Ranking Name of Prefecture GNS

High Risk ← 1 8 15 22 26 33 40 47 → Low Risk

Rank	Prefecture	GNS	Exposure	Vulnerability	Hardware measures	Software measures
1	Tokushima	9.2	23.7	38.9	34.9	43.0
2	Aichi	8.6	21.6	39.7	37.4	42.0
3	Osaka	8.5	21.8	39.2	40.6	37.8
4	Niigata	8.4	20.4	41.4	38.2	44.6
5	Tokyo	8.1	21.9	37.2	34.9	39.4
6	Mie	7.9	20.0	39.6	33.6	45.7
7	Chiba	7.8	18.2	42.7	35.9	49.6
8	Saitama	7.4	17.6	42.1	36.7	47.5
9	Kanagawa	7.4	20.2	36.4	34.6	38.2
10	Wakayama	7.2	18.1	39.7	34.5	44.9
11	Shizuoka	7.1	17.9	39.6	35.5	43.7
12	Ehime	6.9	17.2	39.8	35.7	43.9
13	Kagawa	6.7	16.6	40.2	39.5	41.0
14	Kochi	6.2	15.0	41.1	37.5	44.7
15	Yamanashi	5.6	16.8	33.4	27.7	39.2
16	Yamagata	5.5	13.2	41.4	39.5	43.3
17	Ohita	5.1	13.1	39.3	37.5	41.0
18	Nagasaki	5.0	12.0	42.0	35.0	49.0
19	Gifu	4.8	13.0	36.6	31.0	42.3
20	Miyagi	4.7	11.4	41.2	39.5	43.0
21	Akita	4.3	10.4	41.5	36.0	47.0
22	Ibaraki	4.3	10.2	42.1	38.6	45.5
23	Nagano	4.3	11.2	38.1	36.5	39.7
24	Kyoto	4.2	10.1	41.3	43.6	39.1
25	Shiga	4.0	10.0	39.6	38.3	40.9
26	Hyogo	4.0	10.2	39.1	40.8	37.5
27	Kumamoto	3.9	9.7	40.5	37.8	43.1
28	Toyama	3.9	10.9	35.9	33.5	38.4
29	Fukui	3.8	10.7	35.9	33.7	38.0
30	Fukushima	3.8	8.7	44.0	40.0	48.0
31	Nara	3.7	9.2	40.3	37.2	43.5
32	Okinawa	3.7	7.9	46.8	42.5	51.1
33	Yamaguchi	3.6	9.0	39.7	42.4	37.1
34	Okayama	3.6	8.6	41.5	40.8	42.3
35	Iwate	3.4	8.0	42.3	35.1	49.5
36	Aomori	3.3	8.4	39.3	32.8	45.8
37	Fukuoka	3.0	7.3	41.2	41.6	40.9
38	Ishikawa	2.9	7.6	38.1	36.9	39.3
39	Kagoshima	2.5	6.3	39.5	39.4	39.7
40	Hokkaido	2.4	5.3	45.2	43.5	47.0
41	Shimane	2.3	6.2	38.1	34.9	41.4
42	Gunma	2.1	5.3	40.1	38.1	42.2
43	Hiroshima	2.1	5.1	41.3	40.8	41.8
44	Saga	1.4	3.4	41.3	38.0	44.7
45	Miyazaki	1.2	3.2	39.3	34.3	44.2
46	Tochigi	0.9	2.2	41.6	43.0	40.2
47	Tottori	0.8	2.2	35.0	29.5	40.6

GNS

Gross National Safety for natural disasters

[Version **2015**]

Kanto branch of Japanese Geotechnical Society (JGS-Kanto)
Technical committee for Geotechnical risk and social system such as law and lawsuit

What is GNS?

GNS is an abbreviation of Gross National Safety for natural disasters and an index, expressing quantitative risks for natural disasters. The key aim of GNS is to provide a tool for decision and policy makers, responsible for budget plan for preventing and mitigating natural disasters. Mitigation of natural disasters is closely related to the UN Millennium Development Goals, in particular, (1) to eradicate extreme poverty and hunger, and (7) to ensure environmental sustainability. International community has been working towards creating an index of disaster risk and vulnerability, in accordance with the Hyogo framework for action 2005-2015, both from the aspects of natural and social sciences.

