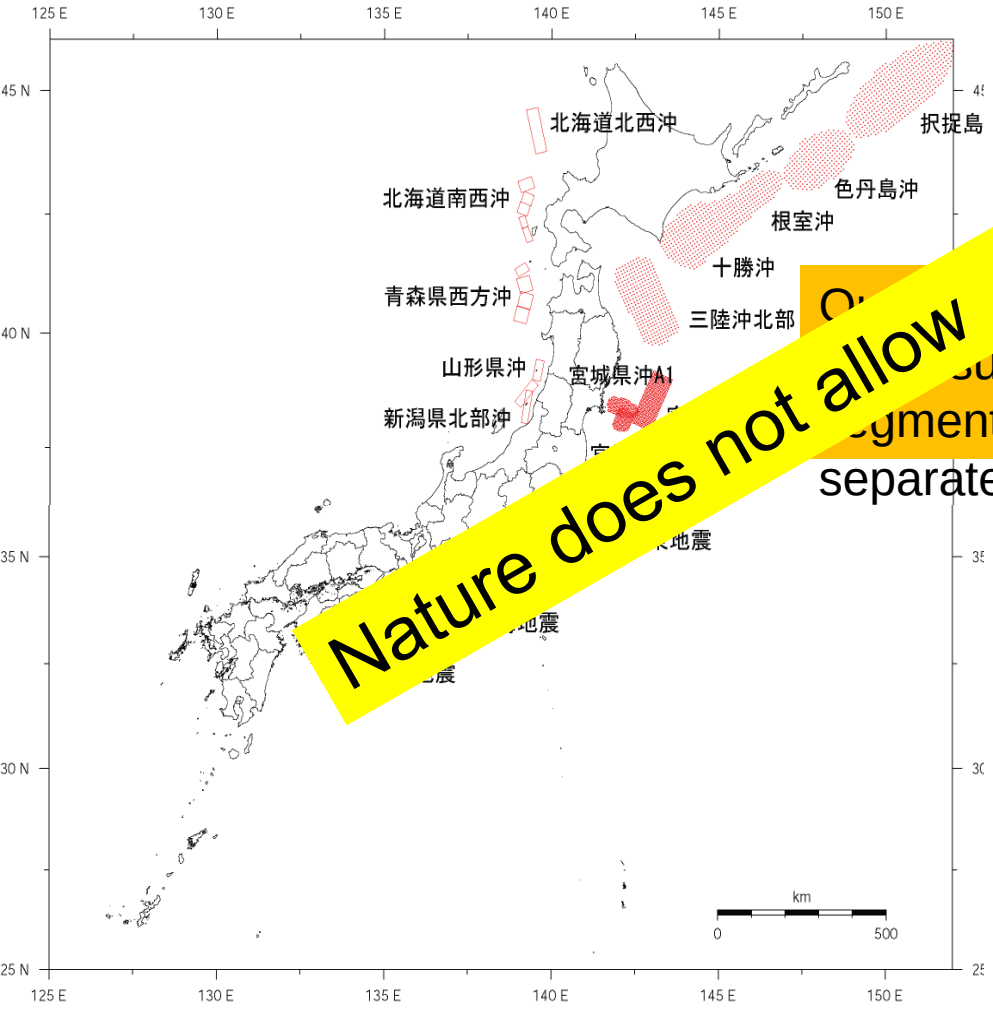
DEALING WITH THE BIG ONE IN THE DISASTER RISK REDUCTION PLANNING: ISSUES AND CHALLENGES

Disaster Prevention Research Institute (DPRI), Kyoto University

Expected inter-plate earthquake sources for long term earthquake prediction



Nature does not allow our assumptions!

Our [illegible] are based on the assumption that each segment moves separately.

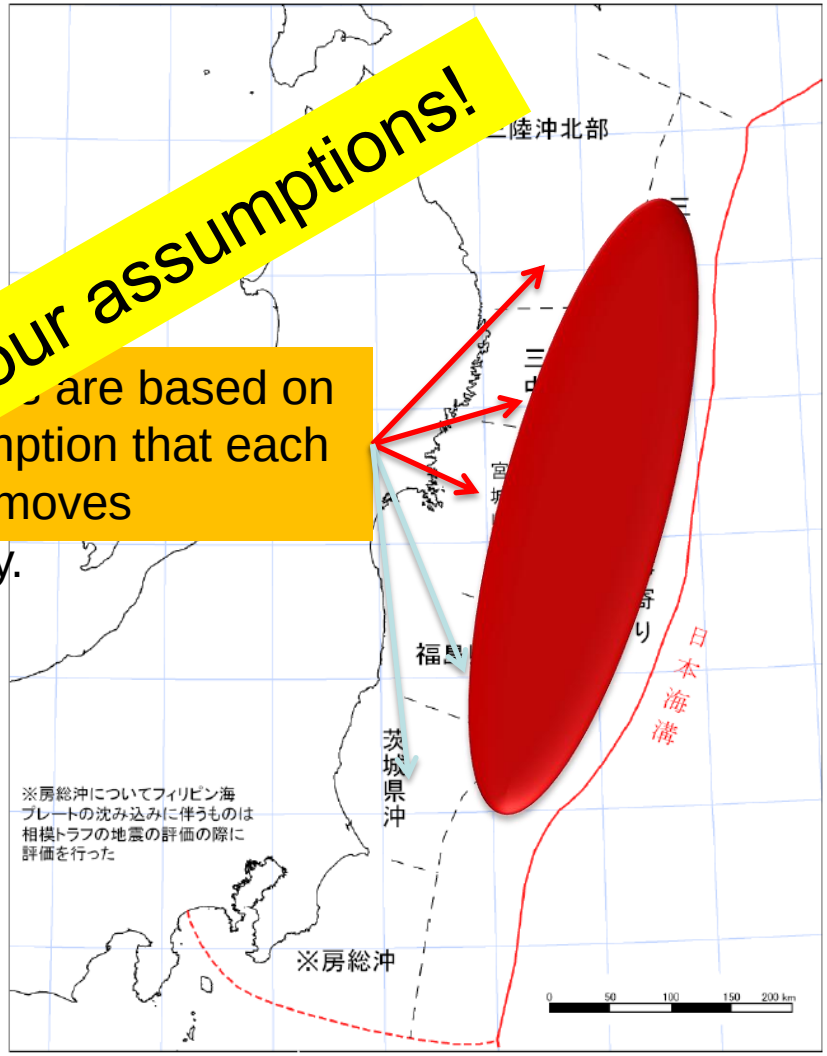
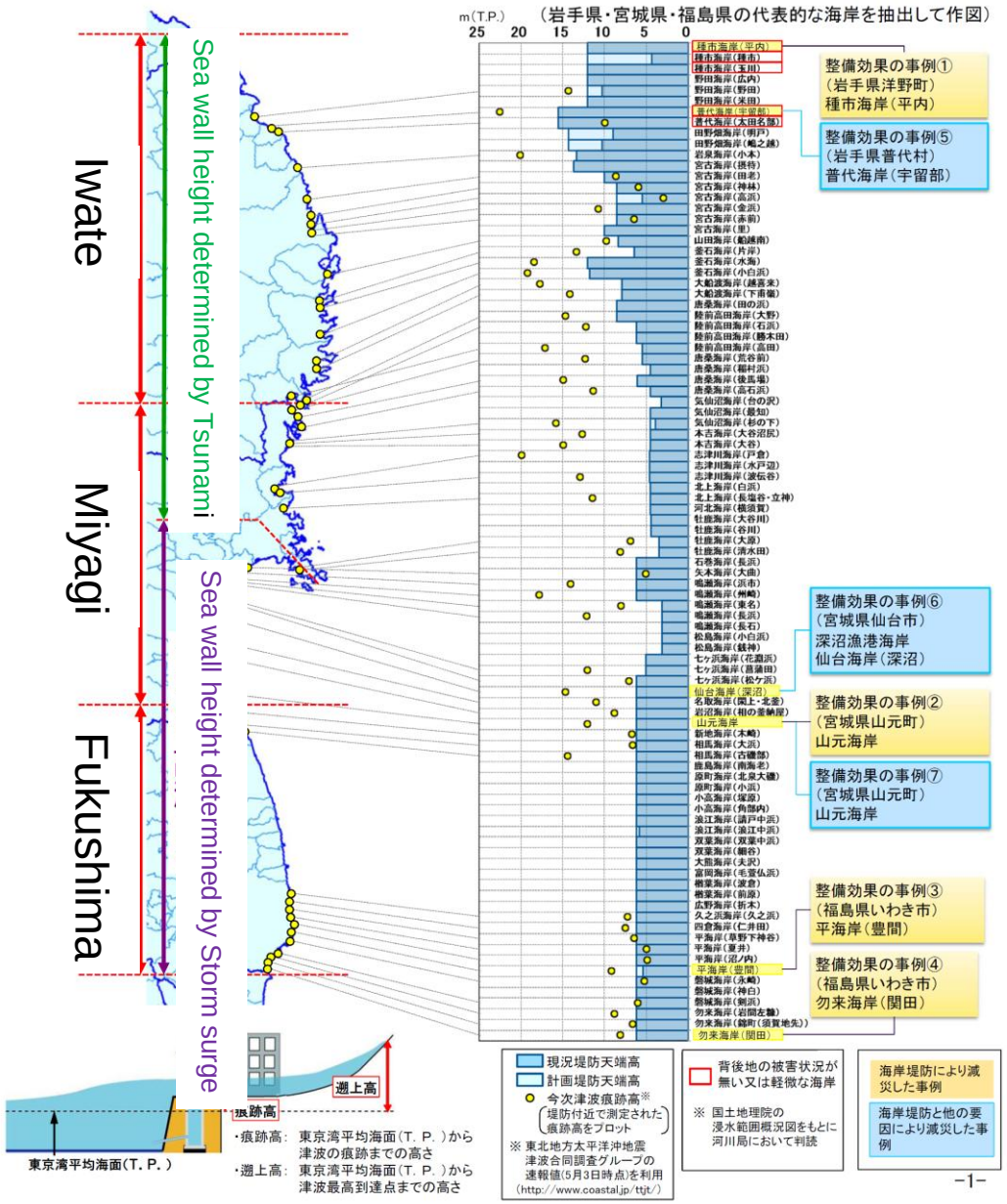


図1　三陸沖北部から房総沖の評価対象領域

地震調査委員会(2009)：三陸沖から房総沖にかけての地震活動の長期評価（一部改訂）（平成21年3月9日公表）

Development of sea walls and their damages



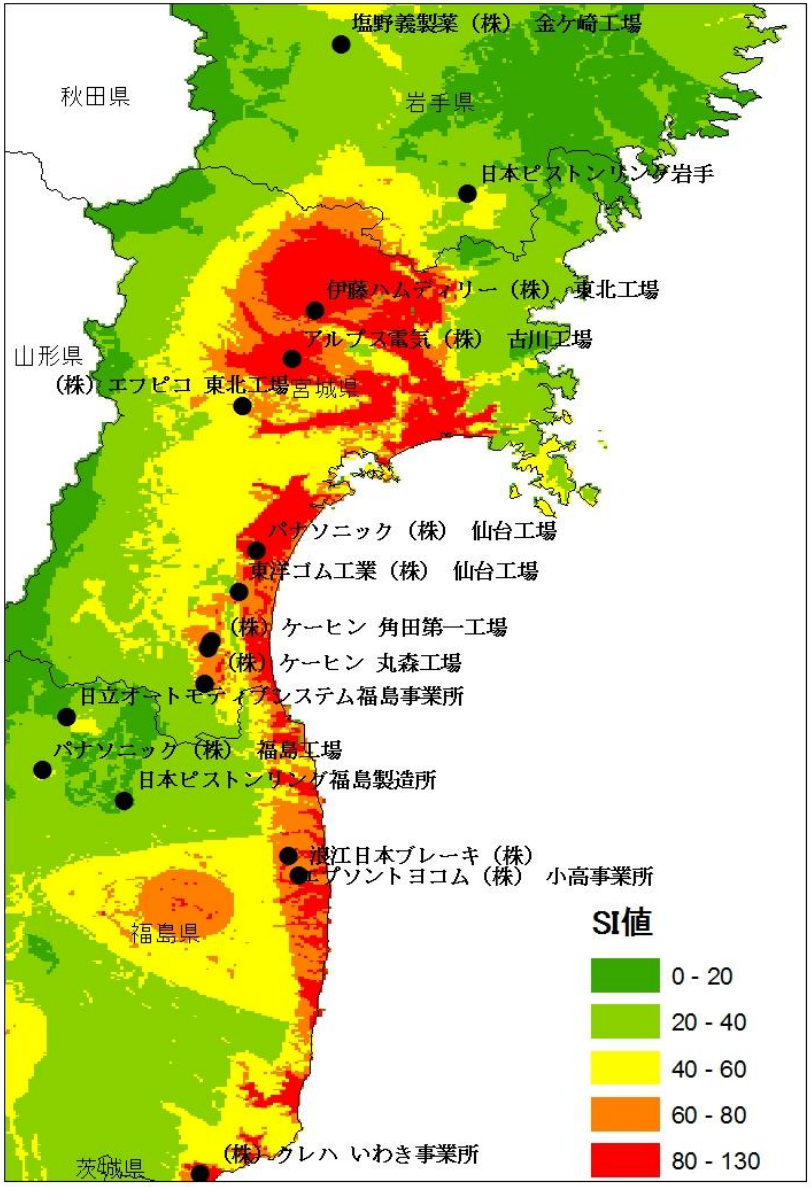
農林水産省・国土交通省

Otsuchi Town

Not only wooden but also steal buildings suffered damage.

Town office was also damaged.

