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Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

Kentaro KUMAGAI

2011年東北地方太平洋沖地震津波による
青森県八戸市の産業の生産能力変化

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Kentaro KUMAGAI*

Synopsis

This technical note includes literature reviews of the previous researches on flow damage due to natural disasters and a case study of estimating production capacity change for an inundation area due to the 2011 Tohoku tsunami.

The study area was the coastal area of Hachinohe city, which was damaged and inundated by the earthquake and the tsunami. The fact data for the activities of 10 industrial sectors were assembled from published information, newspaper articles, and public announcements. The results showed that the estimated amount of economic damage was approximately 101.7 billion yen because of the production capacity change in the industrial sectors of the area due to the earthquake and the tsunami. This estimated amount was equivalent to approximately 84 % of the amount of the stock damage in the city.

Key Words: flow damage, natural disaster, production capacity change, the 2011 Tohoku tsunami

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2011 年東北地方太平洋沖地震津波による青森県八戸市の産業の生産能力変化

熊谷　兼太郎*

要　　旨

本資料は，自然災害によるフロー被害の文献レビューを行うとともに，2011 年東北地方太平洋沖地震津波の浸水域に立地する産業の生産能力変化を推計した．

推計の対象は，同津波で被害が生じ浸水した青森県八戸市の沿岸域である．主な推計方法は，浸水範囲内に所在する 10 業種（通商産業省標準産業分類に基づく．）で建築面積が 1,000 m^2 以上の製造業 60 社を対象に，津波発生前後の企業活動状況に係る公表資料，新聞報道記事，その他の公表資料を収集することにより行った．その結果，生産能力変化としてのフロー被害の推計額は約 1,017 億円であった．この推計額は，当該市の自治体がとりまとめているストック被害の総計の約 84 %に相当していた．

キーワード：フロー被害，自然災害，生産能力変化，2011 年東北地方太平洋沖地震津波

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1. Introduction

Earthquakes and their strong seismic motion cause damage such as destruction of houses, buildings and infrastructures, fire, liquefaction and others. When the earthquakes generate tsunami, the inundation and strong currents also cause damage such as destruction of facilities, loss of inventory stored in commerce facilities and stockyards, damage of ships and fishing gears and other damage in coastal areas. Although the strong seismic motion of earthquakes and tsunamis cause these damage, it is not sufficient to explain all of the damage.

Pelling et al. (2002) introduced three categories of disaster impact. The first one is the kind of damage described above. The second one is flow damage in the affected area. And the last one is secondary damage in affected and unaffected area for the overall performance of economy. It should be noted that Pelling et al. (2002) called the three categories 'direct damages', 'indirect damages and flow losses' and 'secondary effects', respectively. However, in this technical note, they are called 'stock damage', 'flow damage' and 'secondary and higher-level effects', respectively, for the purpose of simplicity and accuracy (**Fig. 1.1**).

If economic activity is suspended because of tsunami inundation, many production activities and services in areas beyond the inundated area will be affected. For example, if factory operation of automobile is suspended because of destroyed facilities, tire plant and steel plant will decrease their production and lose sales opportunities. Workers will lose their jobs in cases of long-term suspension of operations.

The estimation of flow damage has not been pursued to the same extent as that of stock damage. But existing researches show that the amount of flow damage is too extensive to ignore compared with that of stock damage. Additionally, the estimation results of flow damage for production and service should be fundamental parameters for calculating the secondary and higher-level effects.

In this technical note, a literature review was conducted of the previous research for flow damage in the second chapter, and the third chapter is a case study of estimating production capacity change in area the inundation area due to the 2011 Tohoku tsunami.

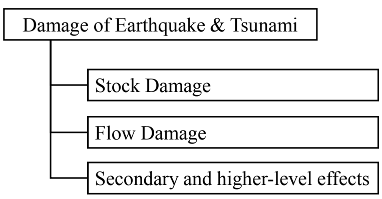

Fig. 1.1 Damage from Earthquake and Tsunami

Reference for Chapter 1

Pelling M., A. Özerdem and S. Barakat: The macro-economic impact of disasters, Progress in Development Studies, 2(4), pp. 283-305, 2002.

2. Literature Reviews

(1) Stock damage

There are many comprehensive reports on past natural disasters that discuss methods of estimating direct damage.

Eguchi et al. (1998) shows losses excluding indirect effects from the 1994 Northridge earthquake in California in the United States; the authors introduced the comparative analysis of multiple estimates that were conducted before and after the event, and of the inspection data on the damaged buildings that were collected after the event.

(2) Flow damage

Leiter et al. (2009) and Mel et al. (2011) show the estimation method of flow damage of flood and tsunami using the firms' survey results. Leiter et al. (2009) applied the method to the October 2000 flood and firms in France, Italy, Spain and the United Kingdom; the total number of firms is approximately 137 thousand from all four countries. Mel et al. (2011) applied the method to the 2004 Indian Ocean tsunami and Sri Lankan microenterprises. The authors conducted a panel survey with owners of 608 microenterprises after the tsunami.

Yang et al. (2015) introduced the methodology to estimate interruption losses of business enterprises resulting from the heavy rainfall in Japan in 2000. They estimated the flow damage of 6 sectors of manufacturing or service using business interruption loss rate, spatial distribution of water depth, and census data on a fine geographical scale.

Conducting panel surveys of firms in affected areas is the basic and typical method of estimating flow damage, but other methods could be available and be effective as well. One of these is the hedonic property price approach for estimating the effects of natural disasters on residential property. Bin and Polasky (2004) and Hallstrom and Smith (2005) applied this method to the hurricanes in the United States respectively, and found that the price discount within a floodplain or a near-miss of a hurricane was significantly higher after the event than before. According to Hallstrom and Smith (2005), property values decreased at least 19 percent after Hurricane Andrew in 1992.

(3) Secondary and higher-level effects

Okuyama (a, b) wrote a critical review of methodologies and case studies on the secondary and higher-level effects of disaster impact estimation. His report referenced four major methodologies: the

Input-Output (IO) model, the Social Accounting Matrix (SAM) model, the Computable General Equilibrium (CGE) model and the Econometric model; the author listed the strengths and weaknesses of each method in a table format and estimated the higher-order effects of ten recent disaster cases by employing the IO and SAM models. The result showed that the higher-order effects of disasters are significant and complex.

Natural disasters force structural changes in the economies of affected areas. Chang (2001) provided the results of his study in structural change of the three to four years recovery process following the 1995 Kobe earthquake.

Rose et al. (1997) developed regional economic impacts to estimate the comprehensive higher effects of electricity disruptions after an earthquake. The result showed that losses from a potential earthquake in Tennessee in the United States could amount to as much as a 7 percent impact on gross regional product.

