Assessment of Natech Risks for Evacuation Planning in Areas Subject to Natech Risks
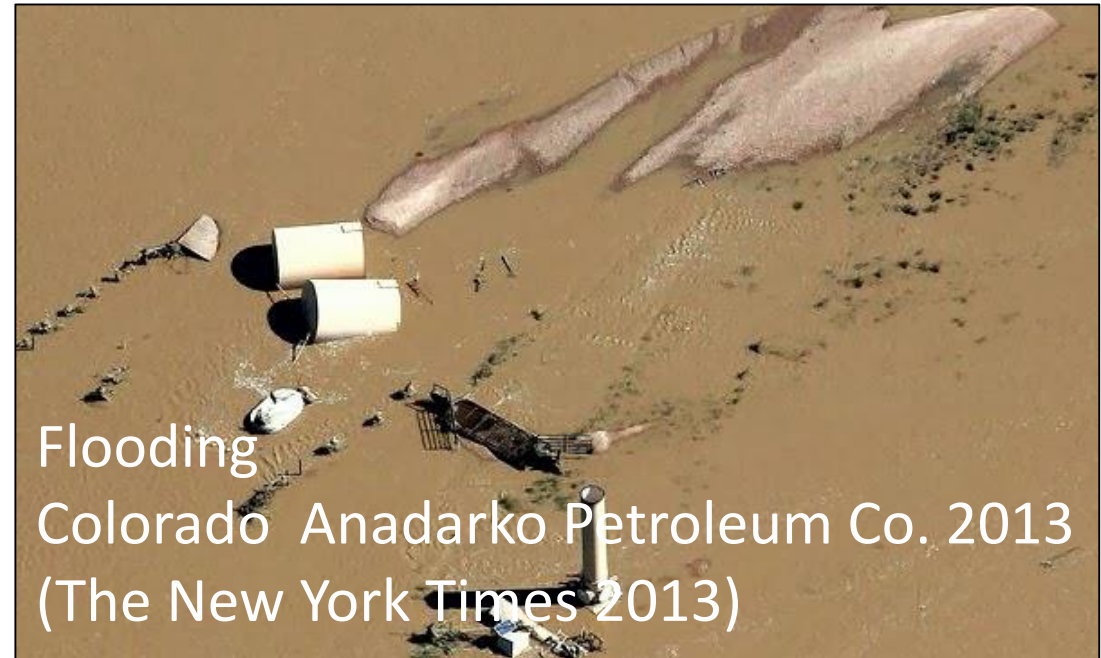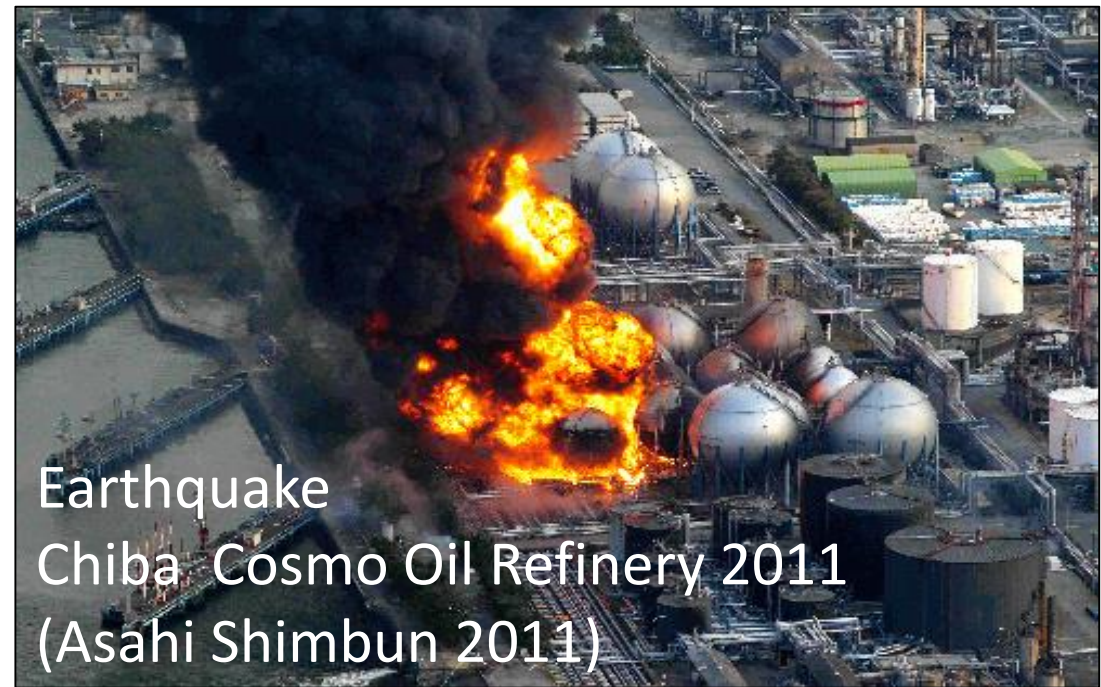
Kyoto Univ. DPRI