Japan is prone to natural disasters. There is a fundamental need for creating a kind of safety index against potential natural disasters to guide us to transform our land into truly safe land. The index

must indicate how effective current hard and soft measures are to resist against potential natural disasters, and what measures are inadequate. Immediately after Great East Japan Earthquake on March 11, 2011, O.Kusakabe advocated an urgent need to create such an index of nation-wide safety index, together with Gross Domestic Product (GDP) and Gross National Happiness (GNH), to steadily transform Japan to safe land. He presented an initial concept of GNS,

This booklet presents the proposed method how to calculate 2015 version GNS, and the calculated results of GNS in the prefecture scale. The authors of this booklet hope that GNS can offer a scientifically sound index to assist the decision and policy makers to allocate proper and effective investment for prevention and mitigation of natural disasters, by showing how each prefecture annually progresses to upgrade the hard and soft measures against natural disasters to a desirable level. To do so, the method and the range of application of GNS will be continuously improved and data available will be continuously updated.

Damage by the 2007 Niigata-Chuetsu Oki earthquake at Ohmigawa Station in Kashiwazaki, Niigata Prefecture ¦ Photographed by Kazuya ITOH (2007.7.23)

 Damage by the 2011 The Great East Japan Earthquake at Shirakawa, Fukushima Prefecture ¦ Photographed by Kazuya ITOH (2011.5.6)

Gross National Safety for natural disasters

GNS Index 2015

Proposed method how to calculate 2015 version GNS, and the calculation results of GNS index in the prefecture scale, Here after.

Fundamental concept of 2015 version GNS

Risk indices for natural disasters presently widely used adopt the following form of function.

$$R = f\,(H,\ E,\ V,\ Re) \qquad (1)$$

where
- *R: risk*
- *H: hazard*
- *E: exposure*
- *V: vulnerability*
- *Re: resilience.*

In here, H x E means "exposure" in a broad sense, which is determined by population distribution, geology and topography in a particular region. V x Re is a value expressing the relationship between society and natural disasters. In the 2015 version GNS, $V = V\,(V, Re)$ is used.

Thus the equation (1) yields

$$R = f\,(H, E, V) \qquad (2)$$

The equation (2) is a form of function adopted in the GNS calculation. One of the simplest forms of the equation (1) may be

$$R = H \times E \times V \qquad (3)$$

The equation (3) is the actually used equation for the 2015 version GNS calculation.

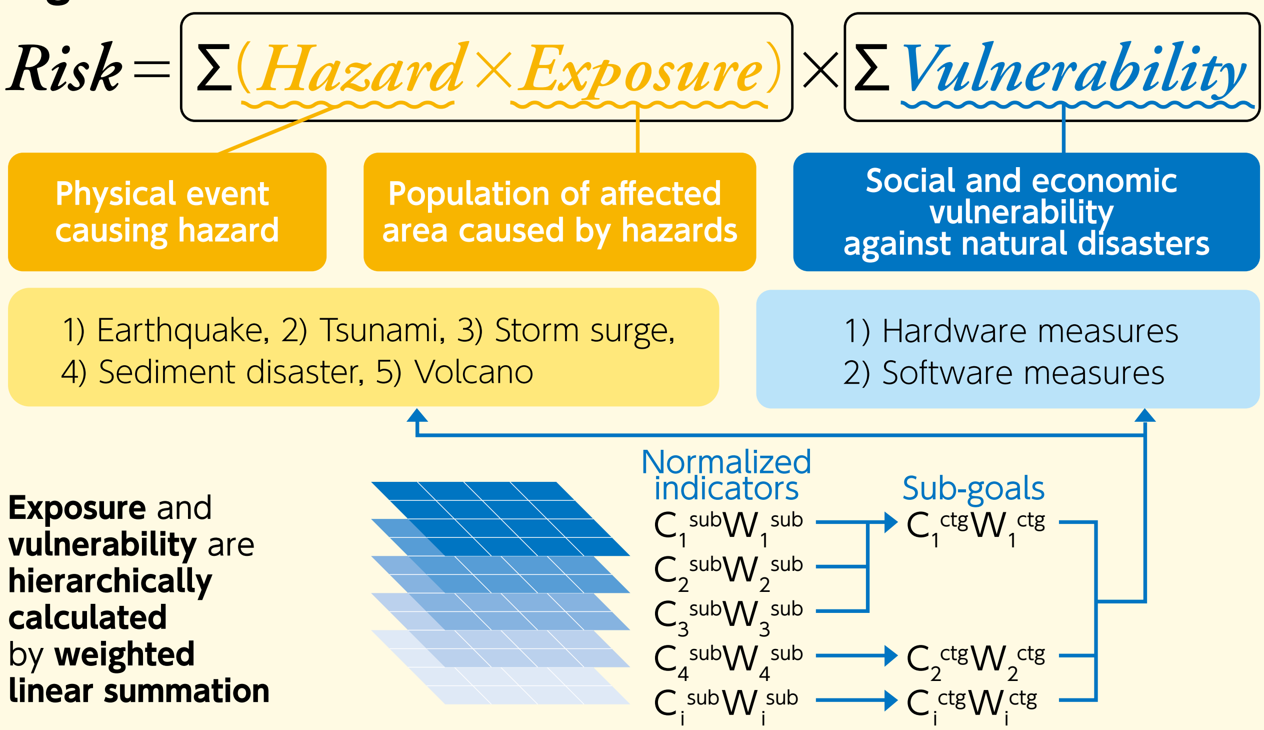
One of the features of the equation (3) is that R becomes null when one of the three parameters is null. Namely, in the cases where no physical event causing hazard occurs $(H = 0)$, nor no people lives in the affected area caused by hazard $(E = 0)$, society is resilient enough against natural disasters $(\lim V)$, R becomes null.