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Yang L., H. Tatano, Y. Kajitani and X. Jiang: Estimates of Business Interruption Losses to Industrial Sectors due to Floods Disaster: A Case Study of Tokai Heavy Rain, *Proceedings of Infrastructure Planning and Management*, Japan Society of Civil Engineering, Vol. 51, CD-ROM, 2015.

3. Case Study of Estimating Economic Impacts

(1) Brief overview

This chapter focuses on production capacity change in industrial sectors due to the 2011 Tohoku tsunami that was generated by the 2011 off the Pacific coast of Tohoku earthquake. The author highlights the coastal area of Hachinohe city, which was damaged and inundated by the earthquake and tsunami. The main method of investigation was collecting fact data on the activities of 10 industrial sectors from information published, newspaper articles, and public announcements. The result showed that the estimated production capacity change was approximately 101.7 billion Japanese yen in the industrial sectors of the area due to the earthquake and tsunami. The estimated amount of the damage was equivalent to approximately 84 % of the stock damage in the city.

(2) Damage to industries

Tsunami inundation causes stock damage such as damage to infrastructure, destruction of industrial plants, deprivation of in-stock items, collapse of residences and other damage. Tsunami fragility curves (TFCs) are available for estimating the fragility of facilities against tsunamis (Mas et al., 2012); it is possible to evaluate stock damage with the proper TFCs, and high-resolution spatial data on the facilities and the tsunami inundation maps in fine-grid mesh.

Tsunamis also cause flow damage, such as decreased production in industrial sectors, economic losses in commercial sectors, and others. Although it seems be true that the industrial sectors plays an important role in economic activities, little information is available for analyzing flow damage of the industries, because many industries belong to private business activities and detailed economic data on their activity is not opened to the public.

However, the visible outlines of the factories can be obtained easily from high-resolution aerial photos, digital maps, or paper maps. Analysts can estimate sizes of factories using these outline data. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan published a technical manual that showed a typical method to evaluate the stock and flow damage of floods. The method shown was a simple one that used the constant coefficient of transformation from the number of employees to economic losses per day for the industrial sector in view of the estimated economic losses from business suspension (MLIT, 2005).

The MLIT manual shows a table of the days of business suspension and the days of stagnation (**Table 3.1**). The former ranges from a minimum of 3.0 to a maximum of 22.6 days for in the maximum, and the latter ranges from a minimum of 6.0 to a maximum of 45.2 days for in the maximum, depending on the inundation depth of the flood. These results were collected from a questionnaire survey after a flood event. MLIT proposed an equation for damage D of business suspension and stagnation:

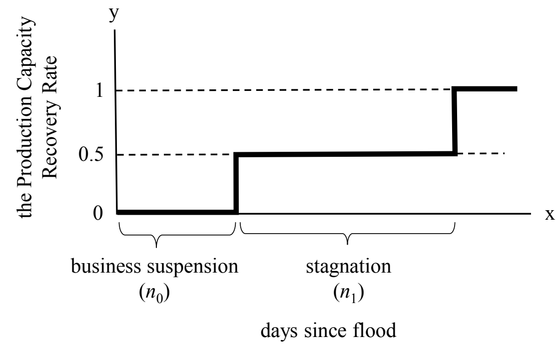
$$D = M \times (n_0 + \frac{n_1}{2}) \times p \qquad (1)$$

where M: the number of labors, n_0: days of business suspension, n_1: days of stagnation, p: added value. The value of p equals to value divided by the number of person and days, in the unit of yen per person and day. In condition that M and p are constant, the equation (1) implies that MLIT modeled production capacity recovery process as shown in **Fig. 3.1** (1). For example, in case that an inundation depth is greater or equals to 3.00 m, **Fig. 3.1** (2) is a time-series of production capacity recovery. The method is simple enough, but the constant coefficient may vary depending on the geographical location of the company, the type of industry, conditions of labor market of the area, the degree of technical innovation, and the other factors.

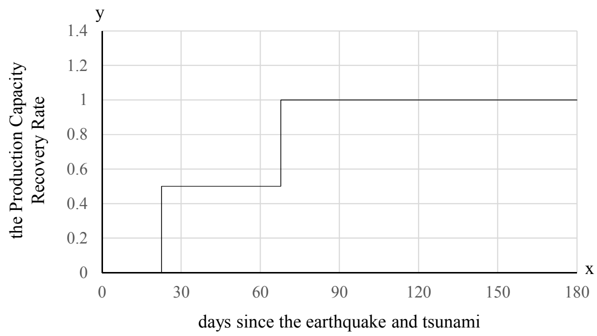
Kajitani et al. (2013) shows the production capacity changes from the day of the 2011 Tohoku earthquake to 180 days after the disaster. Production capacity of the industrial sector was approximately 0.4 on the day of disaster, approximately 0.9 on 60 days after the disaster, and approximately 0.95 on 180 days after the disaster (**Fig. 3.2**). The figure was reproduced from Kajitani et al. (2013) by the author of this technical report. Black points and dotted line in this figure shows average values of manufacturing industries, and the curve line of relation between production capacity on the vertical axis and days after the disaster on the horizontal axis is concave down. This result was collected from the questionnaire survey in Miyagi and Iwate prefecture mainly in areas that were affected by the earthquake, not in the area affected by the tsunami. It appears to be important to conduct a survey

Table 3.1 Days of business suspension and stagnation (Source: MLIT, 2005)

Inundation Depth (m)	below the floor level	above the floor level				
		less than 0.5	0.5-0.99	1.00-1.99	2.00-2.99	greater or equal to 3.00
days of business suspension (=n_0)	3.0	4.4	6.3	10.3	16.8	22.6
days of stagnation (=n_1)	6.0	8.8	12.6	20.6	33.6	45.2



(1) Conceptual diagram



(2) Greater or equal to 3.00 m in inundation depth

Fig. 3.1 Recovery model from flood proposed by MLIT

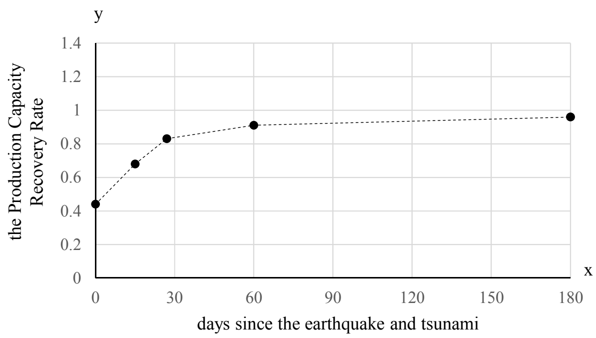


Fig. 3.2 Production Capacity Recovery Rate (Source: Kajitani et al., 2013)

and draw lines for production capacity changes in areas that are affected by tsunamis.