Haruki Suda
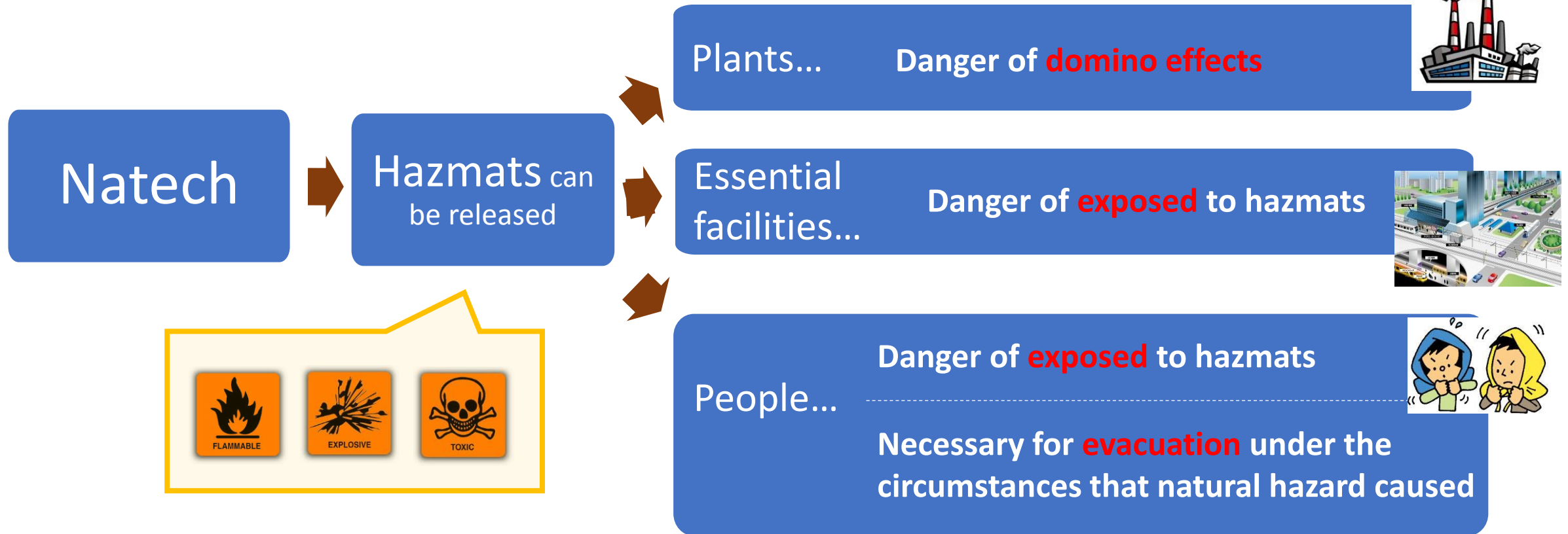
Prof. Ana Maria Cruz

Prof. Michinori Hatayama

Earthquake
Chiba Cosmo Oil Refinery 2011
(Asahi Shimbun 2011)

Flooding
Colorado Anadarko Petroleum Co. 2013
(The New York Times 2013)

Natech

Natech： Natural-hazard triggered technological accidents

Natech → **Hazmats** can be released →

- **Plants…** Danger of **domino effects**
- **Essential facilities…** Danger of **exposed** to hazmats
- **People…**
  - Danger of **exposed** to hazmats
  - Necessary for **evacuation** under the circumstances that natural hazard caused

Specific evacuation planning concerning Natech does not exist.

Natech evacuation

Kobe Higashinada, The Great Hanshin EQ

(57 : 10000)

The evacuation advisory area had

- 4 available evacuation shelters
- 3 available emergency evacuation shelters

: available evacuation shelter

: available emergency evacuation shelter

| : calculated impact area

| : evacuation advisory area issued by Kobe City

Prevention of overflowing people at the shelters will lead to protect people.

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Objectives

(a) To make recommendations on Natech risk assessment methodologies used in this research

(b) To carry out a Natech risk assessment in a case study area

(c) To assess the adequacy of evacuation planning for Natech in a case study area

Risk assessment methodology

Risk assessment

Individual risk assessment

- Conventional risk assessment (CCPS, Salzano et al.)
- Natech risk assessment (Antonioni et al., Busini et al.)