In the course of development of 2015 version GNS, the following points are taken into consideration in such a way that the decision and policy maker responsible for budge plan can easily access.

1. Data to be used should be free access for the purpose of continuous updating.
2. Data to be used should be available at the prefectural level to compare one prefecture to another.
3. Prioritizing the items affecting for improving natural disaster measures and the items with higher propriety should be selected.
4. The values of hazard, exposure and vulnerability should be hierarchically calculated by weighted linear summation as shown in Figure 1.

Three layered hierarchy system is used. The

Figure 1



Souse data of vulnerability Table 1

		Subgoals	Normalized indicator
Vulnerability	Hardware	Buildings	Rate of earthquake resistance of buildings, Rate of non-fireproof houses, Rate of damaged buildings
		Lifelines	Rate of earthquake resistance of water supply and drainage facilities, Percentage of decrepit pipelines
		Infrastructures	Road density index, Repair rate of bridges
		Information, networks	Rate of development of radio communication facilities for disaster prevention, Rate of development of J-alert system
	Software	Emergency stockpile	Stockpiling foods, Stockpiling water, Stockpiling blankets, Supermarket store index, Convenience store index
		Medical services	Number of physiciams per 100,000 population, Number of hospital beds per 100,000 population
		Economy and population	Financial capability index, Gini coefficient, Old-age index, Rate of persons who received public aid
		Insurance	Rate of participation in Earthquake Insurance
		Regulations and governance	Rate of specification of sediment disaster prone areas, Rate of publication of hazard maps, Coverage rate for the voluntary organization for disaster prevention

Source data of exposure Table 2

Risk components	Normalized indicator
Exposure	Earthquake (Interplate, Epicentral), Tsunami, Storm surge, Sediment disaster, Volcano

highest layer composes of hazard x exposure and vulnerability. The two components named indicator are calculated by summing up weighted corresponding sub-indicators. These weighted sub-indicators are obtained by the summation of the corresponding sub-categories. These sub-categories are determined by a cluster of free access data base, which are located at the lowest level in the hierarchy.

Framework of GNS in 2015 version

We have decided to adopt the simplest framework of GNS by the multiplying "vulnerability" and "exposure" for decision and policy makers of mitigation as a simple yet clear indicator. In the "vulnerability" calculation, available data are categorized into two; hardware measures and software measures as an ordinary accepted classification.

Vulnerability

The vulnerability indictor is a summation of weighted hard measures indicators and weighted soft measures indictors. The weighted coefficient (w) is selected as $w_i = 0.5$. Table1 lists sub-indictors with the corresponding sub-categories.

Hardware measures

Hardware measures means physical disaster prevention methods such as aseismic methods of structures, and upgrading methods of aged infrastructures to mitigate against natural disasters. Hardware measures indictors are classified into a group of sub-indicators named a sub-category. Four sub-categories are selected:(1) house, public facilities, (2) utility lines such as gas, water, sewage network (3) infrastructures (4) information, telecommunication.

In the process of calculation of hardware measures indictors, sub-categories are calculated from 14 different data bases and then sub-categories are multiplied by weighted coefficients, leading to the values of these sub-categories. Finally the hardware measures indicators are obtained by multiplying the weighted coefficient of $w_i = 0.25$.

Software measures

Software measures means a measures other than hardware measures, including a social system of conducting frequent disaster education, stocking food for emergency and preparing manuals at the time of disasters. Four sub-categories are selected. (1) relief goods, food stock, (2) medical services, (3) economy& population structure, (4) insurance, (5) regulations/autonomy.

Similar to that in the calculation process of hardware measures index, sub-indicators are obtained from a cluster of 22 database, and sub-categories are multiplied by weighted coefficients. Except the weighted coefficient for insurance, $w_i=0.1$. the same value of $w_i=0.25$ is used.

Exposure

(1) Earthquake

There are two types of earthquake; trench type earthquakes and earthquakes located directly above the focus. In the 2015 version GNS, the data are normalized by different methods for each type of earthquake.