(3) Industrial Sectors Affected by Tsunami and Their Annual Sales

a) Industrial Sectors in the Tsunami Inundation Area

Hachinohe city is one of the major industrialized cities in northern Japan. **Fig. 3.3** shows a location of the city. The maximum tsunami height was approximately 6-8 m in Hachinohe city, Aomori prefecture (The 2011 Tohoku Earthquake Tsunami Joint Survey Group, 2012).

First, the author digitized the maximum inundation area maps of the 2011 Tohoku tsunami in Hachinohe city (Haraguchi and Iwamatsu, 2011) into a line-shape file using ArcMap Ver. 10.3 (ESRI Japan Corporation), Geographic Information System (GIS) software. The digital map data for the building shapes, including industrial factories and residences, was input from Z MAP TOWN II (CD-ROM, Zenrin Co., LTD) to the GIS software. By overlapping the maximum inundation area maps on the building shape map (**Fig. 3.4**), the author picked up 283 large buildings, i.e. a floor area of more than 1,000 m^2 on the first floor, in the tsunami inundation area. The floor area of the 283 buildings was 858,880 m^2 in total.

The building shape map includes not only the building shapes, but also the company names of the building tenants. Using the latter information and 'the street view' function of Google Earth Ver. 7.15.1557, provided by Google Inc., the author identified company names for most of the building; however, for 53 buildings, the company's name is unclear. Finally, the author matched 230 buildings to company name, a total of 748,171 m^2 in floor area (**Fig. 3.5**).

Ministry of Internal Affairs and Communications (MIC, 2013) of Japan provides a table called the Standard Industrial Classification of All Economic Activities (SIC, Rev. 13). The MIC categorize all of Japan's economic activities of Japan into 99 sectors identified by SIC code numbers 1-99, and the sector name. The author assigned the SIC code to the 230 buildings on the basis of the company name.

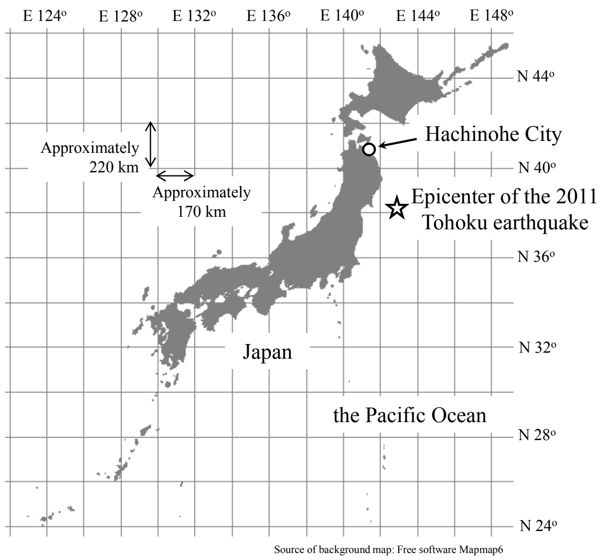


Fig. 3.3 Location of Hachinohe City

Because the SIC targets all economic activities, it includes both the industrial (SIC code: 09-32) and the non-industrial (SIC code: 01-08 and 33-99) sectors (**Table 3.2**). From the 230 buildings, the author identified 155 to be in the industrial sectors, SIC code 09-32.

Many industrial companies had multiple buildings in the target area, so the author integrated the buildings into one column and summed the values of the building floor areas into one value.

Finally, the author produced a list of 60 companies of the industrial sectors in the Hachinohe city inundation area due to the 2011 Tohoku tsunami, with their SIC codes. The total floor area is 543,611 m^2, equivalent to 63 % of the floor area of all buildings, 858,880 m^2. The 60 companies are categorized into ten industrial sectors, as shown in **Fig. 3.6**.

b) Annual Sales of the 10 Industrial Sectors in 2010

Annual sales are a fundamental index of a private company's activity. The author researched the data on the annual sales of the 60 companies from 2011-2015 data published by Toyo Keizai Inc. (CD-ROMs, 2011-2015), government documents, the companies' official websites, and others sources (see **Appendix A**).

Because the Tohoku tsunami occurred in 2011, econo

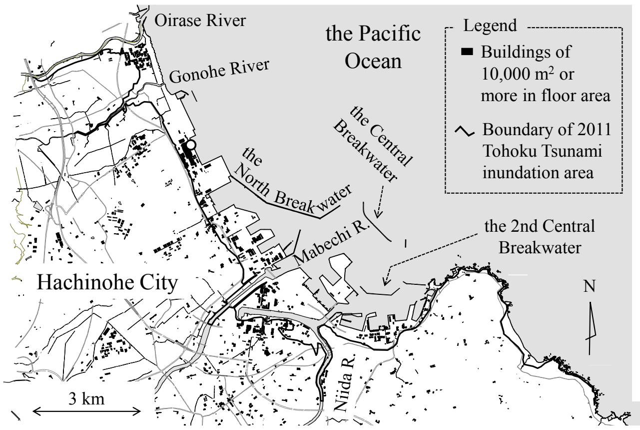


Fig. 3.4 Inundation area and buildings

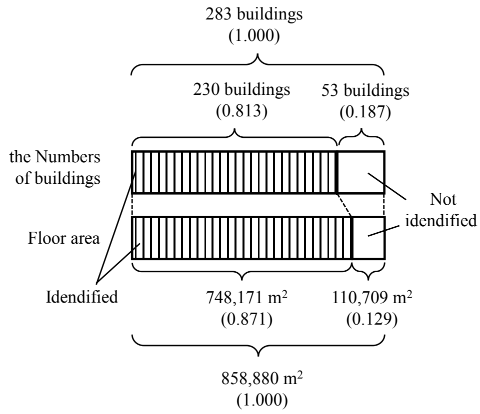


Fig. 3.5 Identification of company names

Table 3.2 SIC codes

(1) Major classification

SIC code	Name of Sector
1 - 2	Agriculture and Forestry
3 - 4	Fishery
5	Mining and Quarrying of Stone
6 - 8	Construction
9 - 32	Manufacturing
33 - 36	Electricity, Gas, Heat Supply and Water
37 - 41	Information and Communications
42 - 49	Transport and Postal Service
50 - 61	Wholesale and Rental Trade
62 - 67	Finace and Insurance
68 - 70	Real Estate and Goods Rental and Leasing
71 - 74	Scientific Research, Professional and Technical Services
75 - 77	Accommodations, Eating and Drinking Serviecs
78 - 80	Living-related and Personal Services and Amusement Services
81 - 82	Education, Learning Support
83 - 85	Medical, Health Care and Welfare
86 - 87	Compound Services
88 -96	Services, N. E. C.
97 - 98	Government, except elsewhere classified
99	Industries unable to classify