Distribution of SI and Location of affected Firms



Impacts

- Dead and Missing: 16,019 and 3,805
- Housing: 118,821 (collapsed) , 181,801(half-collapsed)
- Tsunami Inundated Area: 507 km^2
- Direct Damage: USD about 200 billion
  (16.9 trillion JPYen)(without Nuclear Power plant failure)
- Total Economic Loss may exceeds USD 500~600 billion

Economic Impact of Tsunami

- Direct losses
  - Agriculture, Fisheries and Forestry:
    USD 17 Billon (USD 9 billion, USD 7 billion, USD 1 billion)
  - Industries:
    USD 60-110 Billion by Tsunami
    [production capital USD 900 billion (Iwate, Miyagi, Fukushima)]
- Cascading Effect through supply chain, e.g., Automobile, IT industries, even for Construction Industries
- Electric Power Shortage:

TEPCO: 6000->3400MW (5500to be increased by summer)

Insurance Payout:

1.163 trillion JPN (Households Earthquake Insurance, as of Oct. 12)

529 billion JPN (JA Kyosai (Zenkyoren) as of July 19)

→Muteki bond (sponsored by Munich Re) can reduce $300 million losses. (insurance insider April 4 2011)

Shortage of Material Supply

被災に関連した素材の需給状況

（×＝極端な品薄
△＝品薄
○＝正常化にメド
◎＝正常）

合　板	×	被災地以外の国内メーカーが増産に動くも、物流の混乱で入手困難に
塩化ビニール樹脂	×	信越化学工業とカネカのプラントが停止中。大洋塩ビのプラントは定修に
ポリエチレン・ポリプロピレン	△	三菱化学グループの茨城と千葉の主要プラントが停止中
断熱材	△	一部工場で再稼働の動きも、供給難続く。輸入などで５月にも需給改善へ
合成ゴム	△	ＪＳＲの鹿島工場の一部製造設備が稼働を再開
段ボール原紙	○	被災したレンゴーの仙台工場は生産停止。周辺工場の増産分を振り向ける
建設用ガラス	○	旭硝子鹿島工場が停止中。４月中旬に復旧へ
セメント（一般品）	◎	東北地方中心に公共事業が停止した影響で需要が大幅に減少
Ｈ形鋼	◎	復興需要はまだ限定的。東京製鉄宇都宮工場の稼働再開もあり供給は安定

Compound Wood Board

Ofunato has large share.

Plastic Vinyl Chloride

Shinetsu Chemical and Kaneka is stopping their production.

Polyethylen / Polypropylene

Mitsubishi Chemical group at Kashima and Chiba stops their production.

heat insulator

synthetic rubber

A part of JSR Kashima starts production.

4 /12　Nikkei
日経新聞朝刊

Port Kashima

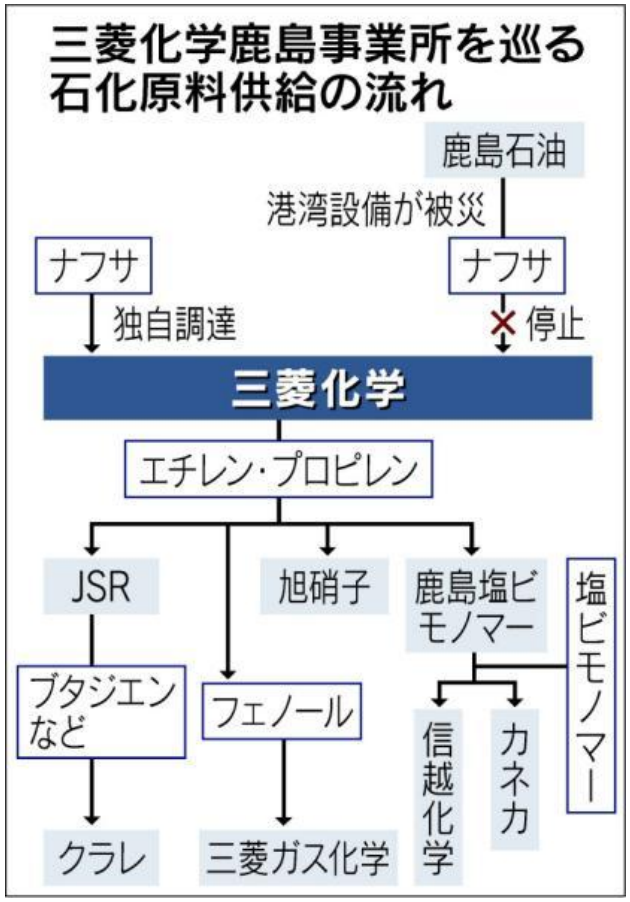
Apr, 26

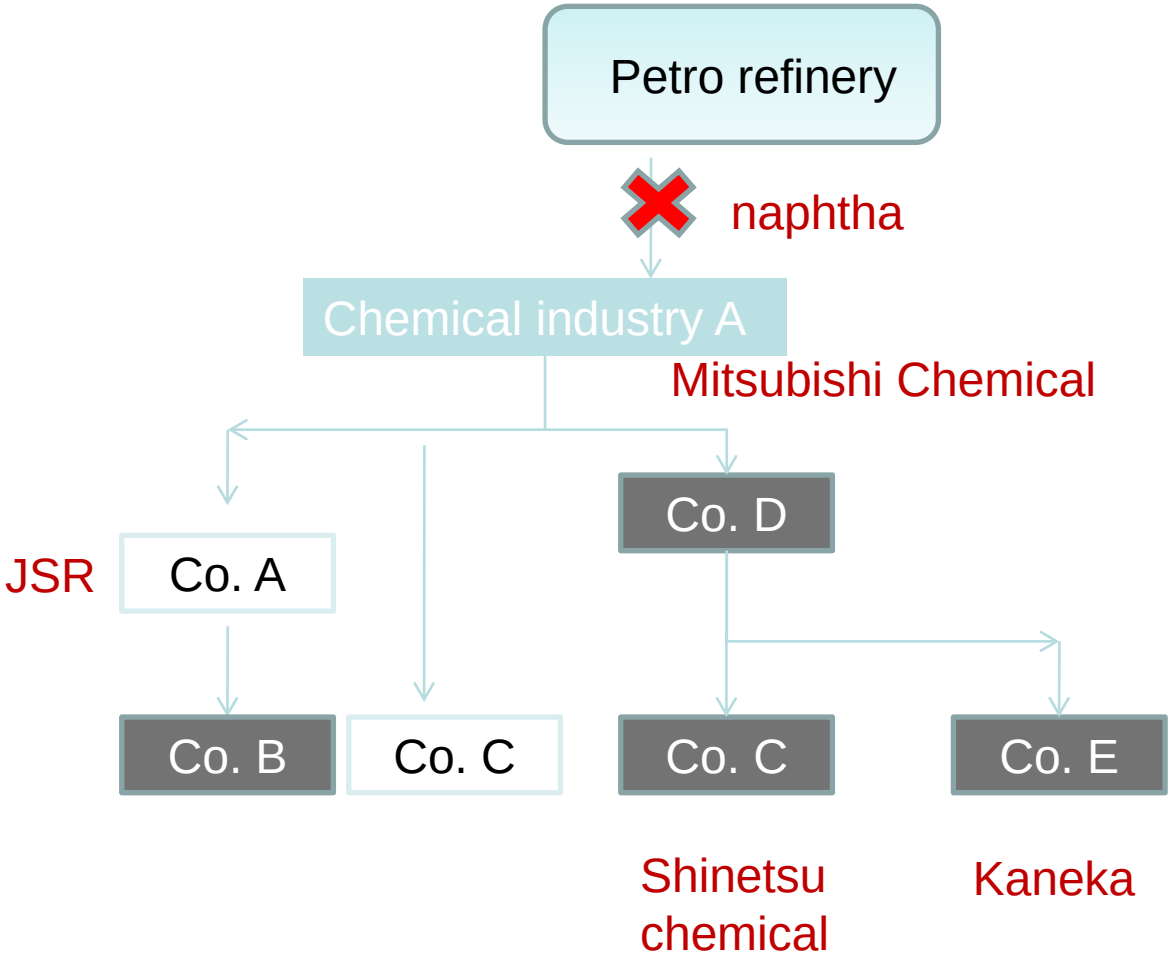
鹿島港

岸壁の損壊

提供：国交省港湾局

What happened in Kashima Port Area?





Liquefaction, ground motion and Tsunami affects production facility heavily at Kashima Port area. Cascading impact of stoppage of naphtha was critical and affected to many companies located at the port area.

Kashima port area

- Industrial complex (above 170 companies)
- Interdependent
  - pipelines
  - Petro chemical materials
- 1.8 triilion JPYen/year

鹿島臨海工業地帯の主な立地企業（鹿島臨海工業地帯企業連絡協議会会員会社）

（平成20年9月1日現在）※一部除く

地区	企業名
高松地区（4社）	住金プラント（株）
	住友金属工業（株）
	中央電気工業（株）
	住友鋼管（株）
神之池東部地区（24社）	旭硝子（株）
	（株）ADEKA
	（株）ユポ・コーポレーション
	鹿島液化ガス共同備蓄（株）
	鹿島塩ビモノマー（株）
	鹿島北共同発電（株）
	鹿島ケミカル（株）
	（株）ティーエムエアー
	鹿島石油（株）
	鹿島電解（株）
	鹿島南共同発電（株）
	（株）カネカ
	関東住雷硝子（株）
	（株）クラレ
	信越化学工業（株）
	三井化学（株）
	東京電力（株）
	JSR（株）
	三菱化学（株）
	三菱ガス化学（株）
	ライオンケミカル（株）
	鹿島共同再資源化センター（株）
	鹿島共同施設（株）
	GTFグリーンパワー（株）
神之池西部地区（26社）	花王（株）
	日本アルコール産業（株）
	鹿島サイロ（株）
	鹿島飼料（株）
	関東グレーンターミナル（株）
	協同飼料（株）
	（株）ジェイ　エス　ピー
	清水港飼料（株）
	（株）ジャパンフィード

地区	企業名
神之池西部地区（26社）	昭和産業（株）
	全国農業協同組合連合会
	全国酪農業協同組合連合会
	全農サイロ（株）
	DIC（株）
	中部飼料（株）
	日本乳化剤（株）
	日本配合飼料（株）
	JA東日本くみあい飼料（株）
	平成飼料（株）
	日清丸紅飼料（株）
	（株）ジェムコ
	明治飼糧（株）
	雪印種苗（株）
	住金大径鋼管（株）
	中国木材（株）
	日本水産（株）
波崎地区（19社）	フレキシス（株）
	石津建材（株）
	エーザイ（株）
	鹿島動力（株）
	クボタ松下電工外装（株）
	（株）サン・ペトロケミカル
	三洋化成工業（株）
	太陽肥料（株）
	ダイキン工業（株）
	高砂香料工業（株）
	タカラスタンダード（株）
	鶴見化学工業（株）
	（株）トクヤマ
	日本化薬（株）
	（株）ニチノーサービス
	日立化成工業（株）
	三菱化工機（株）
	シー・エフ・ケイ（株）
	（株）大湘技研
南海浜地区	JFE条鋼（株）

Supply Chains are affected.

- Micro Computer tips, critical parts production are affected.
- An automobile uses 30-100 micro-computer tips.
- Large share occupied by a Japanese Firm in the affected area.
- Automobile production dropped to 50% for two months.

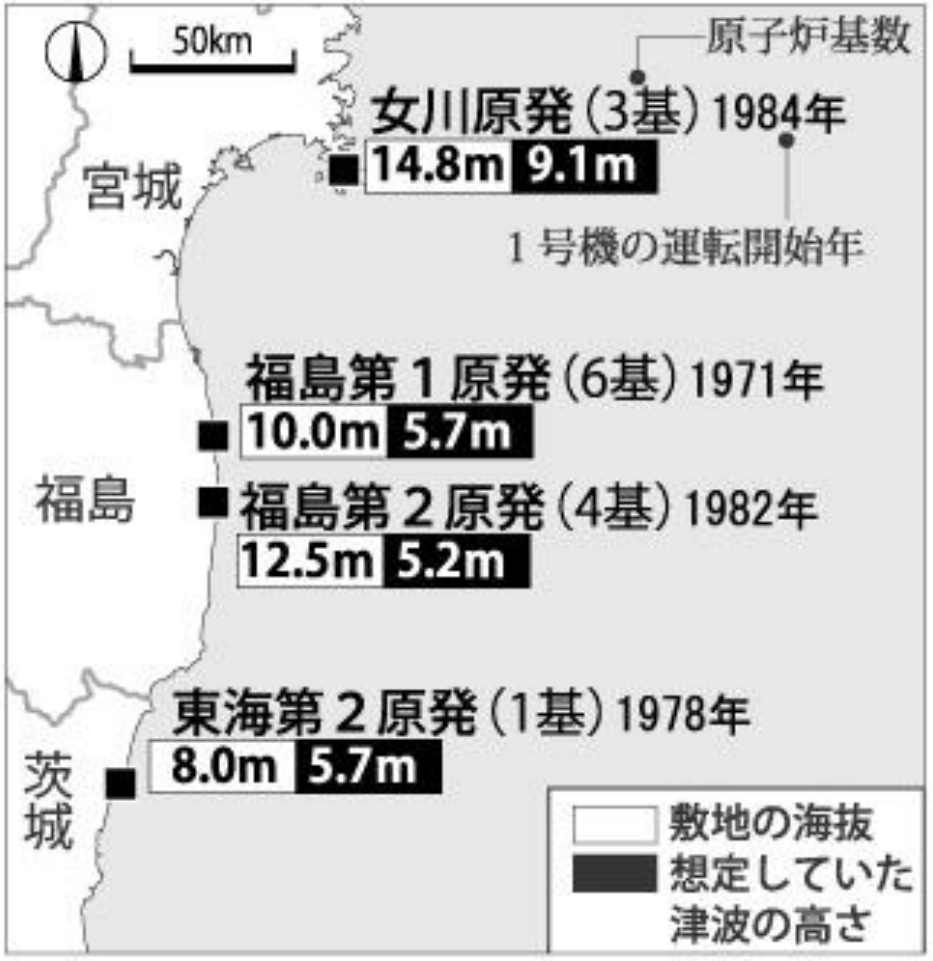
Preliminary Summary

- Structural Damage by the strong ground motion is small (??).
- Tsunami impact is remarkably large:
  - Senario, exposure and fragility should be reconsidered
- Affected Area: enormous
  - Recovery of logistic system
- Economic Impact:
  - Cascading effect: Resilient Supply Chain

Major Lessons : Planning and Management Aspect

- Reduce "expected surprise," by taking account of all the possible consequences for designing DRM Plans and contingency plans.
- Integrated Disaster Risk Management is needed:
  - Structural + Nonstructural Measures taking account of "Excess Design Forces."
  - Eg. Tsunami protection walls reduced impact when they are not destroyed even Tsunami exceeds
- Implementation of IDRM is a big challenge:
  - Governance Issues: multiple authorities, governments, NGOs, Citizens
    - Eg. Raising elevation of highways: who covers the cost, who decide the elevation of the road.