Area-wide risk assessment

- PANR： semi-quantitative Natech risk assessment（Cruz and Okada (2008)）
- RAPID-N： calculation tool for the damage of storage tank

（European Commission）

PANR methodology : Preliminary Assessment of Natech Risks in urban areas
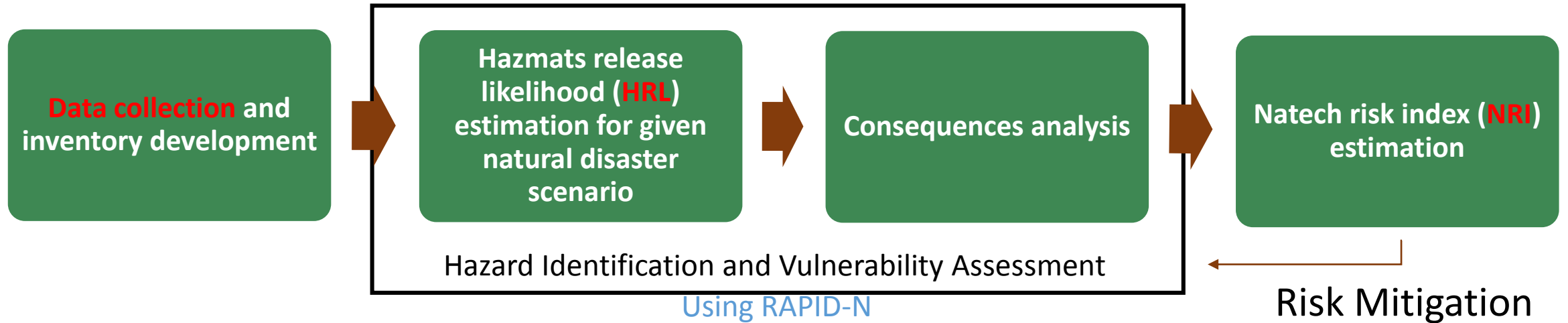
$$[NRI_i] = [HRL_i] \times \{ [D_i] + [Area\_sc_i] + [C_i] \}$$

- NRI_i is Natech Risk Index
- HRL_i is the Hazmat Release Likelihood of each hazmat containing storage tank i.
- D_i is a score that measures the potential domino effects.
- $Area\_sc_i$ is a score that measure the potential consequences on the population.
- C_i is a score that measure the potential consequences on essential facilities.

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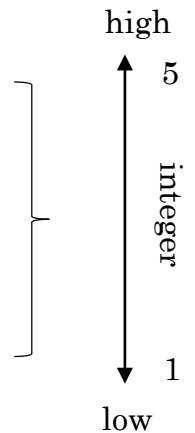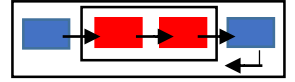
Definition of each term for NRI calculation

$$[HRL] = [H1] \times [H2]$$

[H1] : Severity of the damage of the target storage tank

[H2] : Probability of occurrence of the natural hazard

$$[D] = [D1] \times [D2]$$

[D1] : the number of the storage tanks

[D2] : distribution of the storage tanks

$$[Area\_sc] = [A1] \times \frac{[A2]+[A3]+[A4]+[A5]}{4}$$

[A1] : The number of people   **[A2]** : Population distribution

[A3] : The number of highly vulnerable people

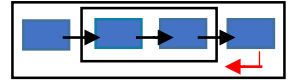**[A4]** : The number of low income neighborhoods

[A5] : Local disaster prevention level

$$[C] = [C1] + [C2] + [C3]$$

[C1] : Vulnerability due to the critical facilities

[C2] : Vulnerability due to the major lifelines

[C3] : Vulnerability due to the emergency response

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Risk mitigation

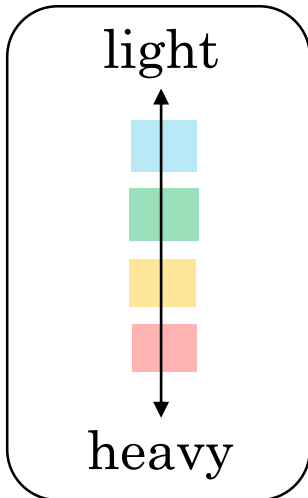$$[NRI] = [HRL] \times \{ D + \text{Area\_sc} + C \}$$

$$[HRL] = [H1] \times [H2]$$

$$[D] = [D1] \times [D2]$$

$$[\text{Area\_sc}] = [A1] \times [\frac{[A2]+[A3]+[A4]+[A5]}{4}]$$

$$[C] = [C1] + [C2] + [C3]$$

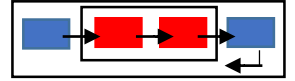| Difficulty of mitigation	Criteria
Easy	[A5]
Difficult	[H1], [A4], [C1], [C3]
Very difficult	[D1], [D2], [A1], [A2], [A3], [C2]
Impossible	[H2]

Probability of occurrence of the natural hazard

First risk reduction measure could include [A5].