Trench type earthquakes

For the trench type earthquakes, the Maps indicating the population in the affected areas in J-SHIS Map prepared by National Research Institute for Earth Science and Disaster Prevention are used. The Map provides the distribution of population (population seismically exposed. PSE) in the areas, of which seismic intensity exceeds a certain value, for a given focus and a given magnitude of earthquake. In the 2015 version GNS calculations, equal or over the seismic intensity of 6 caused by the above 13 earthquake is taken as "Exposure" for the trench type earthquakes.

Earthquakes located directly above the focus

For the earthquakes located directly above the focus, extended lengths of active faults are selected. The extended lengths are divided by the total area of the prefecture, which is equivalent to a density of active faults.

Because clear separation of exposures calculated due to these two types of earthquake is not easy, the average value of the two exposures is used in the calculation.

(2) Tsunami

Frequency coefficient is evaluated by using the data of the number of occurrence of tsunami during the period of 1498 to 2006. Exposure is calculated by multiplying the number of people living less than 3m above the sea level and the frequency coefficient.

(3) High tide (Storm surge)

Frequency coefficient is evaluated by using the data of the number of occurrence of high tide up to the year of 1961. Exposure is calculated by multiplying the number of people living less than 3m above the sea level and the frequency coefficient. The difference between the exposure due to Tsunami and the exposure due to high tide is only the location and the frequency of occurrence.

(4) Sediment disasters

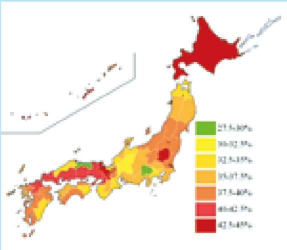
Exposure due to sediment disasters is calculated by the number of people living in a potential affected zone. There are two categories in the potential affected zone; debris flow and steep slopes, in terms of the number of people. In Category I, there are more than five houses, and in Category II there are one to four houses. We assume that there are, in an average, ten houses in Category I, while there are two and a half houses in Category II. In land slide area, we also assume that there are houses. By summing up all the number of houses is divided by the total number of people in the prefecture, Exposure is obtained. The frequency coefficient is defined by a ratio of the number of occurrence per year to the number of locations. Exposure is calculated by multiplying the frequency coefficient and exposure.

(5) Volcanic disasters

Frequency ratio is obtained from the data book of volcanic activities since 1600 complied by Japan Meteorological Agency. Exposure for volcanic disaster exposure is multiplying the number of people living the volcanic areas and the frequency ratio.

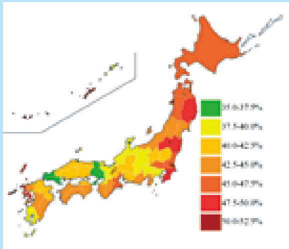
In the 2015 version GNS, weighted values for all five indicators are taken as the same value of 0.20.

Vulnerability

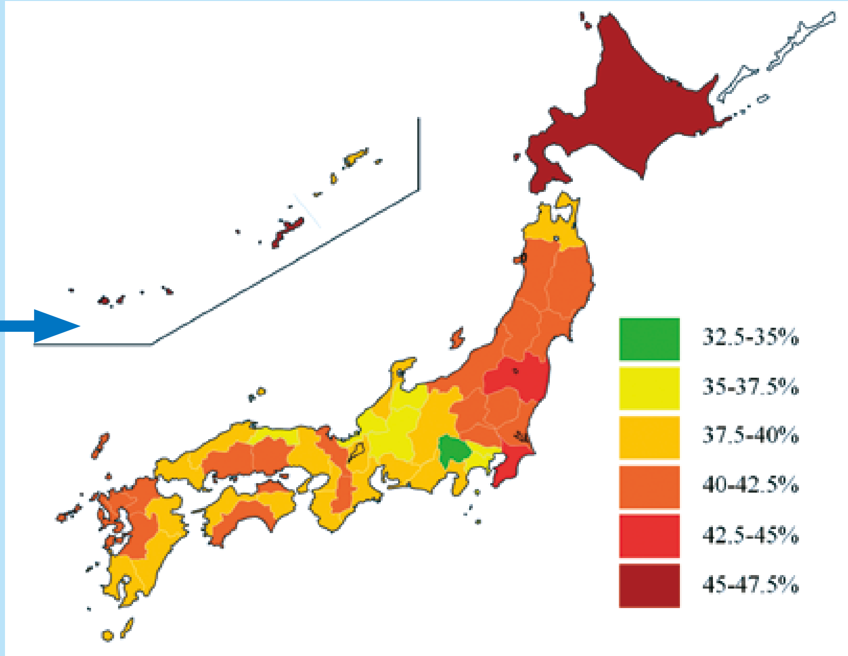


Hardware measures indicator

+



Software measures indicator

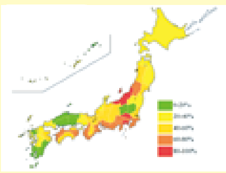


Vulnerability indicator The vulnerability indicator is a summation of weighted hardware measures indicators and weighted software measures indicators. The hardware measures indicators were small in Yamanashi, Tottori and Gifu and large in Kyoto, Hokkaido and Tochigi prefectures. While the software measures indicators were small in Yamaguchi, Hyogo and Osaka and large in Okinawa, Chiba and Iwate prefectures. As a result, the vulnerability indicators were small in Yamanashi, Tottori, Toyama and Fukui and large in Okinawa, Hokkaido and Fukushima prefectures.