Four Nuclear power plants are affected



Nuclear Power Plant Fukushima No.1

TEPCO assumed to have a maximum Tsunami height at 5.7m. TEPCO made a internal research draft which reported Maximum Tsunami height can reach at 15.7m in 2008 but they reported Nuclear Power Authority on March 7th 2011.

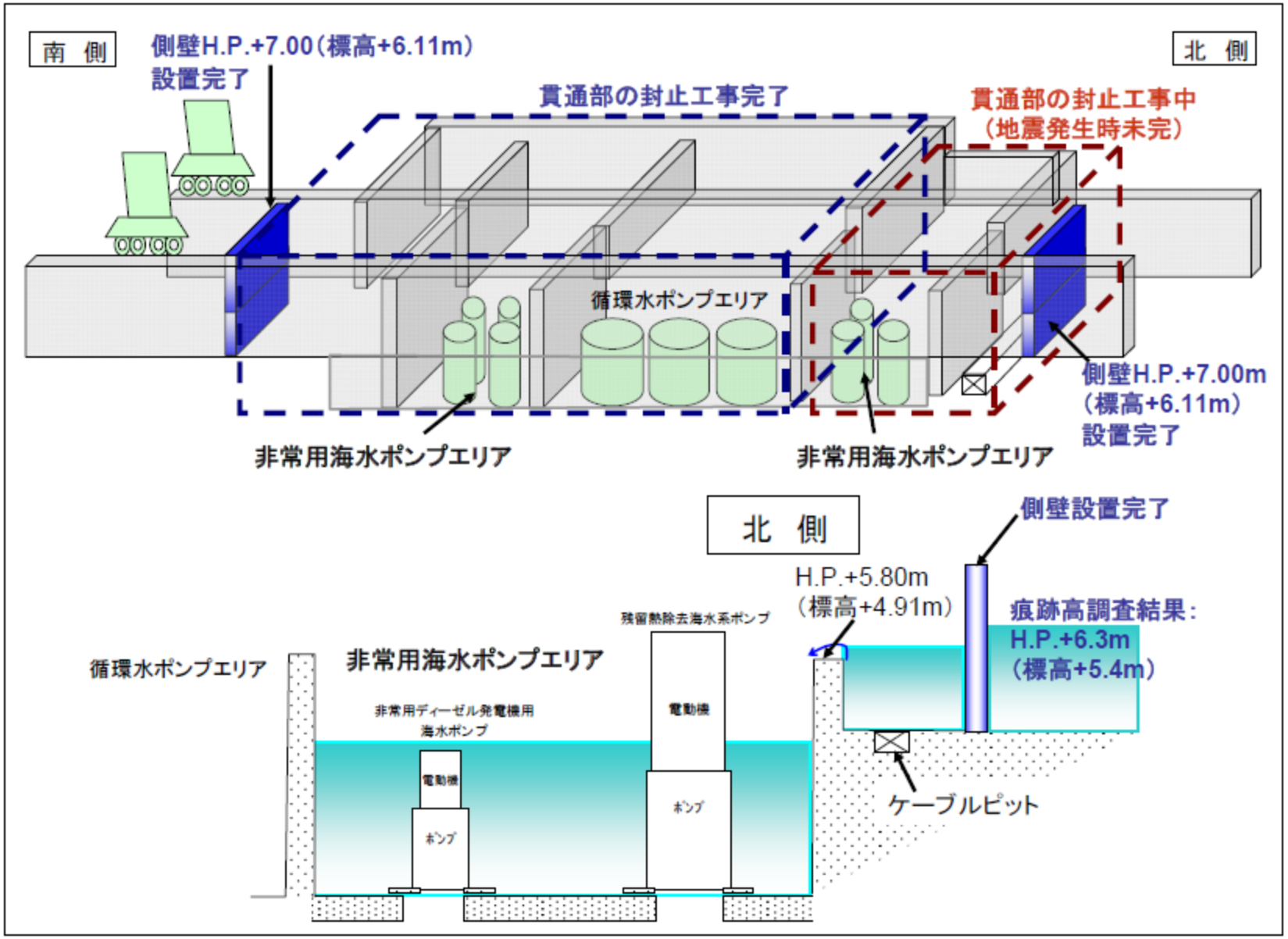
Unfortunately, TEPCO loose the chance for installing additional Tsunami Countermeasures and the Tsunami on March 11th run-up height reached to 15m and Tsunami washed away functionality of the emergency diesel power generator.

Tokai Dai Ni Nuclear Power plant

In 2009.9, they modified the design tsunami height (4.86m→5.7m) based on revised Tsunami hazard assessment by the Ibaragi Pref. (2008.9) and had start constructing of Tsunami protection wall for emergency diesel building (6.1m).

At march 11th, two of the emergency diesel power generator was saved and kept functionality.

【東海第二発電所　海水ポンプ室概要図】



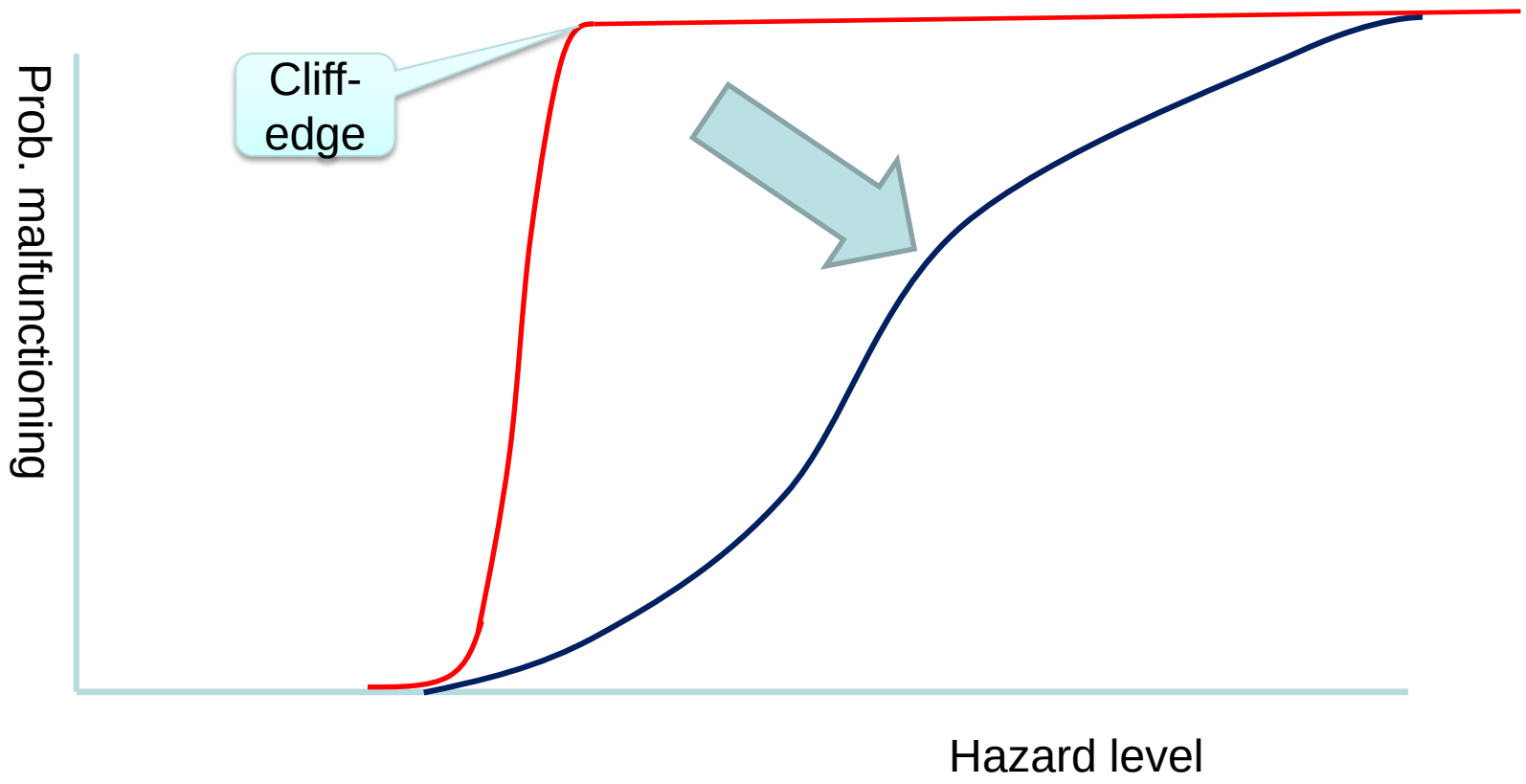
Why we have “expected surprise”?

- Design external force is used for facility design.
- If the actual external force exceeds the design force, it is not a responsibility of the authority.

No authority don’t want to take risk by considering force exceeding the design force.

→ This leads to “cliff-edge fragility” problem (Kameda 2011) .

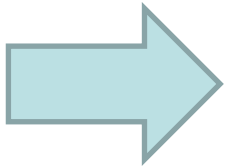
From Cliff-edge to Smooth Fragility (Kameda, 2011)



Allowing uncertainty of functionality of countermeasures for excess external forces, we should increase the coping capacity of the facility against natural hazards.

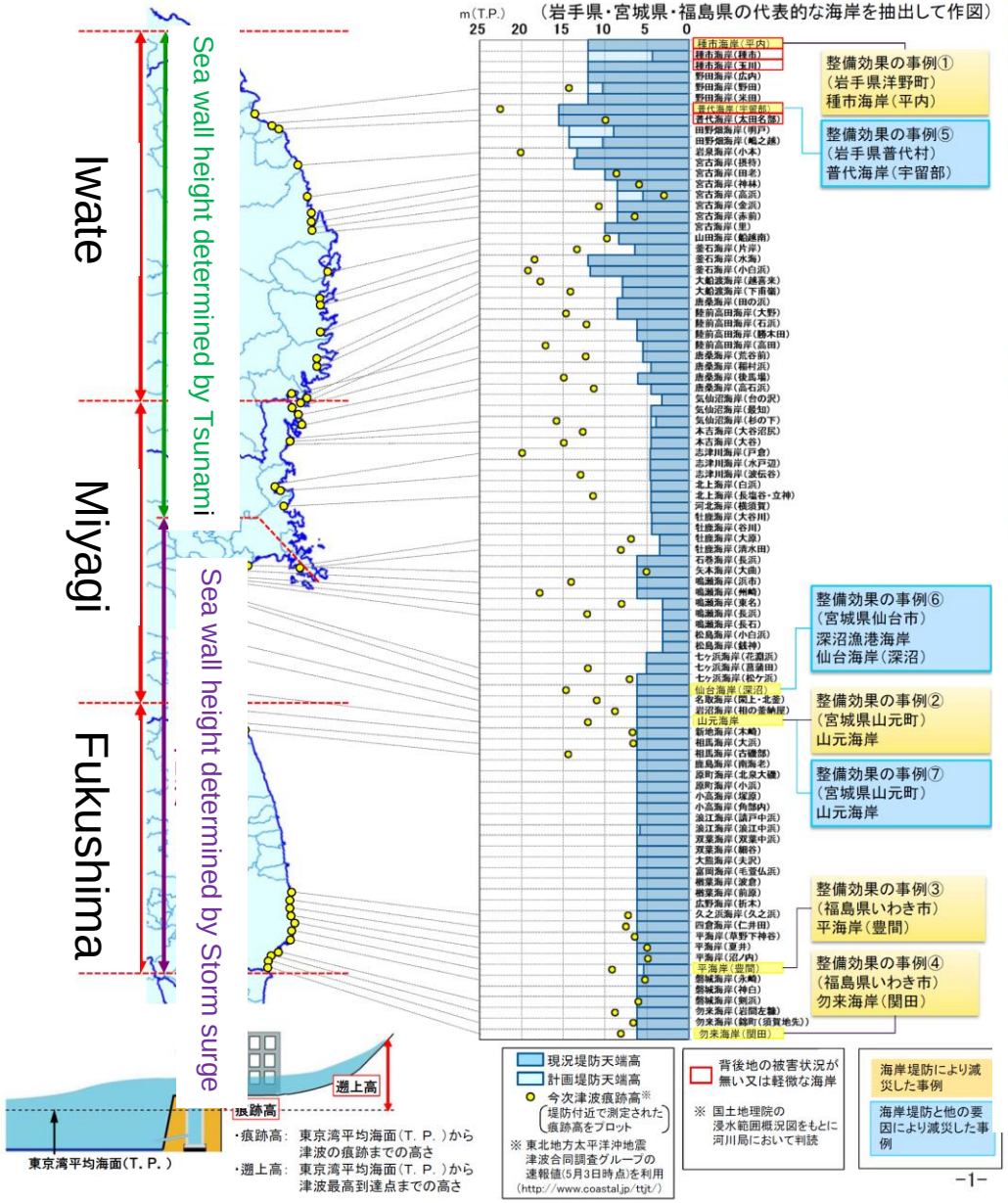
Exceeding external forces

- Safety is a fundamental needs of citizen.
- Design and evaluation standard gradually were getting considering “exceeding external forces.”
  - Robust river dykes
  - Seismic design: economic efficiency investigation



Safety margin should be determined based on the variability of the external forces and facility performances.