Bringing down [H1] is very important.

local disaster prevention level

Severity of the damage of the target storage tank

light

heavy

7

Natech risk assessment metodologies

PANR

Risk = Severity × Probability

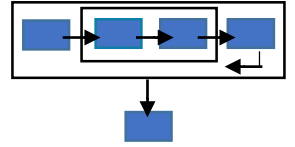| Risk	Severity	Probability
[HRL]	[H1]	[H2]
[D]	-	[D1] × [D2]
[Area_sc]	[A1]	$\dfrac{[A2] + [A3] + [A4] + [A5]}{4}$
[C]	-	[C1] + [C2] + [C3]

Other criteria that should be considered in PANR.

- The risk management of the industrial plant that handle hazmats. (HRL)

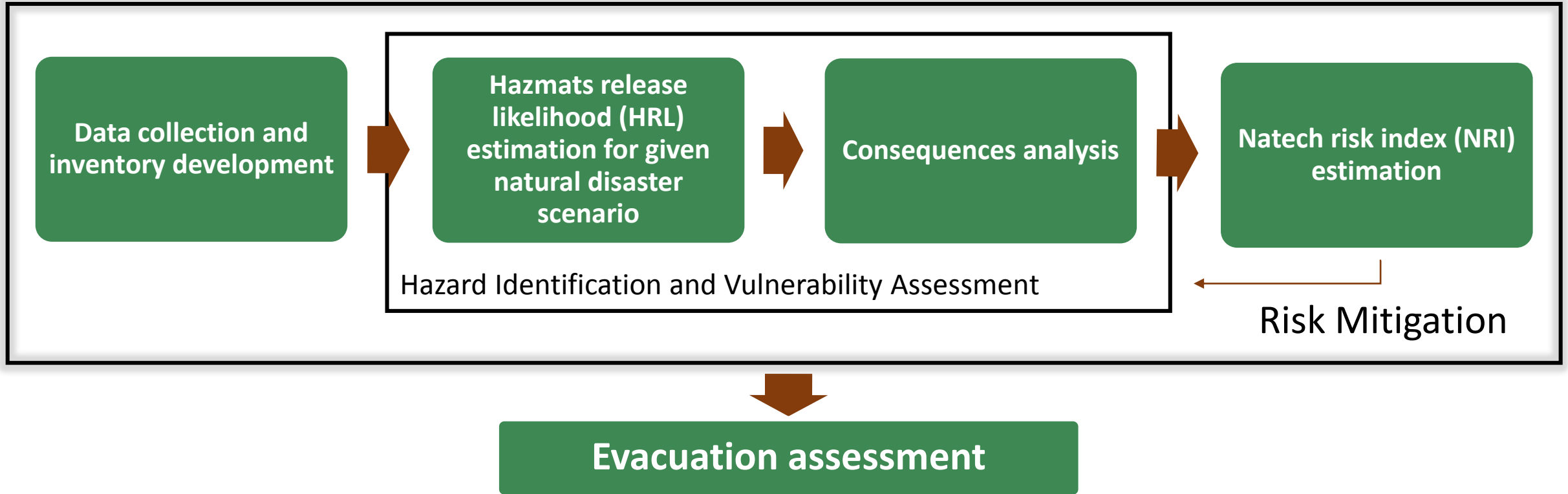- Vulnerability due to the number of physically handicapped persons. (Area_sc)

RAPID-N considers only [HRL]. [D], [Area_sc], [C] should be considered.

⟹ This study proposes that RAPID-N should create Consequence and Vulnerability Assessment module.
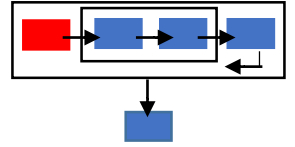
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Outline of the research


```
Data collection and          Hazmats release          Consequences analysis          Natech risk index (NRI)
inventory development   →     likelihood (HRL)     →                            →     estimation
                              estimation for given
                              natural disaster
                              scenario
```

Hazard Identification and Vulnerability Assessment

Risk Mitigation

Evacuation assessment

Main Scenario

- Kobe City Higashinada Ward

- Nankai trough earthquake

Mw9.1 expected
50% in 50 years
It may cause tsunami.