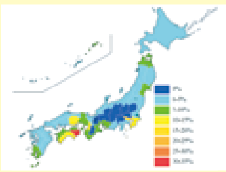
Multiplying "Vulnerability" × and "Exposure" → GNS

Exposure

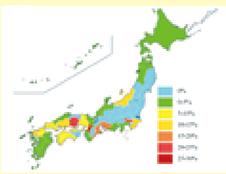
Earthquake



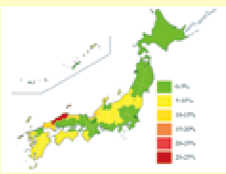
Tsunami



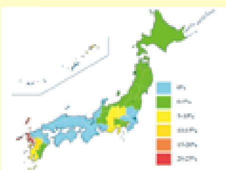
High tide

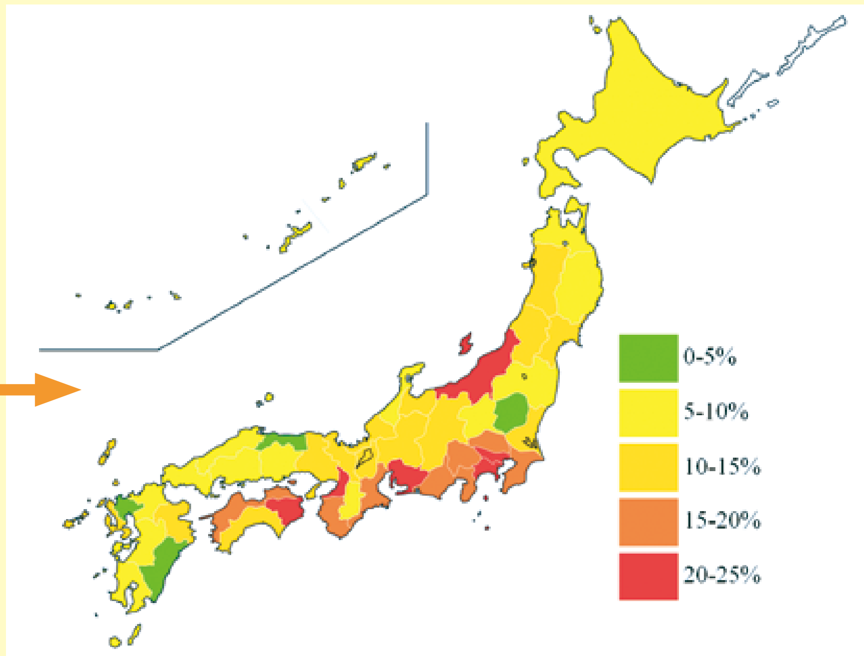


Sediment disasters



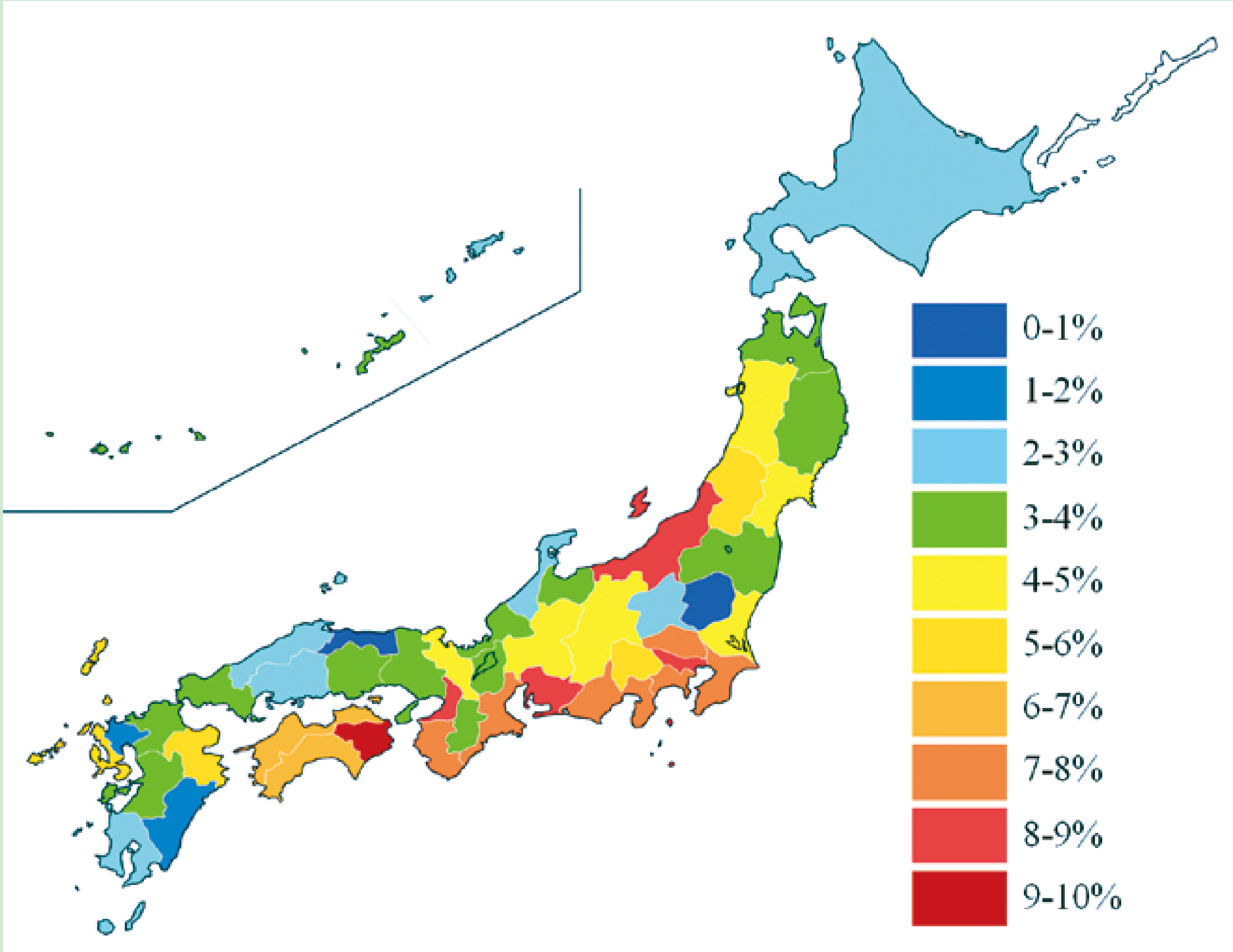
Volcanic disasters





Exposure indicator

The exposure indicators were large in Tokushima, Tokyo and Osaka and small in Miyazaki, Tochigi and Tottori prefectures.



Features of GNS [2015]

GNS is obtained by multiplying values of vulnerability and the value of exposure. The table below lists the values of the best and worst four prefectures. It is noticed that GNS is largely affected by the value of exposure. Suppose that the risks for