Development of sea walls and their damages



海岸堤防により減災した事例

事例① 岩手県洋野町(ひろのちょう) 種市(たねいち)海岸(平内(ひらない))

海岸堤防が津波高より高く、背後地への津波の越流はなし。

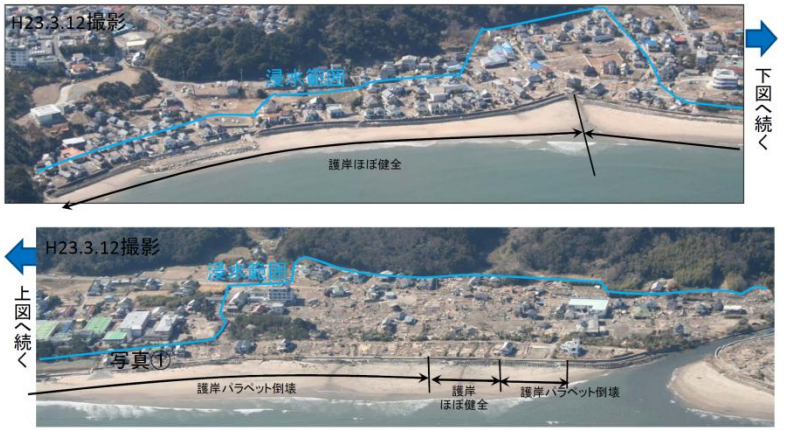
海岸堤防により減災した事例

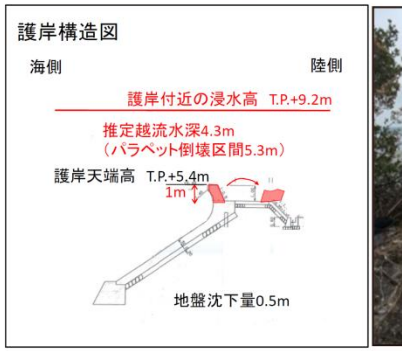
事例③ 福島県いわき市 平(たいら)海岸(豊間(とよま))

パラペットが倒壊した区間では背後地の家屋被害は甚大。護岸がほぼ健全な区間では背後地の家屋被害は比較的小さい。

天端高T.P.+5.4m
推定越流水深4.3m(パラペット倒壊区間5.3m)
(護岸付近の浸水高T.P.+9.2m、地盤沈下量※0.5 m)

※国土地理院資料(等変動量線図(上下変動量))より簡易的に読み取ったもの。

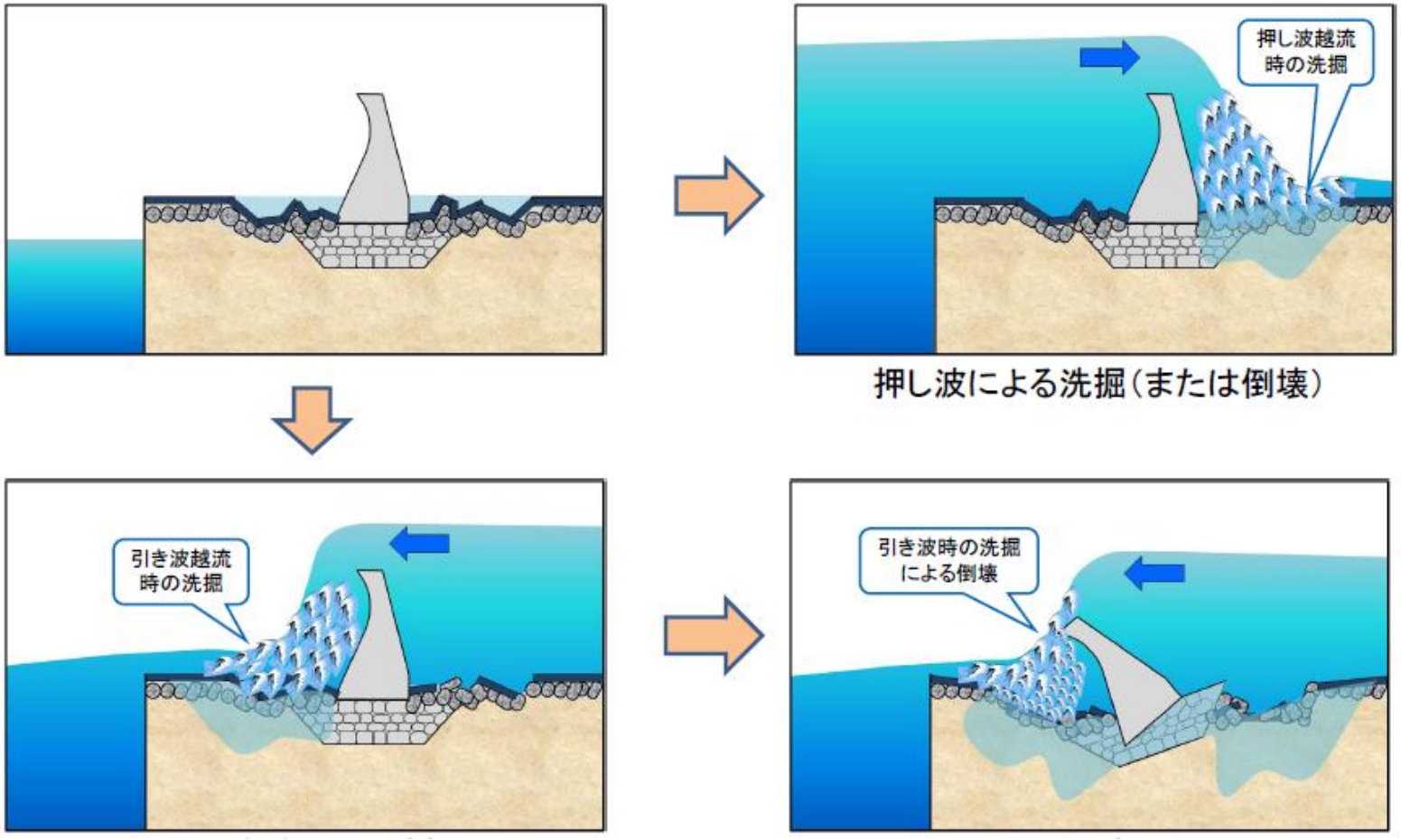




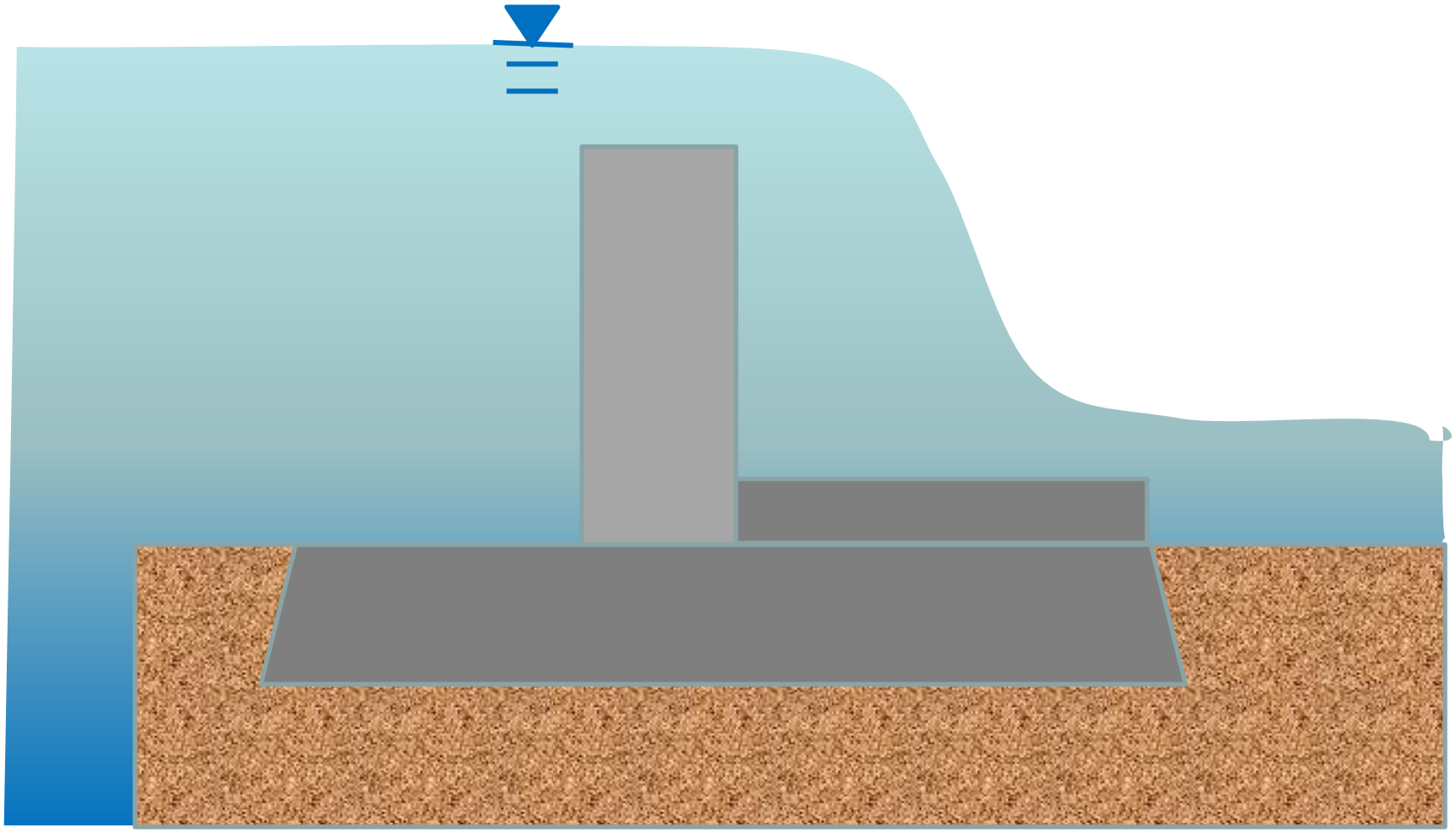
-5-

農林水産省・国土交通省

How sea wall collapsed?



Improvement of sea walls' resiliency

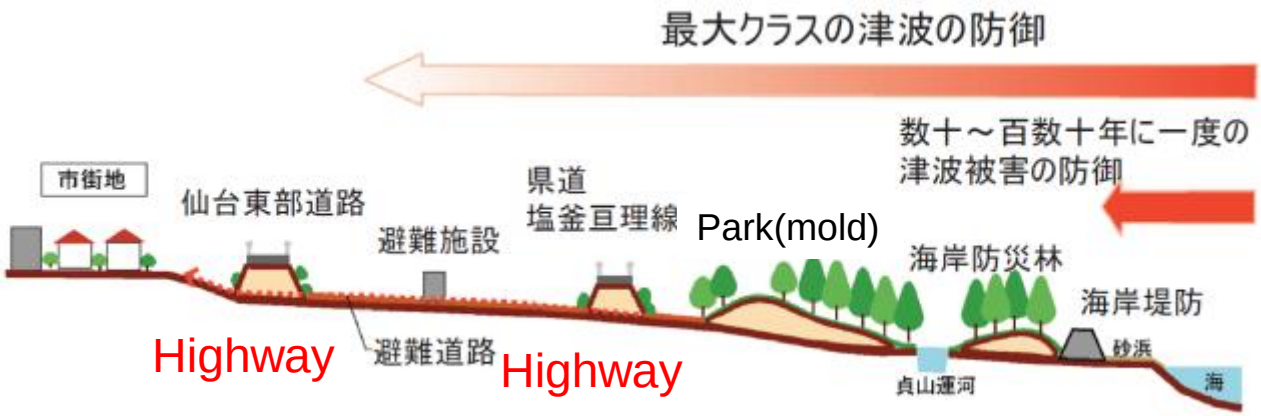


Think “unthinkable”

- Change scope of design: not only a facility but also non-structural measures
- Evaluate the functionality of the integrated countermeasures at all the possible consequences.
- Recognize and prepare for the worst consequences

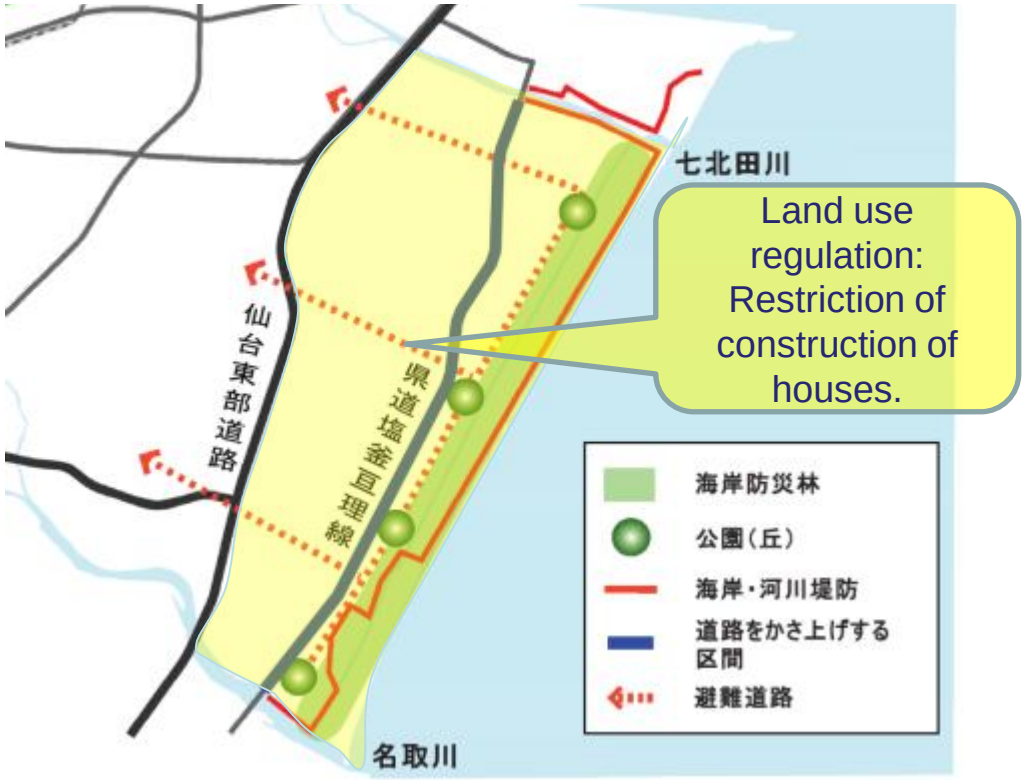
Need for Low cost measures:
Disaster education and Evacuation Plans

Renovation Plan of Sendai City(仙台市)



Protection against maximum Tsunami

Protection against Tsunami once in one hundred and several ten years



Land use regulation: Restriction of construction of houses.