南海トラフ巨大地震による震度の最大値の分布
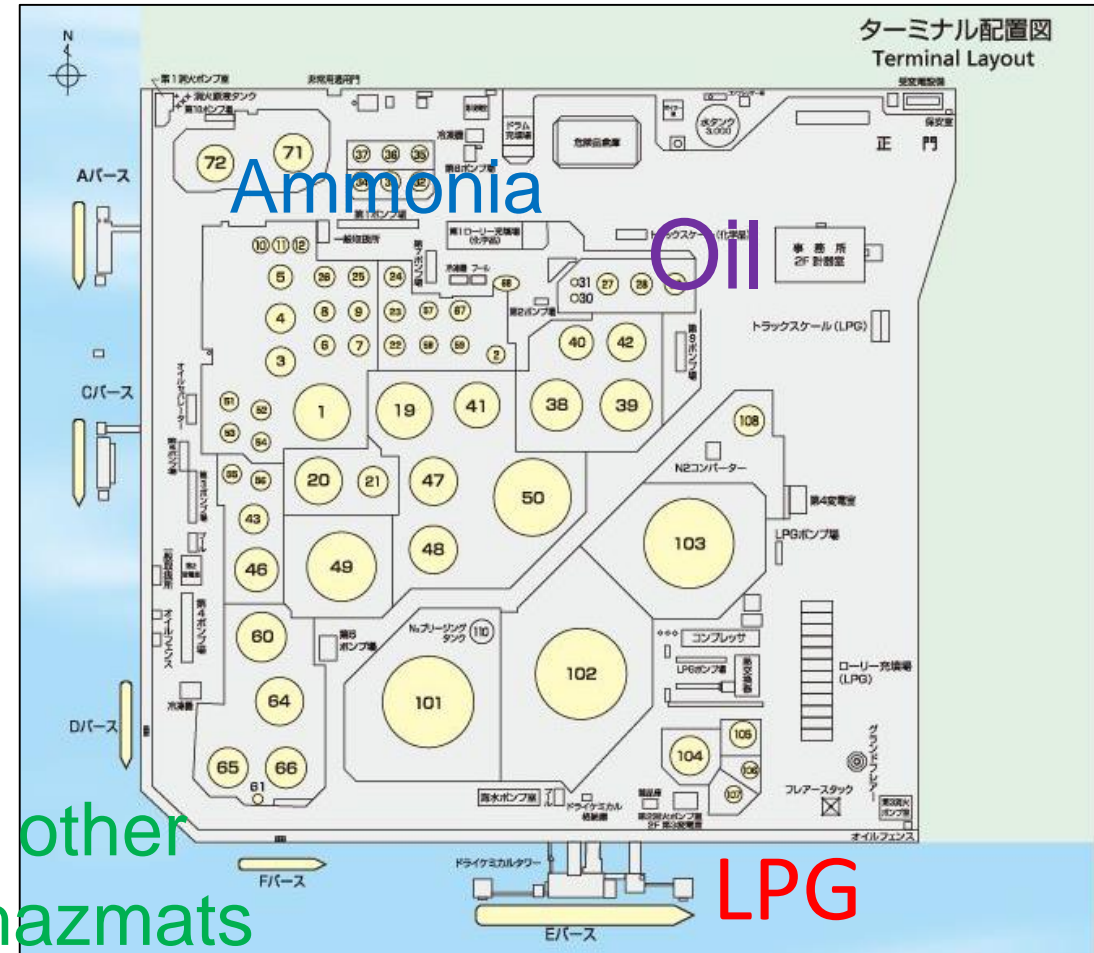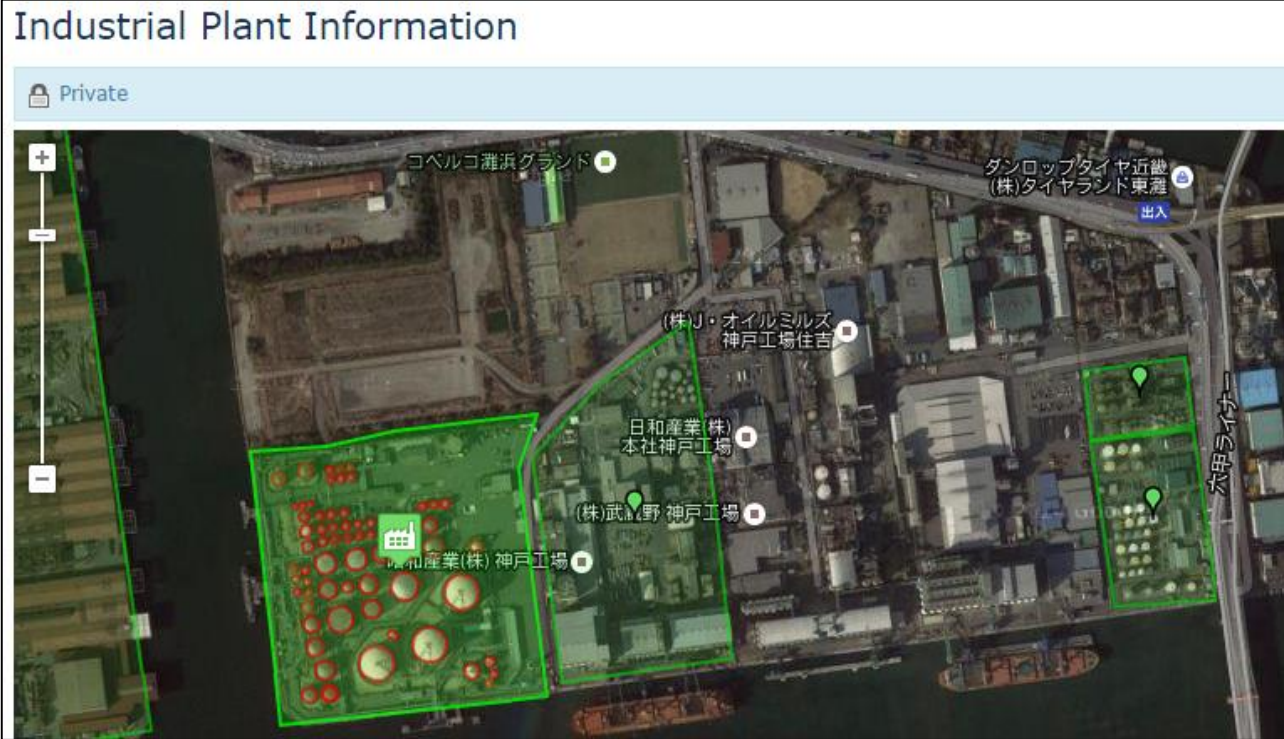※①〜④は被害想定に用いた、
断層が大きく滑る領域
震度
7
6強
6弱
5強
5弱
4
3 以下
想定震源域
南海トラフ