natural disasters are substantially governed by the exposure to natural disasters, an option may be feasible to reduce the exposure itself. Based on equation (1), it is impossible to make occurrence of natural disaster to be null, and measures for reducing the vulnerability may not be guarantee risk to be null and a considerable expenditure is required. In this context, transference of population to safer locations may become a possible option to reduce the value of GNS. Policy of changing population distribution step by step, together with upgrading hard and soft measures, may be possible to reduce potential risks for natural disasters.

Best four prefectures
Ranking Name of prefecture GNS

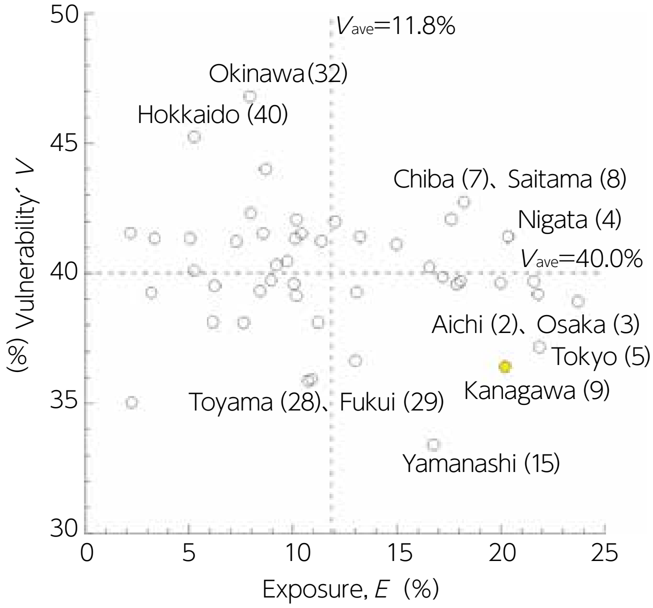
Rank	Prefective	GNS
1	Tottori	0.8
2	Tochigi	0.9
3	Miyazaki	1.2
4	Saga	1.4