Multiple protection lines :

Sea walls, river dykes, raising elevation of highways

Land use regulation :

Areas where expected Tsunami depth exceeds 2m are designated as “Sakigai Kiken Kuiki” (Disaster Prone Zones). In the area, construction of buildings for the purpose for living is prohibited.

Evacuation Shelters and Routes :

Mounded parks closer to sea shore, high-rise building as a shelter

Challenge

- Establish the methodology to evaluate integrated countermeasures:
  - Maximizing Net Benefit subject to social safety requirement (Live-safety)
  - Benefit should cover reduction of business interruption losses (economic impacts)

- Establishing Better Risk Governance
  - Who takes responsibility for the safety against natural hazards?
  - Can we achieve it by enhancing public private partnership?

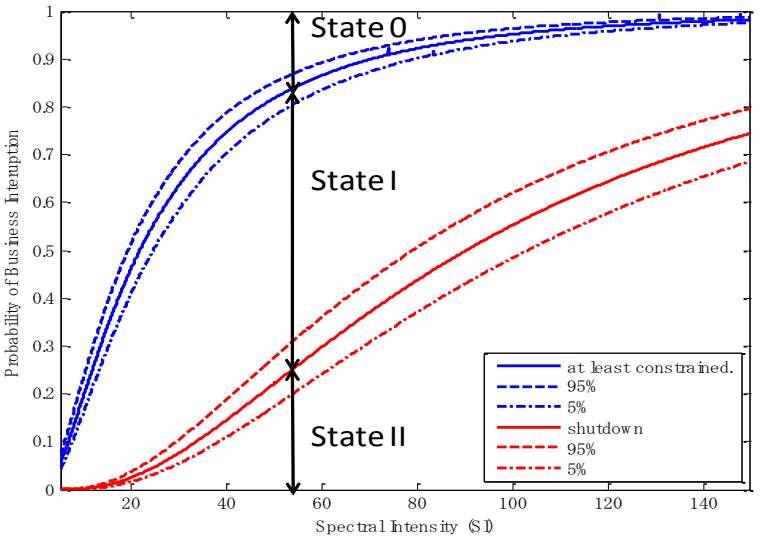
Challenges of Modeling Economic Impact

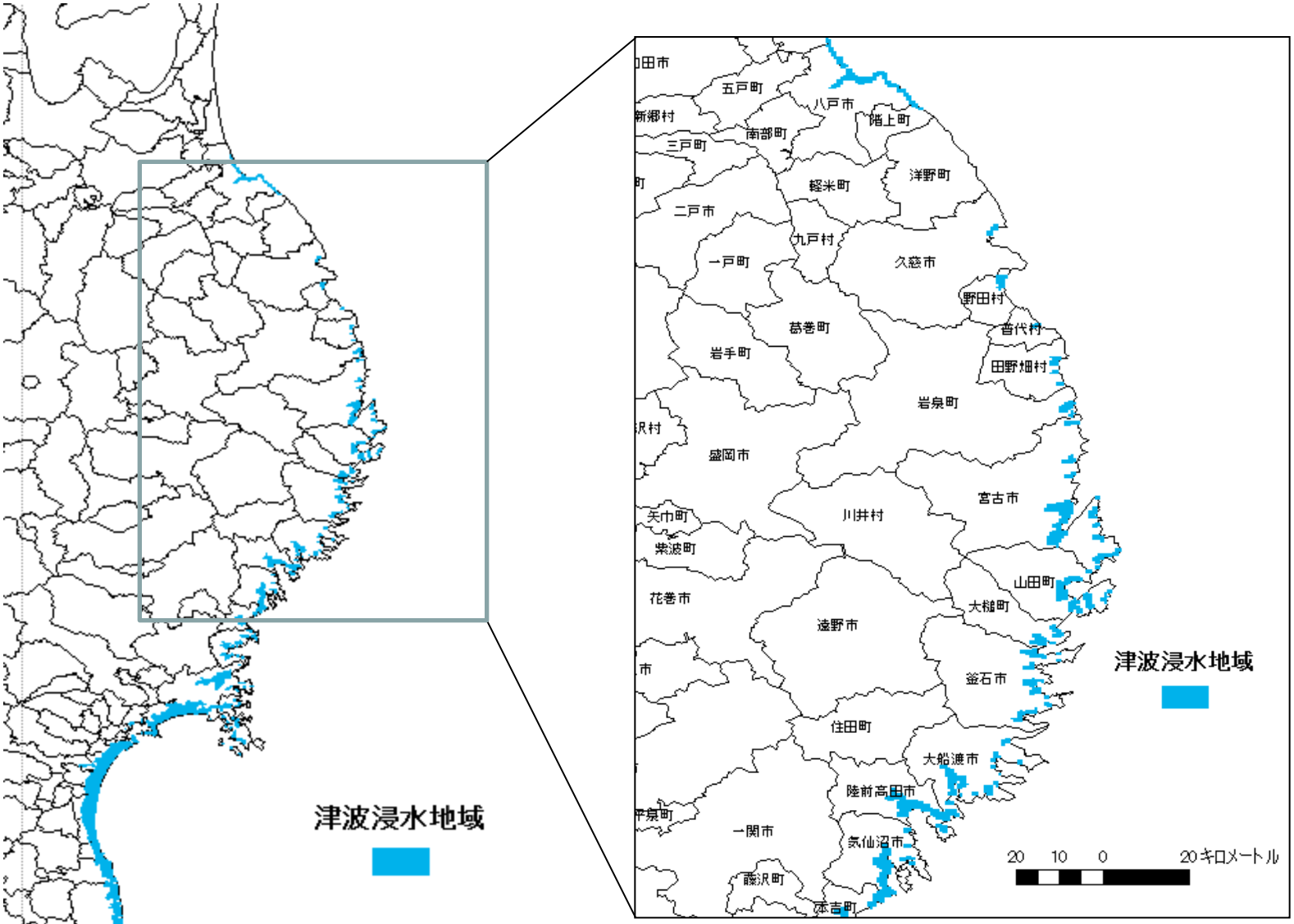
- Human Lives：
  - Value of human lives: about 3 million US$
  - 3mil. × 20,000 = 600 bil. US$
- Business interruption losses:
  - Fragility curves of “functionality” is needed.
  - Cascading impacts through supply chains should be considered.
  - Low substitutability (high share of a few firms) propagates the impact.=>Post event survey?

Estimation of Economic Impacts (to be conducted)

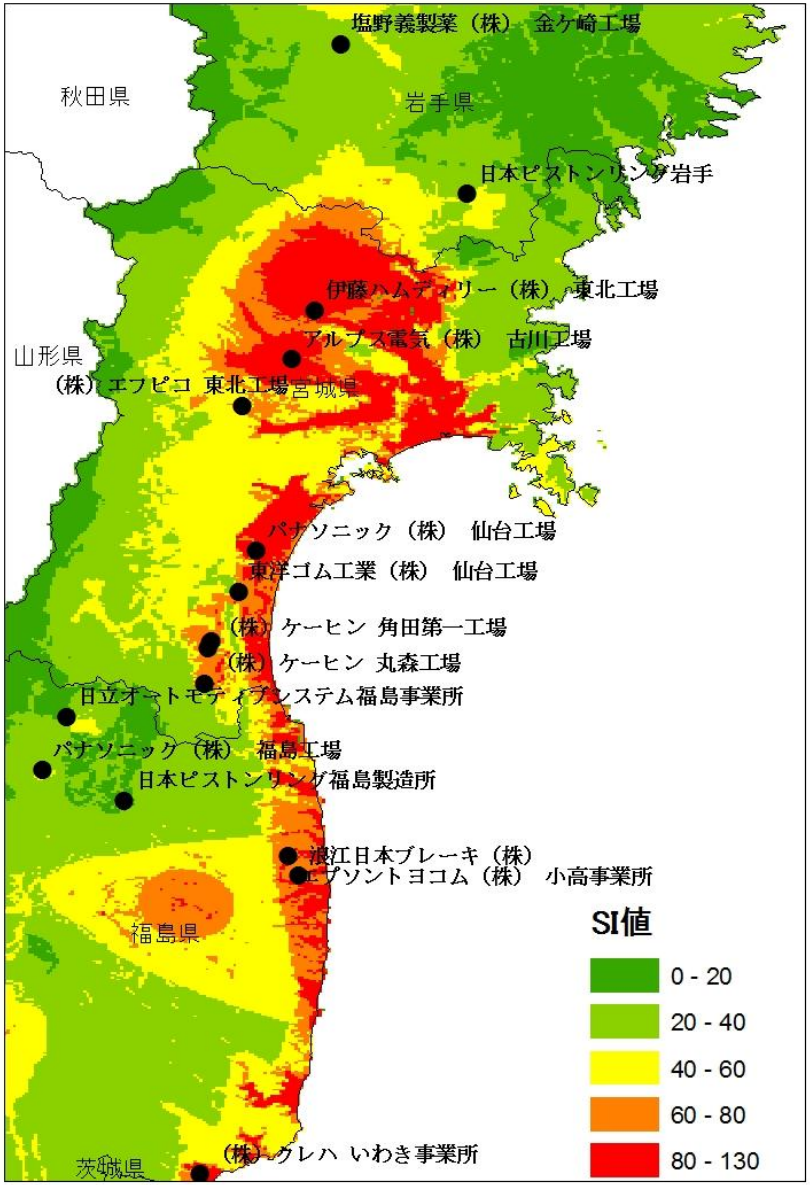
- Earthquake & Tsunami
  - Ground motion distribution/Tsunami affected area
  - Industrial activities
  - Lifelines & Transportation networks availability
  - Resiliency of the industry
  - Substitutability of goods?
  - Spatial computable general equilibrium (SCGE) model
  - Economic impact of the event

Functionality of firm in industrial sector and ground motion intensity (SI)

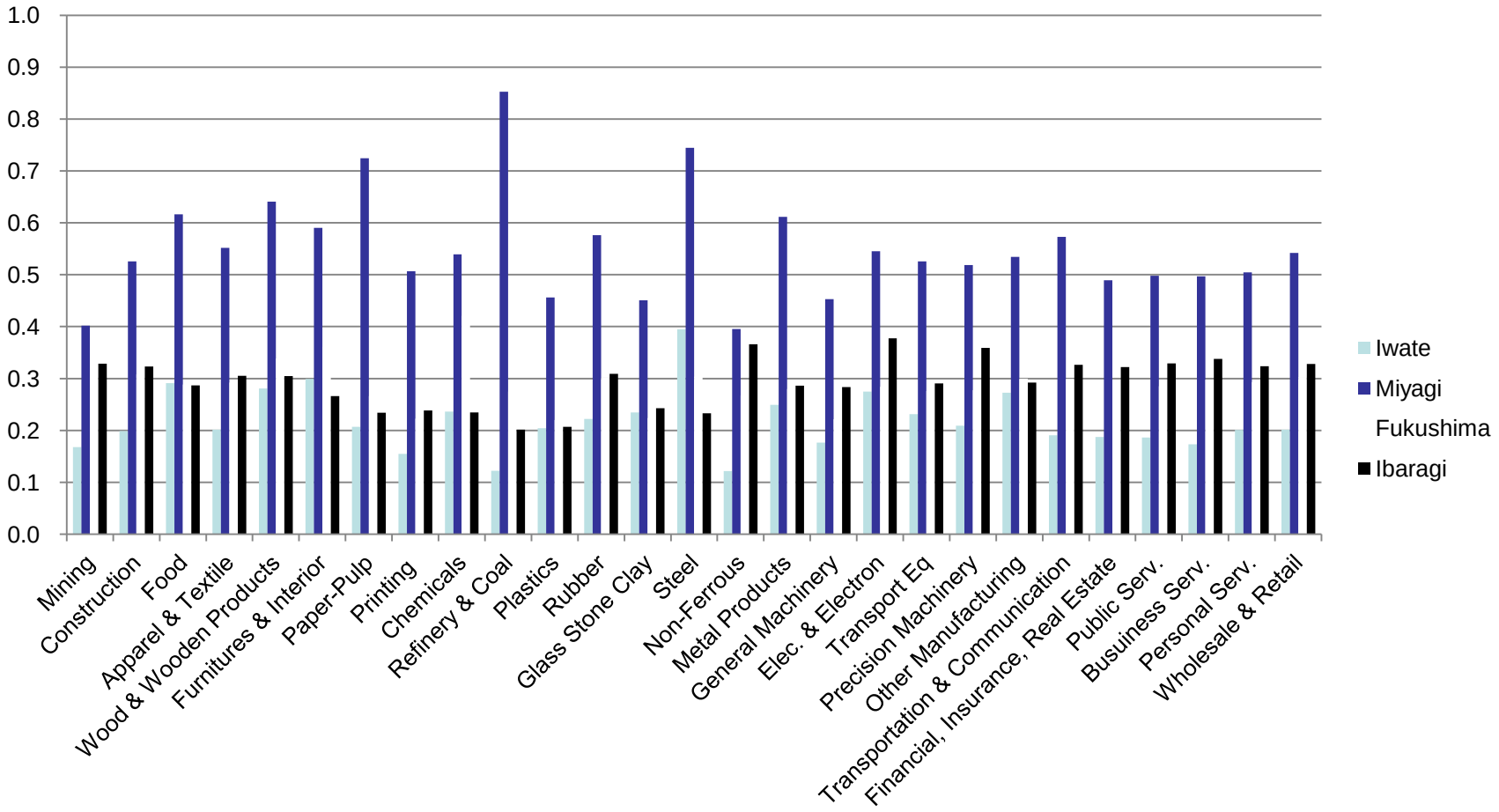



津波浸水地域
50 25 0 50キロメートル
津波浸水地域
20 10 0 20キロメートル
五戸町
八戸市
階上町
南部町
三戸町
洋野町
軽米町
二戸市
九戸村
一戸町
久慈市
野田村
普代村
葛巻町
岩手町
田野畑村
岩泉町
盛岡市
宮古市
川井村
矢巾町
紫波町
山田町
花巻市
大槌町
遠野市
釜石市
住田町
大船渡市
陸前高田市
一関市
気仙沼市
藤沢町
本吉町