The Mainichi (2012)

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Natech risk assessment of each storage tanks in a plant

Kobe Higashinada

Ammonia

Oil

The other
4th hazmats

LPG

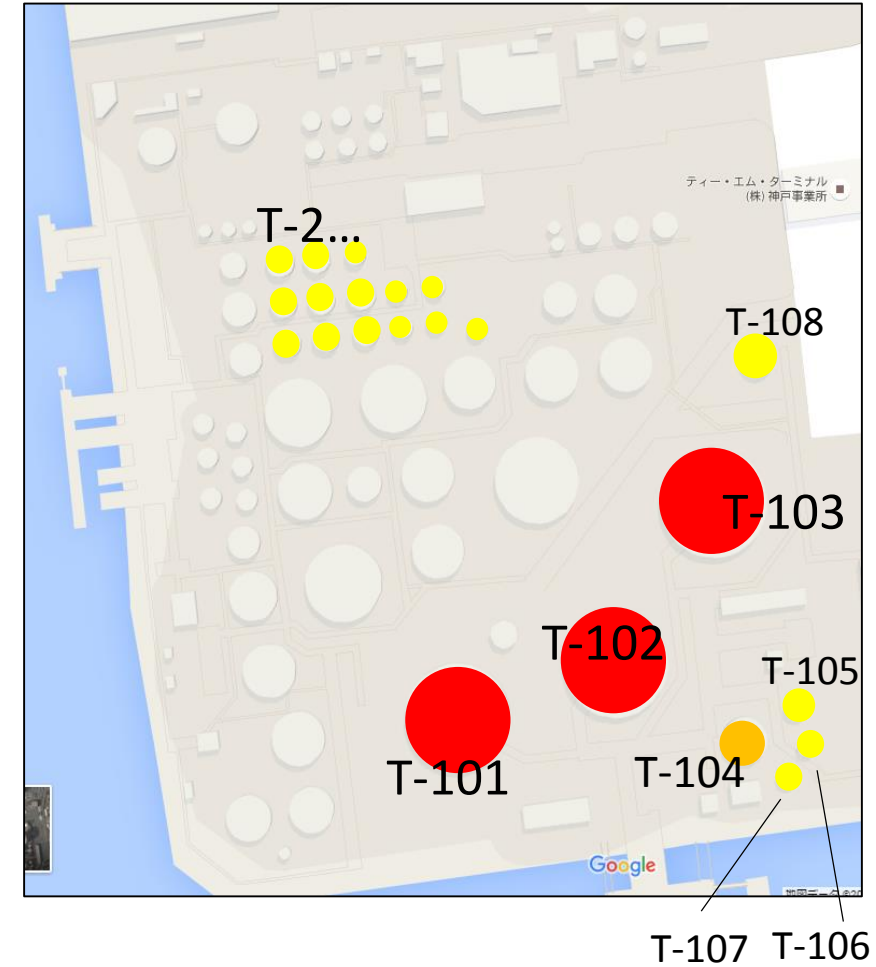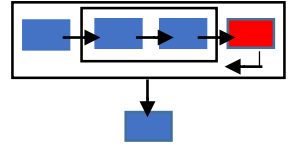Data from Higashinada Fire Station

