2015, Oct.21-23, 2015, Berkeley, CA, USA, 162-167. Available at http://www.iaeng.org/publication/WCECS2015/WCECS2015_pp162-167.pdf

[6] Noriaki Endo, and Hayato Komori, "Regional Differences in Iwate Prefecture Road Usage Recovery Following the 2011 Tohoku Earthquake," Transactions on Engineering Technologies - World Congress on Engineering and Computer Science 2015, Springer, 2017, 219-231. https://doi.org/10.1007/978-981-10-2717-8_16

[7] Noriaki Endo, "Regional Differences in Miyagi Prefecture Road Recovery Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of The International MultiConference of Engineers and Computer Scientists 2016*, IMECS 2016, Mar.16-18, 2016, Hong Kong, 151-156. Available at http://www.iaeng.org/publication/IMECS2016/IMECS2016_pp151-156.pdf

[8] Noriaki Endo, "Road Usage Recovery in Miyagi Prefecture Following the 2011 Tohoku Earthquake," IAENG Transactions on Engineering Sciences - Special Issue for the International Association of Engineers Conferences 2016, World Scientific, 2017, 111-125. https://doi.org/10.1142/9789813226203_0010

[9] Jieling Wu, and Noriaki Endo, "Regional Differences in Fukushima Prefecture Road Recovery Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of The International MultiConference of Engineers and Computer Scientists 2019*, 13-15 March, 2019, Hong Kong, pp164-169. Available at http://www.iaeng.org/publication/IMECS2019/IMECS2019_pp164-169.pdf

[10] Jieling Wu, and Noriaki Endo, "Road Usage Recovery in Fukushima Prefecture Following the 2011 Tohoku Earthquake," *IAENG Transactions on Engineering Sciences - Special Issue for the International Association of Engineers Conferences 2019*, World Scientific, 2020, pp48-62. https://doi.org/10.1142/9789811215094_0004

[11] Jieling Wu, Noriaki Endo, and Mitsugu Saito, "Cluster Analysis for Investigating Road Recovery in Iwate Prefecture Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of the International MultiConference of Engineers and Computer Scientists 2021*, IMECS 2021, October 20-22, 2021, Hong Kong, pp65-69. Available at https://www.iaeng.org/publication/IMECS2021/IMECS2021_pp65-69.pdf

[12] Jieling Wu, Noriaki Endo, and Mitsugu Saito, "Cluster Analysis for Studying Road Recovery of Fukushima Prefecture following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of the World Congress on Engineering 2021*, WCE 2021, July 7-9, 2021, London, U.K., pp107-112. Available at https://www.iaeng.org/publication/WCE2021/WCE2021_pp107-112.pdf

[13] Jieling Wu, Noriaki Endo, and Mitsugu Saito, "Cluster Analysis for Investigating Road Recovery in Fukushima Prefecture Following the 2011 Tohoku Earthquake," *Engineering Letters*, 29(4), 2021, pp1636-1642. Available at https://www.engineeringletters.com/issues_v29/issue_4/EL_29_4_37.pdf

[14] Jieling Wu, Noriaki Endo, and Mitsugu Saito, "Cluster Analysis to Extract Municipal Road Recovery Features in the Tohoku Region Following the 2011 Tohoku Earthquake," *IAENG International Journal of Computer Science*, 49(1), 2022, pp232-240. Available at https://www.iaeng.org/IJCS/issues_v49/issue_1/IJCS_49_1_24.pdf

[15] Jieling Wu, Mitsugu Saito, Noriaki Endo, "Discriminant Analysis for

Predicting Post-Earthquake Municipal Road Recovery," *IOP Conference Series: Earth and Environmental Science*, 1064(1), 2022, article number 012046. https://doi.org/10.1088/1755-1315/1064/1/012046

[16] Jieling Wu, Mitsugu Saito, Noriaki Endo, "Cluster Analysis and Discriminant Analysis for Determining Post-Earthquake Road Recovery Patterns," *Sensors*, 22(6), 2022, article number 2213. https://doi.org/10.3390/s22062213

[17] Records of 2011 Tohoku Earthquake(In Japanese): https://www.pref.aomori.lg.jp/soshiki/kikikanri/bousai/shinsaikiroku.html

[18] Noriaki Endo and Akihide Takehara, Creating a Tsunami Disaster Archive of the Great Northeastern Japan Earthquake Using Images Uploaded to the Internet, Proceedings of the 8th International Symposium on Digital Earth (ISDE 8), Kuching, Malaysia, August 26, 2013. https://doi.org/10.1088/1755-1315/18/1/012079

[19] Shouyi Gao, Noriaki Endo, and Mitsugu Saito, "Regional and Altitudinal Differences in Aomori Prefecture Road Recovery Following the 2011 Tohoku Earthquake," *Lecture Notes in Engineering and Computer Science: Proceedings of The International MultiConference of Engineers and Computer Scientists 2021*, 20-22 October, 2021, Hong Kong, pp59-64
Available at https://www.iaeng.org/publication/IMECS2021/IMECS2021_pp59-64.pdf

[20] Yasunori Hada, Takeyasu Suzuki, Hiroki Shimora, Kimiro Meguro, and Noriko Kodama: Issues and Future Prospect on Practical Use of Probe Vehicle Data for Disaster Reduction -Provision of the Vehicle Tracking Map in the 2007 Niigataken Chuetsu-oki Earthquake- (In Japanese), *Journal of Japan Association for Earthquake Engineering*, 9(2), 148-159, 2009.
Available at http://www.jaee.gr.jp/stack/submit-j/v09n02/090211_paper.pdf

[21] G-Book Telematics Service will be expired on March 31, 2022. (in Japanese)
https://www.toyota-mobi-tokyo.co.jp/information/g-book/

[22] Road Traffic of Tokyo Bay Aqua Line acquired from Road Traffic Statistics Data distributed by ESRI Japan (in Japanese)
https://blog.esrij.com/2023/09/15/post-50820/

[23] Vehicle Tracking Map Constructed by G-BOOK Telematics Data
http://g-book.com/disasterMap/ALL/Tohoku-Jishin_YYYYMMDD.kmz
(For example, Tohoku-Jishin_20110318.kmz. The data files of tracking map are still available on August 31, 2024.)

[24] Official website of QGIS, A Free and Open Source Geographic Information System
http://www.qgis.org/en/site/

[25] Official Website of the LibreOffice Project
http://www.libreoffice.org/

[26] Official website of GDAL: ogr2ogr
http://www.gdal.org/ogr2ogr.html

[27] Official website of Vine Linux (In Japanese)
http://www.vinelinux.org/