Distribution of SI and Location of affected Firms

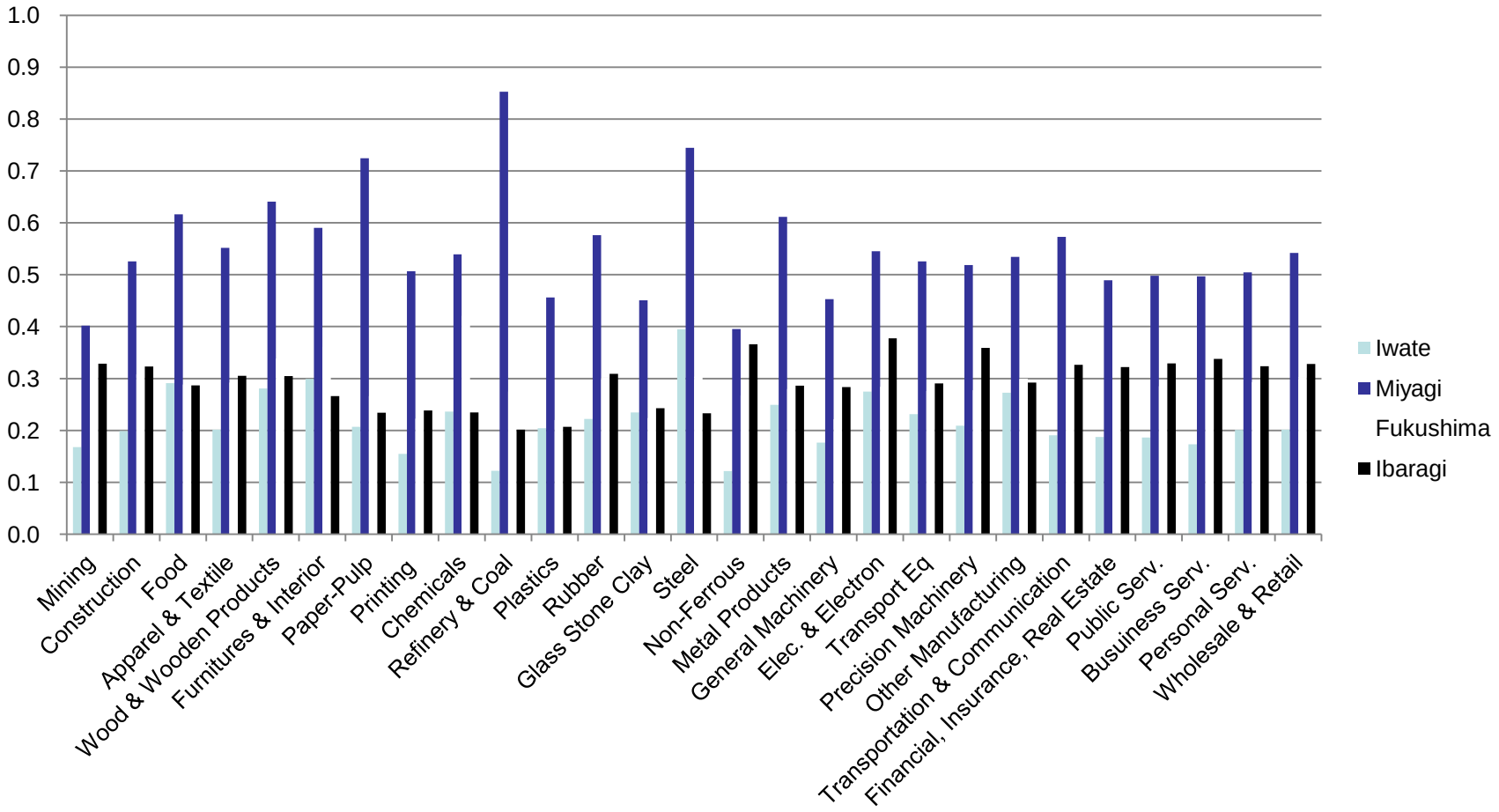


Impact of Earthquake and Tsunami: Production Capacity



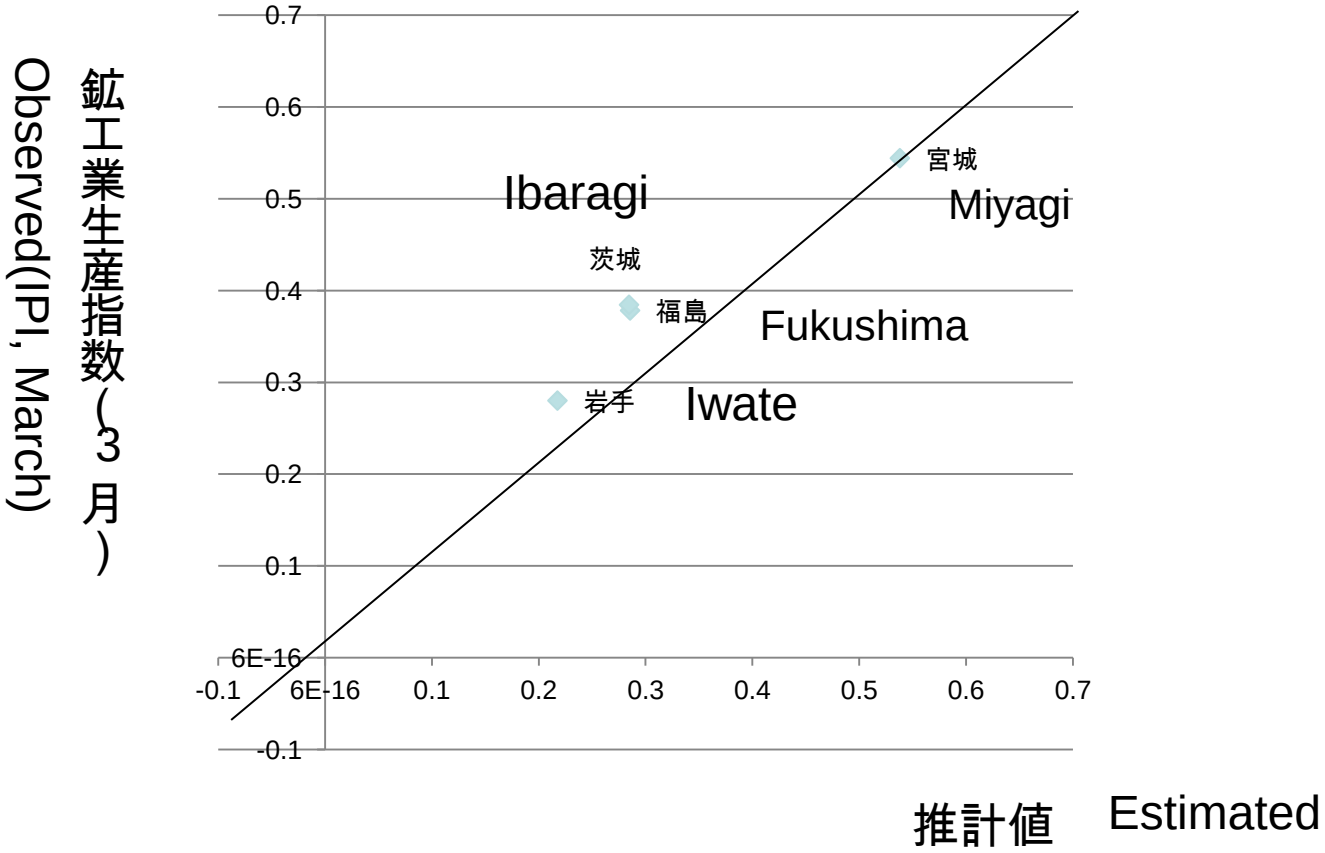
34% of Production Capacity has been lost for a few weeks.

Impact of Tsunami



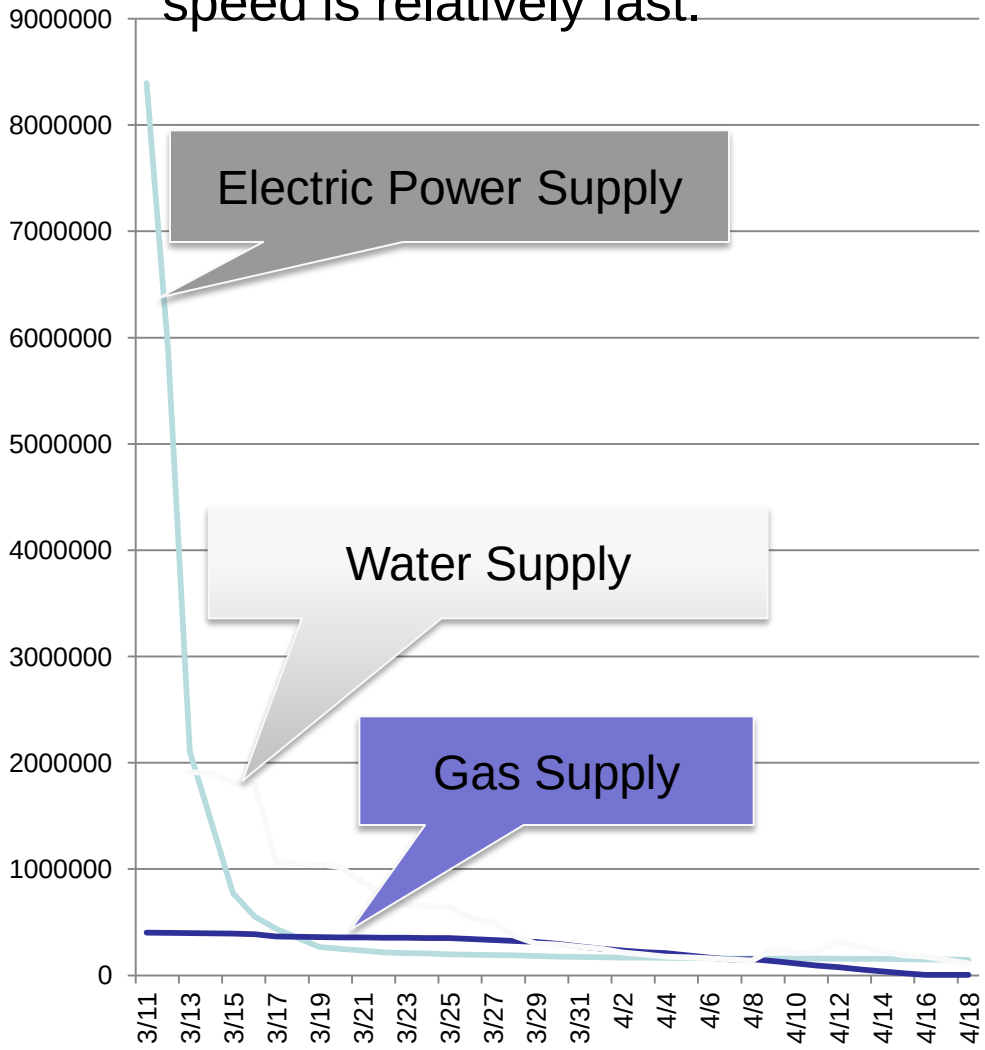
6% of capacity has been lost. Capital Loss could be 40-50 Billion US $.

Comparing with Industry Production Index(IPI)