Worst four prefectures
Ranking Name of prefecture GNS

Rank	Prefective	GNS
1	Tokushima	9.2
2	Aichi	8.6
3	Osaka	8.5
4	Niigata	8.4

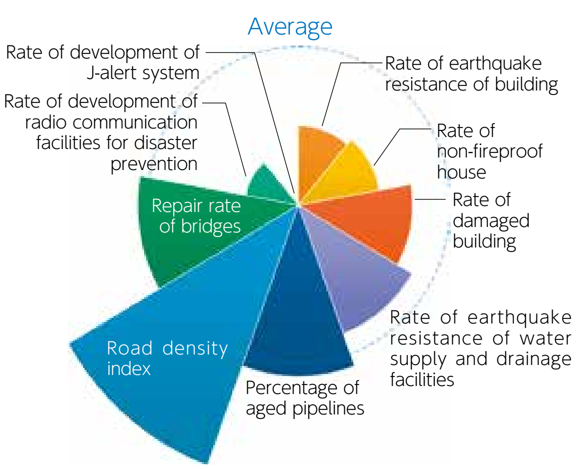
An example of effective use of GNS

The figure on the right side shows vulnerability values plotted against corresponding exposure values for various prefectures. Dotted lines indicate the mean values. As an example, a close look of the values of Kanagawa Prefecture reveals that Kanagawa Prefecture has a smaller vulnerability value and a larger exposure value. Although Kanagawa prefecture has a smaller value of vulnerability, the prefecture actually have issues to be considered and improved when further detailed is examined in hardware and software measures. The figure below shows the values of various vulnerability indicators relative to the national average (indicated by a dotted circle) with respect to the hard and soft measures, respectively. From the figures, it is clear that road density in the prefecture is insufficient for the hard measures, while the numbers of medical doctors and beds, areas covered by independent anti-disaster organizations, are inadequate for the soft measures. Doing such visualization of insufficient indicators leads to prioritization of mitigation measures, which is a beneficial merit of GNS.

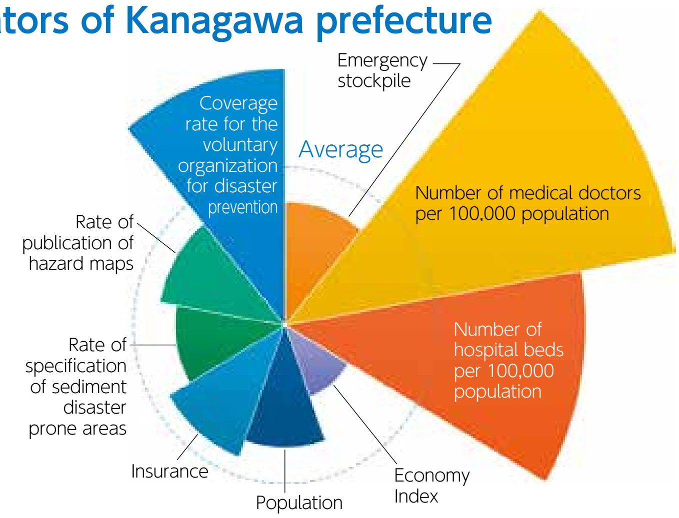


Vulnerability value plotted against corresponding exposure values for various prefectures

Example : The vulnerability indicators of Kanagawa prefecture



Hardware measures



Software measures

 Building Damaged by eruption of Mt. Usu at Toya caldera, Hokkaido Prefecture ¦ Photographed by Hideki INAGAKI (2011.5)

Gross National Safety for natural disasters

GNS Index 2015

List of data used in GNS2015

1 Exposure related data base

The data of population are released together with the indicator statistics about vulnerability in many cases. Then this list includes it together with vulnerability indicator.

1 Web site

1	National Research Institute for Earth Science and Disaster Prevention (2015) J-SHIS, Japan Seismic Hazard Information Station, http://www.j-shis.bosai.go.jp/en/
2	Japan Meteorological Agency (2015) Summary of Tables explaining the JMA Seismic Intensity Scale, http://www.jma.go.jp/jma/en/Activities/intsummary.pdf
3	Geospatial Information Authority of Japan (2015) Active Fault Map in Urban Area, http://www.gsi.go.jp/bousaichiri/active_fault.html
4	The Headquarters for Earthquake Research Promotion (2015) http://www.jishin.go.jp/main/index-e.html
5	Jiban-net (2015) Jiban Anshin Map (Disaster prevention map) http://www.jibanmap.jp/map/main.php
6	Abe, K. (2006) Size of tsunamis around Japan for 1498-2006, http://www.eic.eri.u-tokyo.ac.jp/tsunamiMt.html
7	Japan Meteorological Agency and Volcanological Society of Japan (2003) National Catalogue of the Active Volcanoes Japan, http://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/souran_eng/menu.htm
8	National Land Information Division, National Spatial Planning and Regional Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism (2015) National Land Numerical Information download service, http://nlftp.mlit.go.jp/ksj-e/index.html