(2) Detail of Manufacturing

SIC code	Name of Sector
9	Food
10	Beverages, tobacco and feed
11	Textile mill products
12	Lumber and wood products, except furniture
13	Furniture and fixtures
14	Pulp, paper and paper products
15	Printing and allied industries
16	Chemical and allied products
17	Petroleum and coal products
18	Plastic products, except otherwise classified
19	Rubber products
20	Leather tanning, leather products and fur skins
21	Ceramic, stone and clay products
22	Iron and steel
23	Non-ferrous metals and products
24	Fabricated metal products
25	General-purpose machinery
26	Production machinery
27	Business oriented machinery
28	Electronic parts, devices and electronic circuits
29	Electrical machinery, equipment and supplies
30	Information and communication electronics equipment
31	Transportation equipment
32	Miscellaneous manufacturing industries

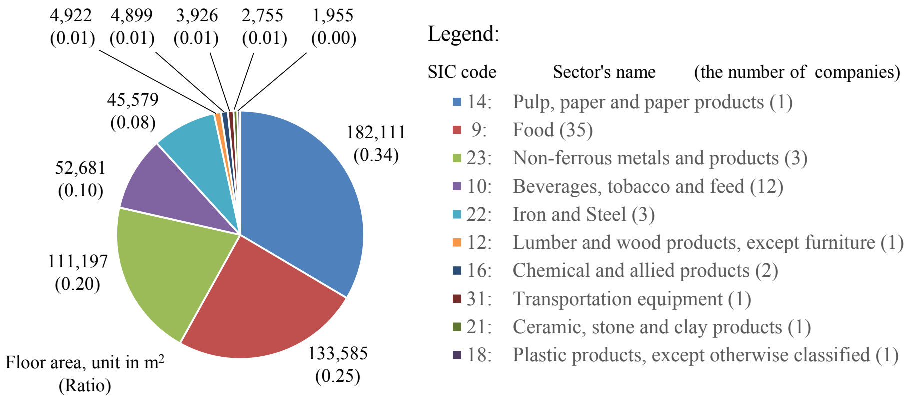


Fig. 3.6 Floor areas of 60 companies in 10 industrial sectors

-mic conditions and other may have changed after the event. Annual sales also may have changed. Thus, it was necessary to collect or estimate the 2010 annual sales for the identified 60 companies.

Annual sales data for 2010 were available for six companies; however, the 2010 data was not available for the remaining 54 companies. Thus, the author estimated the value using three estimation methods.

The first method was applied to companies ID Nos. 2, 4-9, and 12-36 of manufacture SIC code 9 (see **Appendix A**). The linear relationship between the floor area and the annual sales was estimated based on data from three companies, ID Nos. 3, 10 and 11. For companies ID Nos. 3 and 10, annual sales data on 2010 were available (Toyo Keizai Inc., 2011). For company ID No. 11, annual sales data on 2010 was not available. But annual sales on 2008 was available (Ryutsukikaku Co., Ltd., 2010), and the value was corrected from 2008 to 2010 using a ratio based on data of company ID No. 3 (i.e., ratio between 14.4 billion yen on 2008 and 14.1 billion yen on 2010) (**Table 3.3**). **Fig. 3.7** (1) was a correlation chart and linear relationship between the floor area and annual sales. Arabic numbers in the figure indicates the company ID Nos. An approximate algorithm adopted was the least-square fitting, and R^2 value equaled to 0.8711, and showed a good result in fitting. Annual sales which was function of floor area a (m^2) was defined by equation (2).

$$S_{2010}(9) = 0.00129a \tag{2}$$

where $S_t(x)$ (billion yen) was annual sales for companies which belong to manufacture SIC code x on year t.

The second method was applied to the company ID Nos. 38-54 of manufacture SIC code 23, 10 and 22.

Table 3.3 Floor area and annual sales

(1) SIC code 9

Company ID no.	Floor area (m^2)	Annual sales in 2008 (billion yen)	Annual sales in 2010 (billion yen)	Estimated annual sales in 2010 (billion yen)
3	8,590	14.4	14.1	14.1
10	13,217	N/A	15.0	15.0
11	1,148	2.0	N/A	2.0

* N/A : Not available

(2) SIC code 23

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2013 (billion yen)
37	7,237	5.5	5.8
38	82,969	N/A	55.9

* N/A : Not available

(3) SIC code 10

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2014 (billion yen)
40	9,689	N/A	4.6
41	3,066	N/A	0.4
42	2,739	N/A	0.5
43	2,550	N/A	0.4

* N/A : Not available

(4) SIC code 22

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2014 (billion yen)
52	36,775	16.6 *	23.3 *
53	1,199	N/A **	0.3

* Estimated value (see **Appendix B**) ** N/A : Not available

Linear relation between floor area and annual sales were estimated based on 2013 and 2014 data, and corrected from 2013 or 2014 values to 2010 values.

For manufacture SIC code 23, annual sales data on 2010 was available only for company ID No. 37, and it was impossible to estimate a linear relation similar to the equation (2). The value on 2013 was available for two companies, ID Nos. 37 and 38 (**Table 3.3**(2)) (Agency for Natural Resources and Energy, 2014, and Epson Atomix Corporation, 2015). **Fig. 3.7** (2) was a correlation chart and linear relationship between the floor area and annual sales on 2013. Unfortunately there was only two points in the chart, and it was difficult to evaluate an accuracy of the fitting. Although evaluation of accuracy has remained to be solved, this relationship was applied to company ID No. 39 because no alternative data was available. Ratio of annual sales on 2010 to 2013 of company ID No. 37 was 0.948, and an assumption was adopted that this value was common to all companies of this manufacture. Annual sales on 2010 was defined by equation (3).