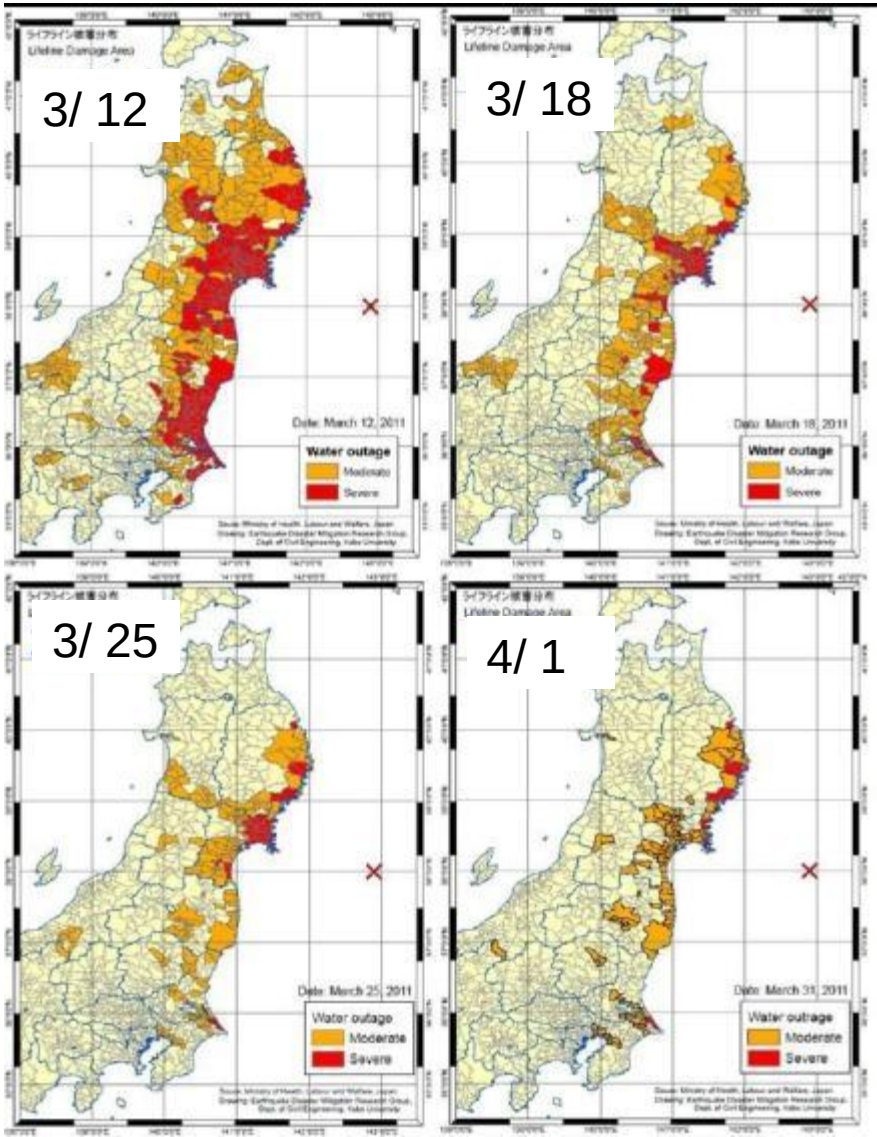


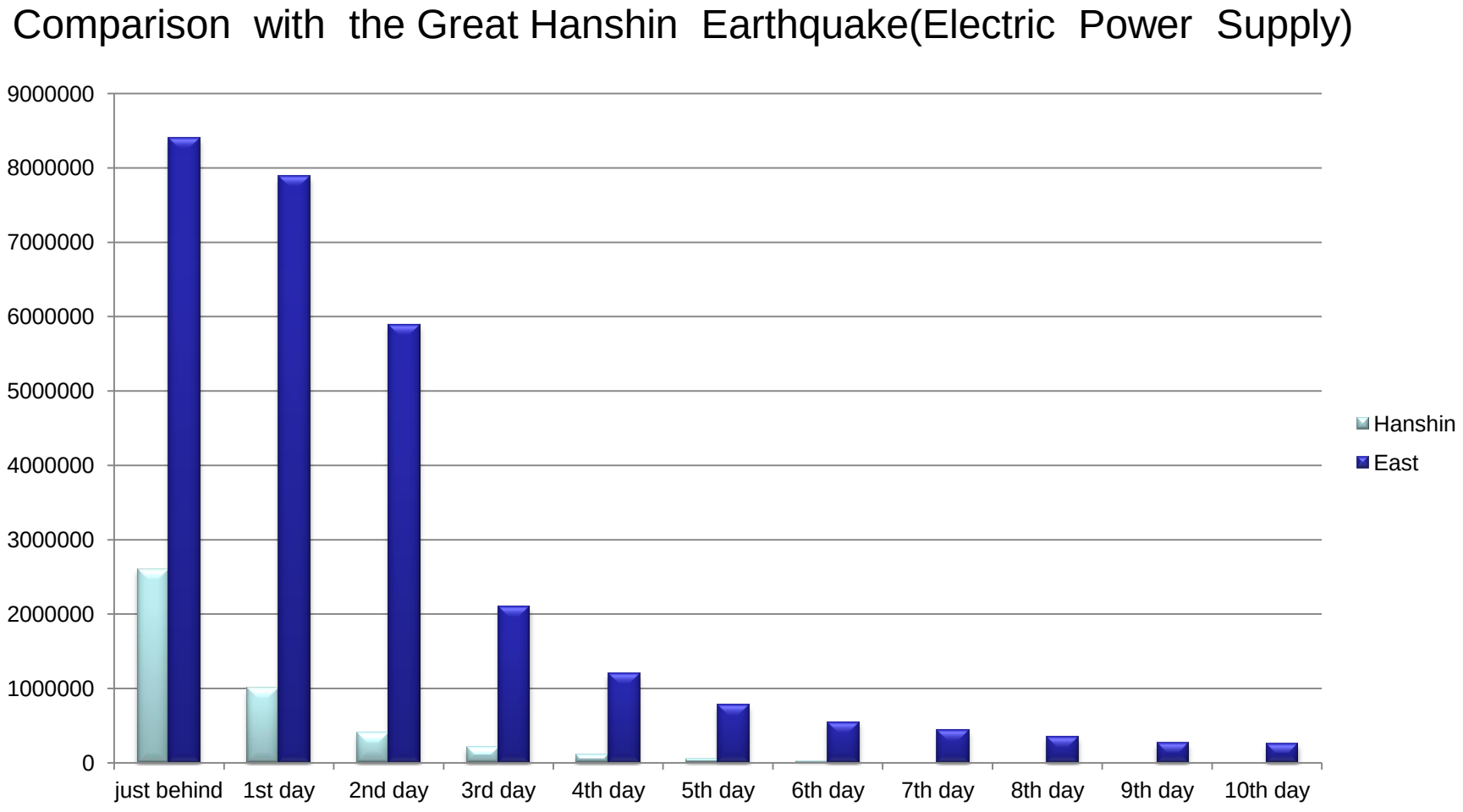
Functional fragility curves appropriately fit to IPI in all the industrial production.
Investigation of fitting in each industry sectors is needed.

Although malfunction of lifeline occurred widely, their recovery speed is relatively fast.



Recovery of Water Supply




Comparison with the Great Hanshin Earthquake(Electric Power Supply)
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
just behind
1st day
2nd day
3rd day
4th day
5th day
6th day
7th day
8th day
9th day
10th day
Hanshin
East

Resiliency Factor

$$r_{ui} = \frac{f(\mathbf{x}^1 \mid \mathbf{u}^1)}{f(\mathbf{x}^0 \mid \mathbf{u}^0)}$$

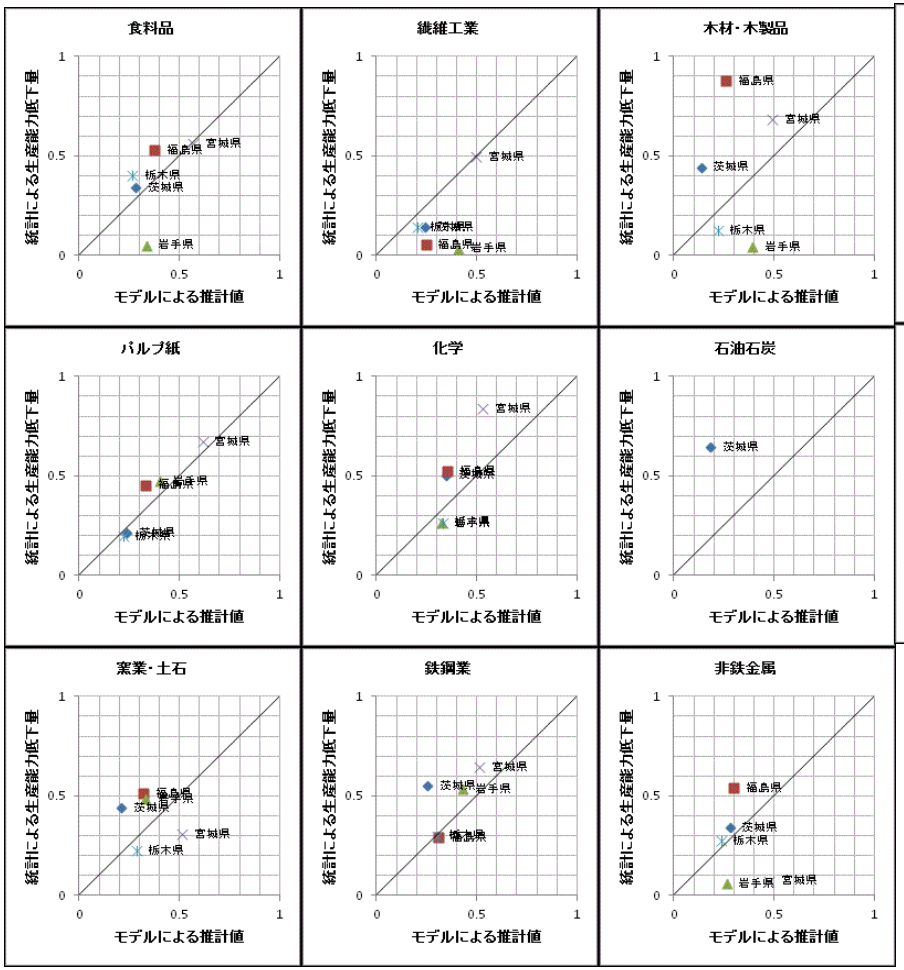
Resiliency factors (shut down in power, water and Gas)

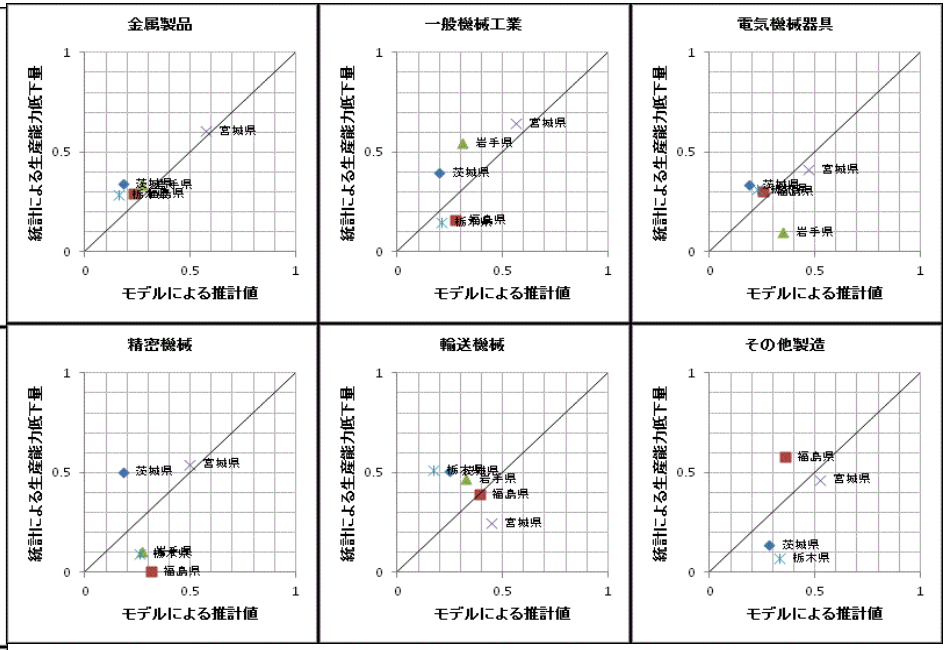
	E× W○ G○	E○ W× G○	E○ W○ G×	E○ W× G×	E× W○ G×	E× W× G○	E× W× G×	Sample #
Food	0.0429	0.4323	0.6302	0.3883	0.0372	0.0106	0.0000	51
Aparrel & Textile	0.0776	0.7241	0.8276	0.7328	0.1121	0.0776	0.0690	29
Wood & Wooden Prodı	0.0625	0.9063	1.0000	0.9063	0.0625	0.0625	0.0625	11
Glass Stone Clay	0.0345	0.4196	0.5862	0.3534	0.0862	0.0259	0.0172	30
Paper-Pulp	0.0313	0.5938	0.7969	0.5938	0.0167	0.0156	0.0156	17
Chemicals	0.0786	0.3571	0.7353	0.3286	0.0571	0.0588	0.0500	35
Refinary-Coal	0.1818	0.7045	1.0000	0.7045	0.1818	0.0000	0.0000	11
Metal Product	0.0381	0.6519	0.7219	0.6088	0.0424	0.0216	0.0212	61
Steel	0.0000	0.5000	0.6964	0.4107	0.0000	0.0000	0.0000	15
Non-Ferrous	0.0500	0.4211	0.6947	0.3684	0.0526	0.1053	0.0526	21
General Machinery	0.0417	0.6067	0.8636	0.6113	0.0109	0.0000	0.0000	25
Precision Machinery	0.0417	0.6875	0.9167	0.6667	0.0625	0.0208	0.0083	12
Elec. & Electron	0.0662	0.7353	0.8897	0.7059	0.0303	0.0441	0.0368	34
Transport Eq	0.0313	0.5426	0.5573	0.4427	0.0208	0.0213	0.0104	49
Misc. Manufact	0.0708	0.4750	0.6653	0.4083	0.0833	0.0805	0.0410	62
Total	0.0533	0.5533	0.7235	0.5093	0.0537	0.0387	0.0260	469

(kajitani, et. al, 2005)

Goodness of Fit: Functional fragility, lifeline recovery and recovery of facility

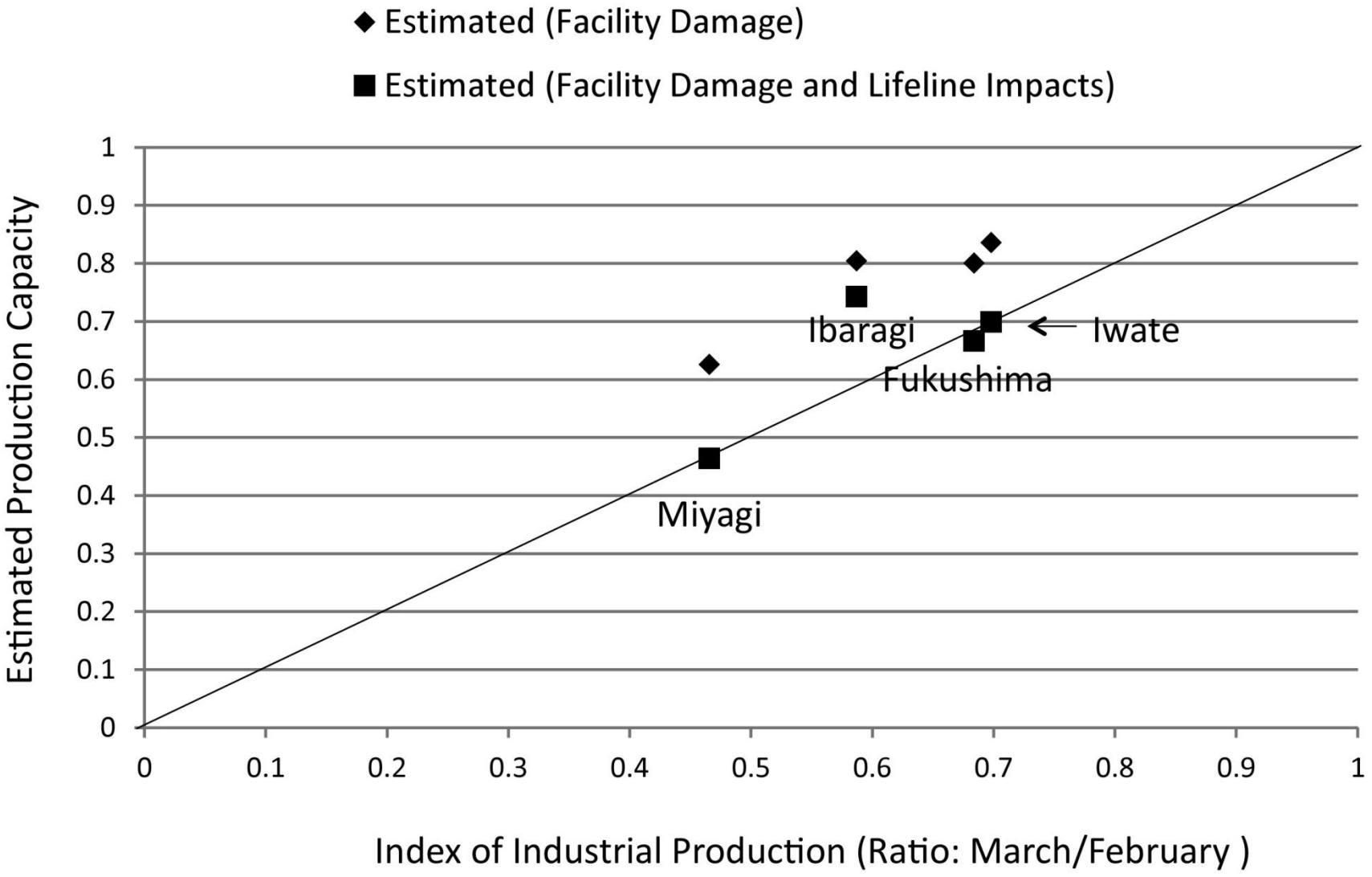
Comparison between manufacture production index and estimated results