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NRI estimation of each storage tank

$$[NRI_i] = [HRL_i] \times \{ [D_i] + [Area\_sc_i] + [C_i] \}$$

| Storage tank	Hamats	NRI	HRL	D	Area_sc	C
T-101	LPG	39	3	5	3	5
T-102	LPG	39	3	5	3	5
T-103	LPG	39	3	5	3	5
T-104	LPG	24	3	2	3	3
T-105	LPG	18	3	2	2	2
T-106	LPG	15	3	2	1	2
T-107	LPG	15	3	2	1	2
T-108	LPG	18	3	2	2	2
T-2...	Ammonia	14	2	-	2	5
T-43...	methanol	-	2	-	-	-
T-60...	ethanol	-	3	-	-	-
T-1...	oil	-	3	-	-	-
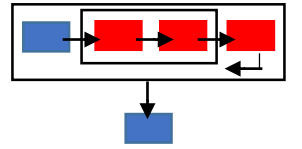
Layout of the plant

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NRIs and consequences on human

Natural hazard	Plant	NRI	Deaths	Injured	Note
The Great East Japan earthquake	Kashima	12	0	0	
Tokachi-oki earthquake	Tomakomai Idemitsu	14	0	0	
Niigata earthquake	Showa oil refinery	16	0	Unknown	286 houses burned
The Great Hanshin earthquake	TM terminal Kobe plant	18	0	0	
The Great East Japan earthquake	Chiba Cosmo oil refinery	21	0	6	118 glasses shattered
Nankai trough earthquake	TM terminal Kobe plant	39	?	?	

Drawing of graph to understand the value of NRI
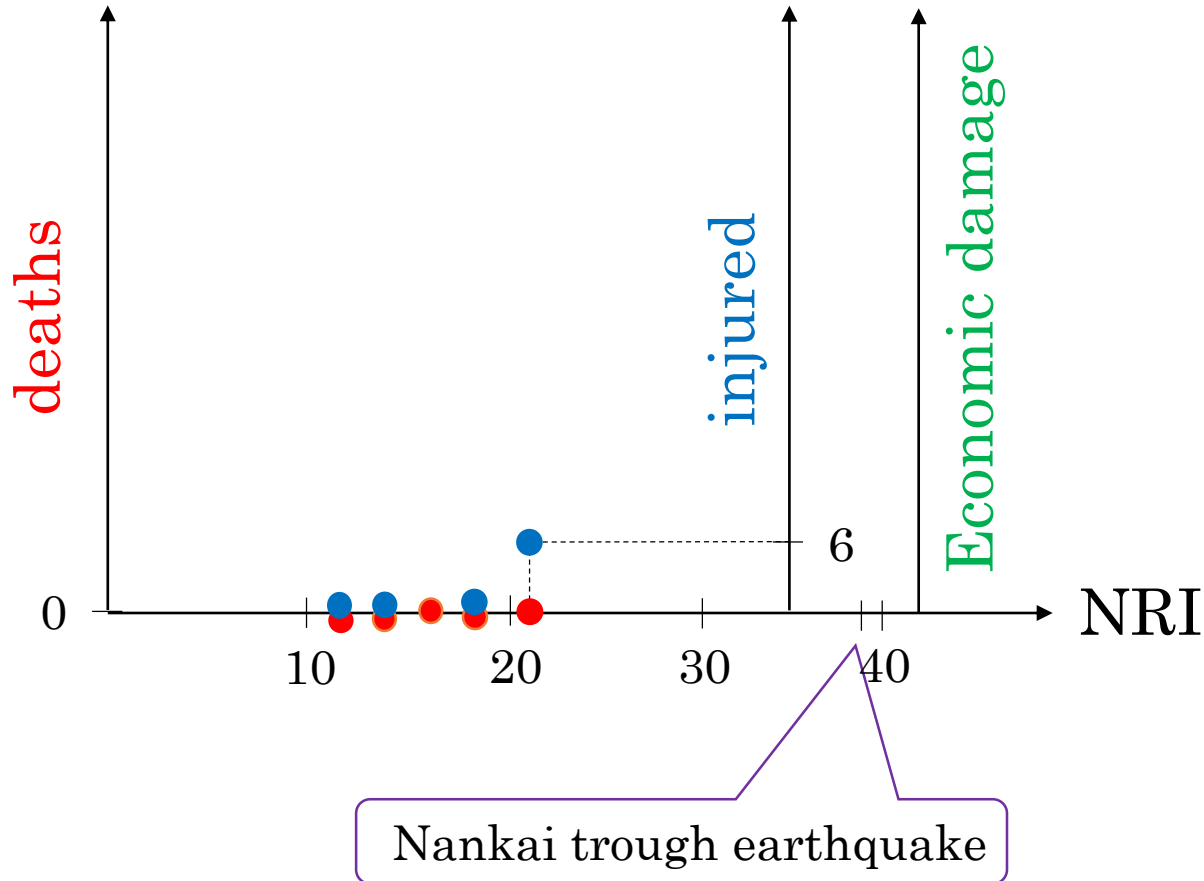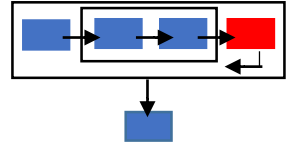
- More samples must be collected and filed in directory, such as RAPID-N.