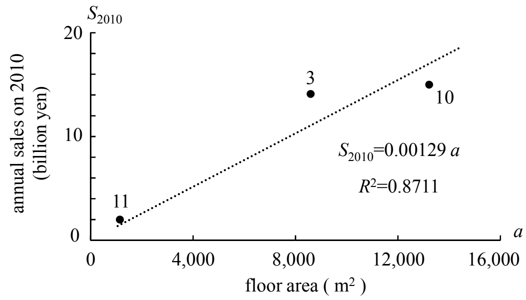
$$S_{2010}(23) = 0.948 \times 0.00067a \tag{3}$$

For manufacture SIC code 10, annual sales data on 2010 was not available, but the values on 2014 was available for four companies, ID Nos. 40-43 (**Table 3.3**(3)) (Toyo Keizai Inc., 2015, and Agency for Natural Resources and Energy, 2015). **Fig. 3.7** (3) was a correlation chart and linear relationship between the floor area and annual sales on 2014. R^2 value equaled to 0.8497, and showed a good result in fitting, and this relationship was applied to companies ID No. 44-51. Ratio of annual sales on 2010 to 2014 was set to be 0.833, based on a news article for company ID No. 40. The article reported that 'Monthly production level was raised to 120 % in June 2011 than that in June 2010.' (Daily Tohoku Shimbun, Inc., 2011). An assumption was adopted that the condition of production level was common to all companies of this manufacture and was constant after the tsunami. Annual sales on 2010 was defined by equation (4).

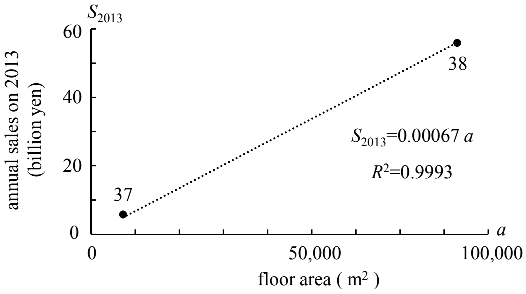
$$S_{2010}(10) = 0.833 \times 0.00041a \tag{4}$$

For manufacture SIC code 22, annual sales data on 2010 was available only for company ID No. 52, and it was impossible to estimate a linear relation similar to the equation (2). The value on 2014 was available for two companies, ID Nos. 52 and 53 (**Table 3.3**(4) and **Appendix B**) (Financial Services Agency, 2011 and 2015, and Hachinohe Chamber of Commerce and Industry, 2014). **Fig. 3.7** (4) was a correlation chart and linear relationship between the floor area and annual sales on 2014. Unfortunately there was only two points in the chart, and it was difficult to evaluate an accuracy of the fitting. Although evaluation of accuracy has remained to be solved, this relationship was applied to company ID No. 54 because no alternative data was available. Ratio of annual sales on 2010 to 2014 of company ID No. 52 was 0.722, and an assumption was adopted that this value was common to all companies of this manufacture. Annual sales on 2010 was defined by equation (5).

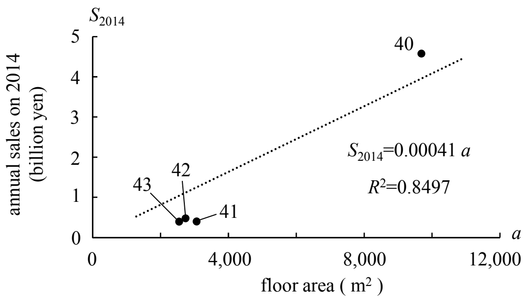
$$S_{2010}(22) = 0.722 \times 0.00067\,a \qquad (5)$$



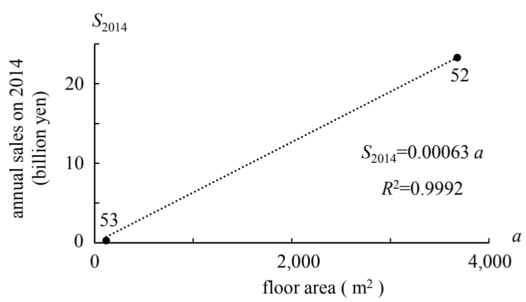
(1) SIC code 9



(2) SIC code 23



(3) SIC code 10



(4) SIC code 22

Fig. 3.7 Floor area and annual sales

The third method was applied to company ID Nos. 1, 55-57, and 60 of manufacture SIC code 14, 12, 16, 31, 21 and 18. This method is similar to that adopted by MLIT, which was discussed earlier in Section (2). **Fig. 3.8** is a flow diagram to estimate annual sales. First, floor area a was converted to the number of employee e using constant coefficient z_1. Subsequently e was converted to annual sales in 2010, S_{2010}, using constant coefficient z_2 and z_3 (Equation (6), (7a) and (7b)).

$$e = z_1(x) \times a \qquad (6)$$

$$S_{2010} = z_2(x) \times e \qquad (e =< 300) \qquad (7a)$$

$$S_{2010} = z_3(x) \times e \qquad (e > 300) \qquad (7a)$$

The values of z_1-z_3 were provided by the 2010 Census of Manufactures (Aomori prefecture, 2011), the 2011 Basic Survey on Small and Medium Enterprises (Small and Medium Enterprise Agency of Japan, 2011), and the

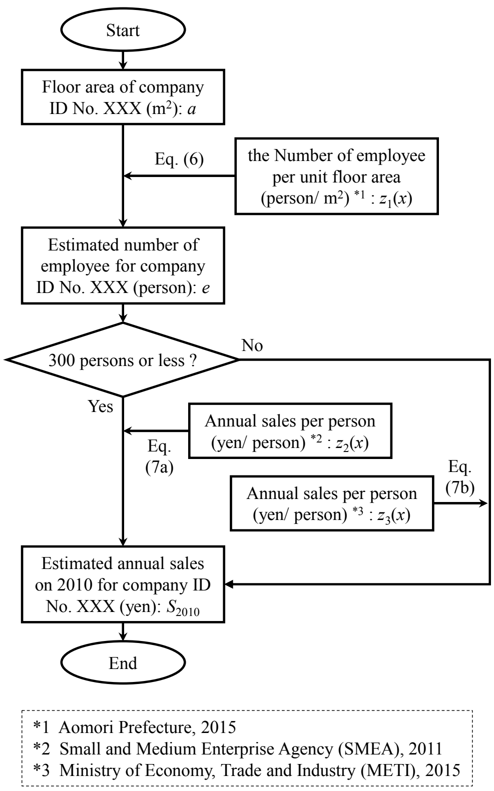


Fig. 3.8 Floor area and annual sales (SIC code 14, 12, 16, 31, 21 and 18)

Basic survey for activities of enterprises (Ministry of Economy, Trade and Industry, 2011). **Table 3.4** shows values of z_1-z_3. Target companies of the SMEA survey was limited to relatively small and medium enterprises, there was a limitation to apply the results of the survey to large size companies. Meanwhile, that of the METI survey was limited to large enterprises. That was reason that we had to sort out companies depending on the numbers of employees for applying Equation (7a) or (7b).

Finally, the author got the estimated annual sales in 2010 of 60 companies of the industrial sectors in the inundation area of Hachinohe city due to the 2011 Tohoku tsunami. **Fig. 3.9** shows the annual sales, and the estimated annual sales in 2010 was 370.0 billion yen in total.