2 Publications

1	Active Faults Research Group (1991) Active faults in Japan, University of Tokyo Press, p. 437.
2	Nakata,T. and Imaizumi, T. (2002) Detail Active Faults of Japan, University of Tokyo Press, p. 59, DVD.
3	Arakawa, T., Ito, Y. and Ishida, C. (1961) The History of storm surge in Japan, Meteorological Research Institute.
4	Miyazaki, M. (1956) Japan's coast menaced by storm surge damage, Proc. 3 Conference on Coastal Engineering, pp. 1-8 (in Japanese).

2 Vulnerability/ susceptibility/ coping capabilities/ adaptive capabilities related data base

1 Web site

1	Cabinet Office, Government of Japan (2015) White Paper on Disaster Management (Damage costs), http://www.bousai.go.jp/kaigirep/hakusho/index.html
2	Ministry of Land, Infrastructure, Transport and Tourism (2015) Rate of seismic upgrades to buildings, http://www.mlit.go.jp/common/000133730.pdf
3	Statistics Bureau (2015) National Survey of Family Income and Expenditure, http://www.stat.go.jp/english/data/zensho/index.htm
4	Ministry of Health, Labour and Welfare (2015) National Survey on Public Assistance Recipients, http://www.e-stat.go.jp/SG1/estat/eStatTopPortalE.do
5	Cabinet Office, Government of Japan (2015) SNA (National Accounts of Japan), http://www.esri.cao.go.jp/en/sna/menu.html
6	Statistics Bureau (2015) Population Estimates, http://www.e-stat.go.jp/SG1/estat/eStatTopPortalE.do
7	Japan Water Research Center (2012) WRC Hot News No342 (Rate of seismic upgrades to water system,) http://www.jwrc-net.or.jp/hotnews/pdf/HotNews342.pdf
8	Japan Water Research Center (2012b) WRC Hot News No330-2 (Old tube to more than 40 years), http://www.jwrc-net.or.jp/hotnews/pdf/HotNews330-2.pdf
9	Ministry of Land, Infrastructure, Transport and Tourism (2015) Road Statistics (Maintenance and Repair), http://www.mlit.go.jp/road/sisaku/yobohozen/yobo5_3.pdf
10	Fire and Disaster Management Agency (2015) White Paper on Fire Disaster, http://www.fdma.go.jp/concern/publication/index_2.html
11	Fire and Disaster Management Agency (2015) Prevent disasters in regional areas, http://www.fdma.go.jp/disaster/chihoubousai/
12	New Supermarket Association of Japan (2015) Supermarkets number of statistics, http://www.super.or.jp/?page_id=2646.
13	Nippon Telegraph and Telephone Corporation (2015) i Town Page, http://itp.ne.jp/?rf=1

14	Ministry of Health, Labour and Welfare (2015b) Survey of Physicians, Dentists and Pharmacists, http://www.e-stat.go.jp/SG1/estat/eStatTopPortalE.do
15	Ministry of Internal Affairs and Communications (2015) Local Public Finance, http://www.soumu.go.jp/iken/ruiji/(accessed 2015-12-09).
16	General Insurance Rating Organization of Japan (2014) Earthquake Insurance in Japan, http://www.giroj.or.jp/english/pdf/Earthquake.pdf
17	Ministry of Internal Affairs and Communications (2015) The earth and sand disaster prevention, http://www.soumu.go.jp/menu_news/s-news/000066869.html
18	Ministry of Land, Infrastructure, Transport and Tourism (2015) Hazard map portal site, http://disaportal.gsi.go.jp/
19	Ministry of Health, Labour and Welfare (2015) Securement and cultivation of medical professionals, http://www.mhlw.go.jp/jigyo_shiwake/gyousei_review_sheet/2015/h26_1-2-1_saisyu.html
20	Ministry of Internal Affairs and Communications (2015) Local allocation tax, http://www.soumu.go.jp/main_sosiki/c-zaisei/kouhu.html

2 Publications

1	Ministry of Internal Affairs and Communications (2008) Housing and Land Survey 2008,
2	Statistical Information Institute Consulting and Analysis (2015) Demographic statistics according to the topography and analysis

Gross National Safety for natural disasters

GNS [Version **2015**]

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Technical committee for Geotechnical risk and social system such as law and lawsuit
GNS Working group

[Cover Photo]

Damage by the 2011 The Great East Japan Earthquake at iwaki, Ibaragi Prefecture ¦ Photographed by Kazuya ITOH (2011.5.7)

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