- Natech accidents of only occurred in Japan are not sufficient to analyze NRI.

- NRI estimation needs more test for its refinement of process.

- We must consider all the tanks in a complex.

Evacuation assessment for explosional event
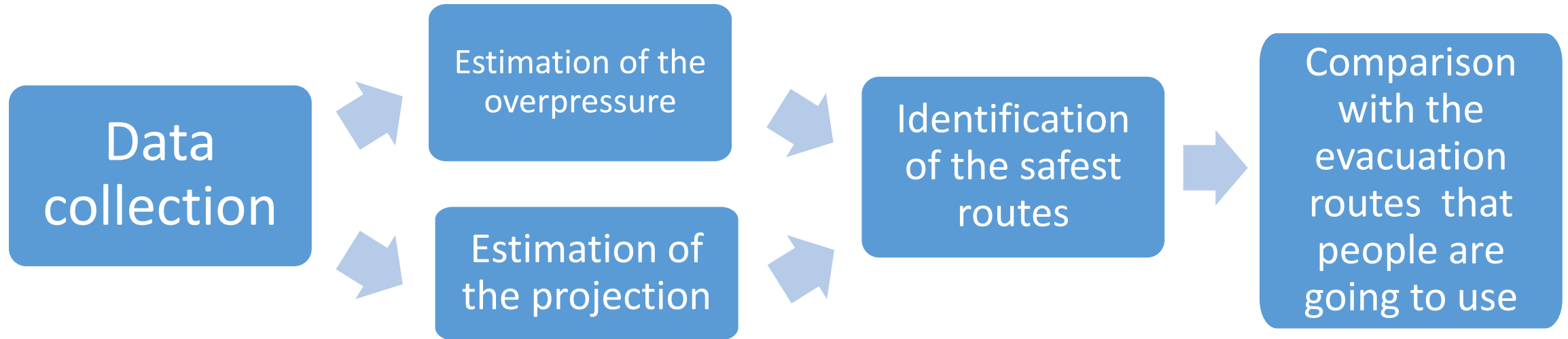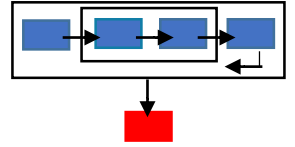
1. Identification of the hazmats in the combinato

2. Estimation of the three dimensional impact area

3. Identification of the obstacles which will protect roads from the debris caused by a Natech accident in the case study area

4. Identification of the safest routes to the evacuation shelters

5. Comparison of the identified safe evacuation routes to the evacuation routes people are going to choose based on the a questionnaire survey in the case study area

Conclusions

- The PANR methodology can be refined with better, more detailed data and procedures to obtain more accurate results.

- An important measure to reduce Natech risk is that industrial facility owners carry out detailed process hazard assessments. (H1)
  Residents should be well informed about the Natech dangers in their area, as well as the disaster prevention and preparedness measures they should take. (A5)

- RAPID-N could benefit by having a Consequences and Vulnerability Assessment module.

- Natech risk following Nankai trough earthquake in Higashinada Ward is not negligible and urgent need to assess Natech risks in Higashinada Ward is demonstrated.

Future Research

- To refine of the PANR by improving the way each criteria is estimated, and by introducing other criteria into the assessment process.

- To investigate and identify all the hazmats and quantities that are stored, processed and/ or handled in each facility in Higashinada Ward.

- To make database with many Natech events and identify the damage for human due to the Natech events.

- To perform a quantitative Natech risk assessment that provide more detailed information on possible scenarios and their credible combination of events.

- Application of the past research of fragment projection and application of the W_{TNT} methodology

- To apply the other areas that are subject to the Natech risks such as the Sakai Industrial Park in Osaka Bay.

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Thank you for your kind attention