Table 3.4 Constant coefficients z_1-z_3

(1) z_1 based on survey in Aomori Prefecture

SIC code	Employee (person)* : α	Floor area (m²)* : β	$z_1 = \alpha/\beta$ (person/ m²)
14	1,530	302,393	0.0051
12	106	10,389	0.0102
16	440	37,660	0.0117
31	668	28,112	0.0238
21	371	72,193	0.0051
18	883	61,572	0.0143

* Complete survey for 385 companies of 30 or more in employee

(2) z_2 based on survey throughout Japan

SIC code	Annual sales on 2010 (billion yen) : γ	Employee (person) : α	$z_2 = \gamma/\alpha$ (billion yen/ person)
14	3,325	167,848	0.0198
12	1,981	96,029	0.0206
16	6,453	212,069	0.0304
31	6,346	322,278	0.0197
21	3,879	202,264	0.0192
18	5,238	306,793	0.0171

* Sample survey for 1,668,082 companies of 300 or less in employee, or 300 million yen or less in capital stock

(3) z_3 based on survey throughout Japan

SIC code	Annual sales on 2010 (billion yen) : γ	Employee (person) : α	$z_3 = \gamma/\alpha$ (billion yen/ person)
14	5,038	102,613	0.0491
12	984	26,743	0.0368
16	31,265	496,546	0.0630
31	55,481	939,580	0.0590
21	4,204	98,045	0.0429
18	7,282	188,884	0.0386

* Sample survey for 37,600 companies of 50 or more in employee, and 30 million yen or more in capital stock (Collection rate: 84.6 %)

(4) Production Capacity Change

a) Production Capacity Rate

The author researched data on the 60 companies' production capacity. There were two required items: date, and the production capacity rate r. In this technical note, r was defined as follows: r of 0 indicated no production at that time. However, r of 1 indicated that production capacity was completely recovered and in the same level as before the tsunami. In some cases, r was more than 1 because of increased production along with capacity investment and increment of extra demand, and other factors.

The data was collected from two sources: the first ones were news articles that were provided by a local newspaper company, Daily Tohoku Shimbun Inc. from March 14, 2011, to March 6, 2014. The second ones were official websites of companies. A total of 23 data were found for 11 companies from these sources (**Appendix C**). The 23 data were related to the five industrial sectors, SIC codes of 10, 14, 22, 23, and 31; no data were collected for the industrial sectors with SIC codes of 9, 12, 16, 18, and 21. The failure to collect data on these five industrial sectors is a limitation of this survey.

Fig. 3.10 (1) to (6) shows the relation between r and the days since the earthquake and tsunami for overall data and the five industrial sectors, respectively. The Arabic number in the figure indicates the serial number of the data, shown in the seventh column of a table in **Appendix C**. The dotted line in each figure reflects the algorithm adopted was the least-square fitting. It is linear

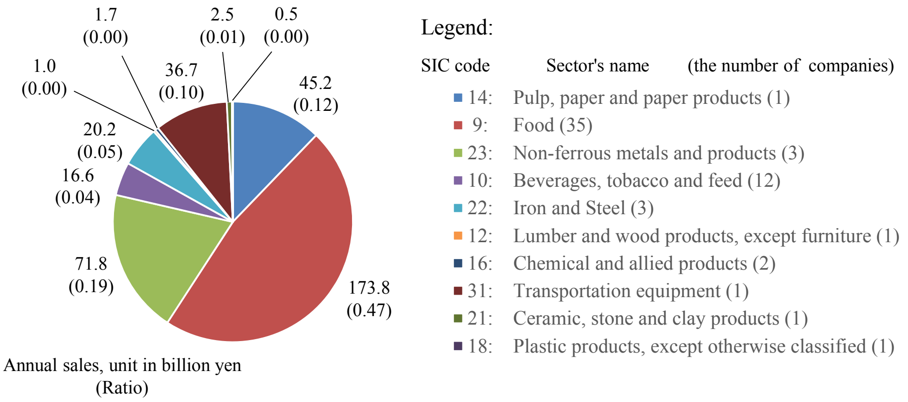


Fig. 3.9 Annual sales in 2010

relation between time t and r, and the approximate obvious that the R^2 values are not good for **Fig. 3.10** (1), (3), and (5). These R^2 values are quite low, in the range between 0.208 and 0.437. **Fig. 3.10** (6) has only two samples, which is not enough for evaluating R^2 value for the fitting line. Despite the difficulties described above, the author adopted the result in this study because no alternative data was available, an important issue to be addressed in the future. There is a possible question in assuming that the fitting line is linear, but it can be a quadratic curve or higher-dimensional curve shape.