	生産設備一定モデル		生産設備が回復するモデル	
	乖離度	分散	乖離度	分散
食料品	-0.005	0.123	-0.016	0.127
繊維工業	0.158	0.206	0.144	0.187
木材・木製品	-0.124	0.626	-0.139	0.649
パルプ紙	-0.032	0.024	-0.044	0.025
化学	-0.097	0.157	-0.105	0.160
石油石炭	-0.091	0.209	-0.092	0.214
窯業・土石	-0.056	0.160	-0.065	0.164
鉄鋼業	-0.098	0.114	-0.106	0.120
非鉄金属	0.076	0.268	0.050	0.263
金属製品	-0.076	0.038	-0.092	0.054
一般機械工業	-0.054	0.113	-0.071	0.121
電気機械器具	0.023	0.090	0.001	0.097
精密機械	0.062	0.265	0.052	0.258
輸送機械	-0.102	0.241	-0.112	0.248
その他製造	0.049	0.142	0.047	0.141

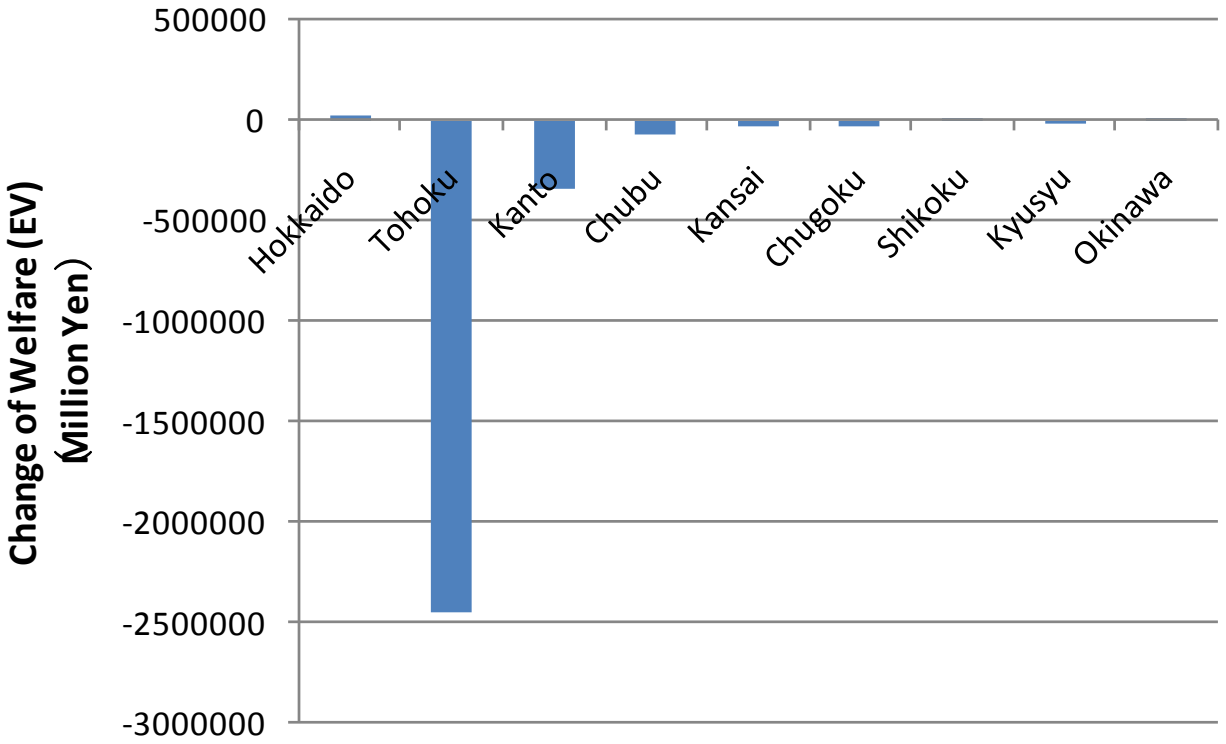
Estimated capacity loss v. Index of Industrial Production, by prefecture



SCGE Analysis

(Elasticity of Substitution for Intermediates among regions =**2.0**)

Total Loss =3.0 trillion JPYen

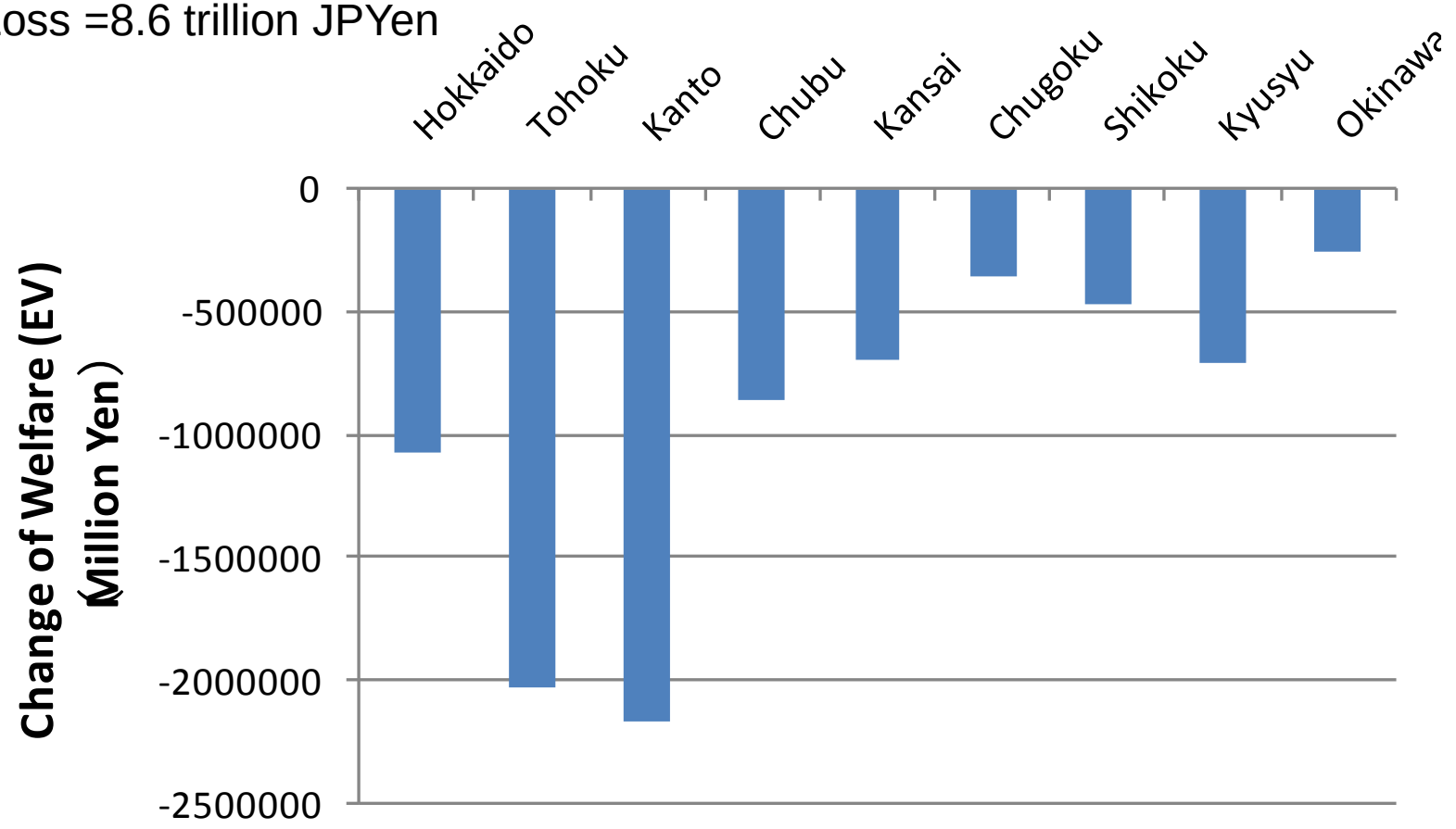


12 regions, 9 sectors IO Table(2005), Operational rate in Tohoku = -20%, no capital and labor movements among regions and industries, etc.

SCGE Analysis

(Elasticity of Substitution for Intermediates among regions =**0 (Leontieff)**)

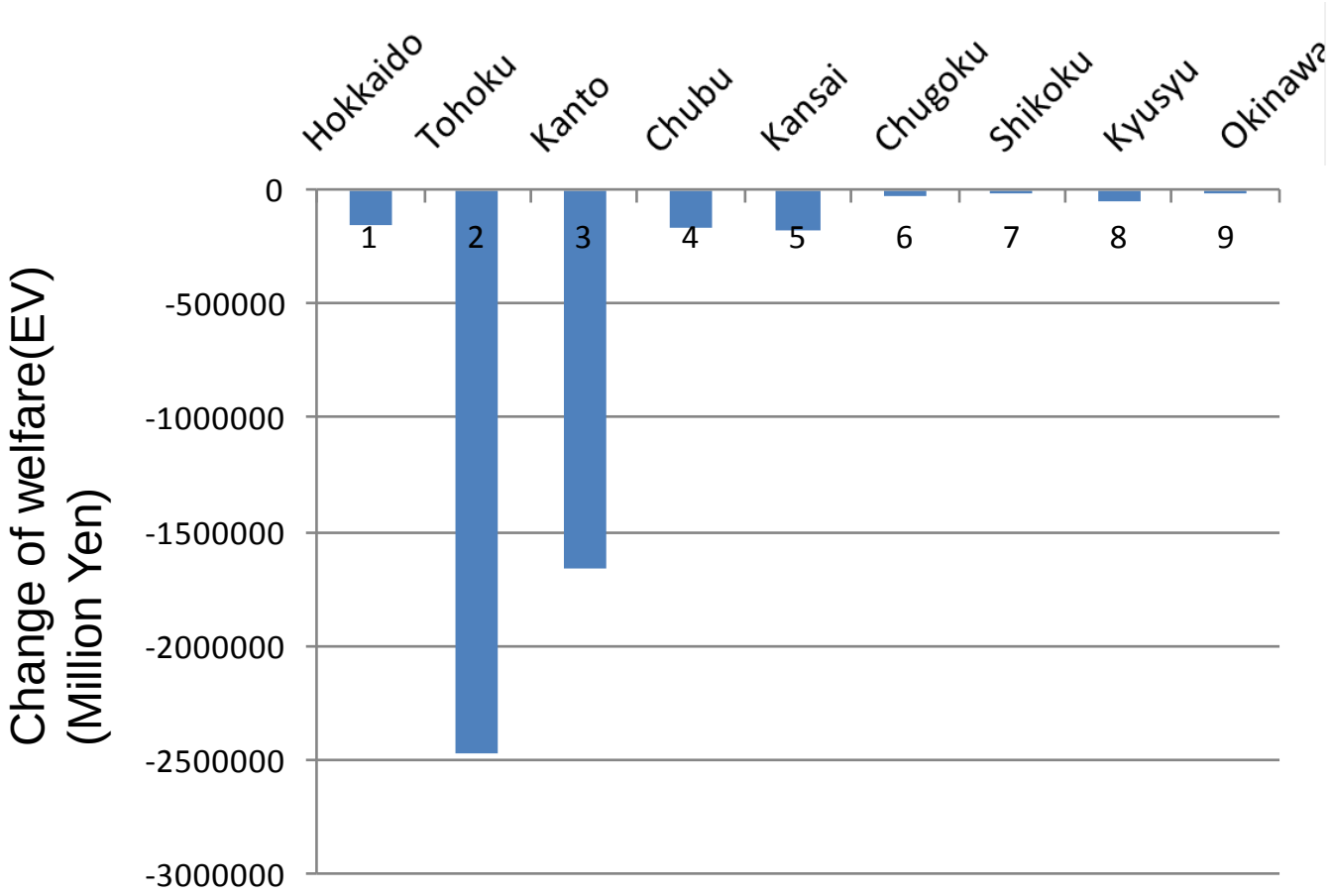
Total Loss =8.6 trillion JPYen



SCGE Analysis

(Elasticity of Substitution for Intermediates among regions =0.5-1.0 (Koike et.al., 2011))

Total Loss =4.5 trillion JPYen



Final comments

- To evaluate the functionality of the integrated countermeasures at all the possible consequences, we need to develop more sophisticated tools for loss estimation and cost-benefit analysis.
- Based on such understanding, we should built up a robust and flexible system of countermeasures to cope with these events.

Thank you for your attention!

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