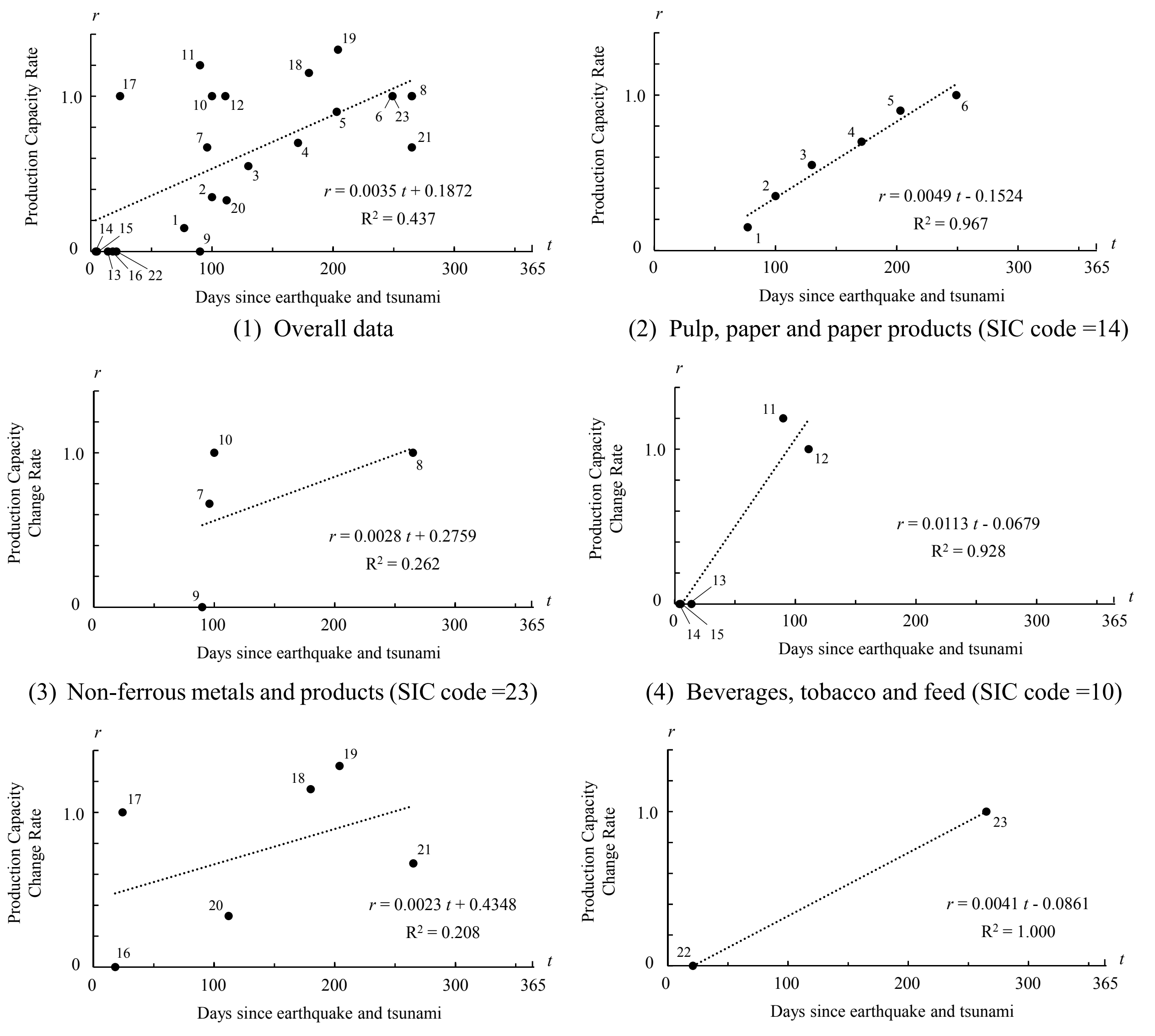
The point where the dotted line and $r = 1.0$ cross tells the estimated day when the production capacity had recovered completely. According to **Fig. 3.10** (1) to (6), the estimated days of complete recovery are 232, 235, 259, 95, 245, and 265 days since the earthquake and tsunami. These days were October 29, November 1, November 25, June 14, November 11, and November 30 of 2011, respectively.

Fig. 3.11 shows a conceptual diagram for calculation of production capacity change rate $\bar{r}_i(x)$. Area A is flow damage after the earthquake and tsunami, and area B is an actual annual sales. An integrated complement component of r in one year, $\bar{r}_i(x)$, was defined as:

$$\bar{r}_i(x) = \frac{A}{A+B} \tag{8}$$

where the over-line and index i of r indicated complement and integrated component of r, respectively.

In **Fig. 3.10** (1), it is easy to calculate an area of the triangular shape, i.e. an area surrounded by two lines and one axis, such as $r = 0.0035\ t+0.1872$, r=1.0, and t =0. After the calculation, the value of the area was divided by 365, thus giving the value of 0.258. This value was equal



(1) Overall data

(2) Pulp, paper and paper products (SIC code =14)

(3) Non-ferrous metals and products (SIC code =23)

(4) Beverages, tobacco and feed (SIC code =10)

(5) Iron and steel (SIC code =22)

(6) Transportation equipment (SIC code =31)

Fig. 3.10 Production Capacity

to $\bar{r}_i(x)$ in a year. Using this method, **Fig. 3.10** (2)-(6) gave 0.364, 0.257, 0.138, 0.190, and 0.392.

b) Production Capacity Change

An amount of stock damage caused by the earthquake and tsunami was approximately 121.2 billion yen, according to a document announced by the Hachinohe city office at the end of 2011 (Hachinohe City Office, 2011) (**Appendix D**).

Evaluating production capacity change $C(x)$ required two values: annual sales in 2010, $S_{2010}(x)$, which was the results from (3) b) of this chapter, and $\bar{r}_i(x)$ which was the results from (4) a) of this chapter. Multiplying the two values gave $C(x)$.

$$C(x) = S_{2010}(x) \cdot \bar{r}_i(x) \quad (9)$$

For SIC codes 9, 12, 16, 18, and 21, there was no direct data on $\bar{r}_i(x)$, and thus, the value for the overall case of **Fig. 3.10** (1) was applied.

The estimated flow damage from the production capacity change was approximately 101.7 billion yen in the industrial sectors of the area due to the earthquake and tsunami (**Table 3.5**). This estimate is equivalent to approximately 84 % of the stock damage in the city.

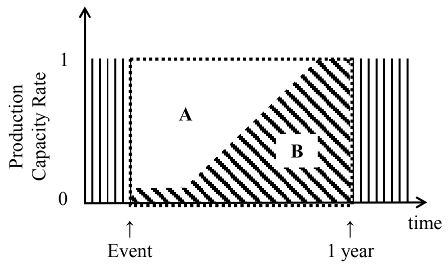


Fig. 3.11 Conceptual diagram for calculation of $\bar{r}_i(x)$

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Table 3.5 Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

SIC code	Name of Sector	Annual Sales in 2010 (billion yen)	Production Capacity Change Rate in a year	Production Capacity Change (billion yen)	Ratio
14	Pulp, paper and paper products	45.2	0.364	16.5	0.162
9	Food	173.8	0.258	44.8	0.441
23	Non-ferrous metals and products	71.8	0.257	18.5	0.182
10	Beverages, tobacco and feed	16.6	0.138	2.3	0.023
22	Iron and Steel	20.2	0.190	3.8	0.037
12	Lumber and wood products, except furniture	1.0	0.258	0.3	0.003
16	Chemical and allied products	1.7	0.258	0.4	0.004
31	Transportation equipment	36.7	0.392	14.4	0.142
21	Ceramic, stone and clay products	2.5	0.258	0.6	0.006
18	Plastic products, except otherwise classified	0.5	0.258	0.1	0.001
Total		370.0		101.7	1.000

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4. Conclusions

This technical note includes literature reviews of the previous researches on estimating natural disaster impact, stock damage, flow damage, and secondary and higher-level effects. The author focused on production capacity changes in industrial sectors due to the 2011 Tohoku tsunami, which followed the 2011 off the Pacific coast of Tohoku earthquake. The author highlighted the coastal area of Hachinohe city, which was damaged and inundated by the earthquake and tsunami. The main investigation method was collecting data on the activities of ten industrial sectors from published information, newspaper articles, and public announcements. The results showed that the estimated flow damage is approximately 101.7 billion yen in the industrial sectors of the area due to the earthquake and tsunami. This estimate is equivalent to approximately 84 % of the stock damage in the city.

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Prevention Division of NILIM for their kind supports, and Ms. Yoko Nishikawa, DPRI of Kyoto University, for her assistance to conduct the study.

Appendix A Annual sales of the 60 companies

Table A.1 Annual sales of the 60 companies

SIC code	Company's ID	Annual sales (billion yen)	Year	Data source/ sources
14	1	N/A	-	-
9	2	4.0	2014	Document published by Government [1]
	3	13.4 - 14.8	2007- 2014	Toyo Keizai Inc. [2)-7)]
	4	5.5	2014	Company's website [8]
	5	2.0	2012	Company's website [9]
	6	0.1	2012-2014	Document published by the Government [10)-12)]
	7	5.8	2014	Websites of the local news company or others [13]
	8	0.9	2014	Websites of the local news company or others [14]
	9	4.6	2013	Websites of the local news company or others [15]
	10	14.1 - 15.6	2010 - 2014	Toyo Keizai Inc. [3)-7)]
	11	2.0	2008	Ryutsukikaku Co., Ltd. [16]
	12-36	N/A	-	-
23	37	5.5 - 6.4	2010 - 2013	Toyo Keizai Inc. [3)-4)] Websites of the local news company or others [17]
	38	45.9 - 55.9	2012 - 2014	Document published by the Government [10)-12)]
	39	N/A	-	-
10	40	4.4 - 4.6	2012 - 2014	Toyo Keizai Inc. [10)-12)]
	41	0.4	2014	Document published by the Government [11]
	42	0.5	2014	Toyo Keizai Inc. [12]
	43	0.4	2012 - 2014	Toyo Keizai Inc. [10)-12)]
	44 - 51	N/A	-	-
22	52	40.0 - 53.4	2011 - 2014	Document published by the Government [10)-12), 18)]
	53	0.3	2014	Websites of the local news company or others [19]
	54	N/A	-	-
12	55	N/A	-	-
16	56	0.4 - 0.6	2012 - 2014	Document published by the Government [10)-12)]
	57	N/A	-	-
31	58	14.7 - 36.7	2006 - 2014	Toyo Keizai Inc. [2)-7)]
21	59	2.0 - 2.7	2006 - 2012	Company's website [20]
18	60	N/A	-	-

* N/A : Not available

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Appendix B Annual sales of Company ID No. 52

The annual sales on 2014 of Company ID No. 52 was estimated using documents provided by Financial Services Agency [1)-2)].
The company had two factories in Hachinohe and the other city, and one office. Estimated annual sales for the Hachinohe factory was calculated based on the numbers of employee in the factories and office. Results of the calculation were 12.1 and 16.7 billion yen in 2010 and 2014.

In the site of the Hachinohe factory, there were a sister company, and its annual sales was 4.4 [3)] and 6.6 [4)] billion yen in 2010 and 2014.

Finally estimated annual sales of company ID No. 52 were 16.6 and 23.3 billion yen.

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Appendix C Production capacity rate *r* and data sources

Table C.1 Production capacity rate *r* and data sources

SIC code	Company ID No.	Date (MM-DD-YYYY)	Days since tsunami	Production capacity rate *r*	Data source (Date of publishing)	Sequential serial number
14	1	05-27-2011	77	0.15	DTS (05-28-2011)	1
		06-19-2011	100	0.35	DTS (06-21-2011)	2
		07-19-2011	130	0.55	DTS (07-21-2011)	3
		08-29-2011	171	0.70	DTS (08-28-2011)	4
		09-30-2011	203	0.90	DTS (07-21-2011)	5
		11-15-2011	249	1.00	DTS (11-16-2011)	6
23	38	06-15-2011	96	0.67	DTS (07-13-2015)	7
		12-01-2011	265	1.00	DTS (07-13-2015)	8
	39	06-09-2011	90	0.00	DTS (06-12-2011)	9
		06-19-2011	100	1.00	DTS (06-12-2011)	10
10	40	06-09-2011	90	1.20	DTS (06-09-2011)	11
	44	06-30-2011	111	1.00	DTS (05-23-2011)	12
	46	03-25-2011	14	0.00	Document posted on website of company (03-25-2011) http://www.co-op.co.jp/	13
	48	03-15-2011	4	0.00	DTS (03-17-2011)	14
	49	03-16-2011	5	0.00	DTS (03-17-2011)	15
22	52	03-29-2011	18	0.00	DTS (04-05-2011)	16
		04-04-2011	24	1.00	DTS (04-05-2011)	17
		09-07-2011	180	1.15	DTS (09-07-2011)	18
		10-01-2011	204	1.30	DTS (09-07-2011)	19
	53	07-01-2011	112	0.33	Information posted on website of company http://kitanihon-mekki.co.jp/ (accessed on August 30, 2015)	20
		12-01-2011	265	0.67	Information posted on website of company http://kitanihon-mekki.co.jp/ (accessed on August 30, 2015)	21
31	58	04-01-2011	21	0.00	Information magazine of the Ports and Harbours Association of Japan, Vol. 91, April, pp. 36-37, 2014.	22
		12-01-2011	265	1.00	Information magazine of the Ports and Harbours Association of Japan, Vol. 91, April, pp. 36-37, 2014.	23

*DTS: News article of Daily Tohoku Shimbun, Inc., http://cgi.daily-tohoku,co.jp/cgi-bin/web_kikaku/m9_shinsai/news/ (accessed on April 24, 2013.)

Appendix D Stock Damage in Hachinohe City

Table D.1 Stock damage in Hachinohe City due to the earthquake and tsunami

Category	Damage in terms of Money, unit in thousand yen
Buildings	2,767,313
Commerce & Industry	56,688,622
Agricultural & Forestry	1,473,186
Fishery	16,773,024
Tourist business	127,679
Social welfare	180,682
Construction	41,319,554
Cultural & Education	364,977
The other public facilities	1,538,610
Total	121,233,647

Supplemental:

1) Intensity of the earthquake: 4 to 5 upper, measured on Japanese intensity scale of Japan Meteorological Agency

2) Human suffering:

Death	1 person
Missing	1 person
Serious injury	19 persons (including 5 persons due to aftershock in April 7, 2011)
Minor injury	52 persons (including 1 person due to aftershock in April 7, 2011)

3) Building damage:

Complete collapse	254 buildings
Middle of complete collapse & partially destroyed	181 buildings
Partially destroyed	590 buildings
Inundation above floor level	1,600 households

4) Updated date: December 31, 2011

Source: Hachinohe City Office, http://www.city.hachinohe.aomori.jp/index.cfm/26,39551,84,222,html (accessed on August 30, 2015.)

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