Proposal and evaluation of the flood risk management using the new insurance system for flood damage combined with flood control

- *Department of Civil and Environmental Engineering, Faculty of Science and Engineering, Setsunan University, Japan, Dr/Eng and Weather Forecaster : Hiroaki SHIRAYANAGI ★*
- *Osaka Prefecture University College of Technology Civil engineering and Environment Course Department of technological systems, Japan, Dr/Eng : Yukisada KITAMURA*
- *Kyoto University of Disaster Prevention Research Institute, Disaster Information Systems with Information Technology, Japan, Master's Course : Ryo HIRAKO*

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Introduction

- ***In recent years, frequent extreme disasters have occurred all over the world.***

1) Climatological disasters (Extreme temperature, Drought, Forest fire)

2) Hydrological disasters (Flood, Mass movement)

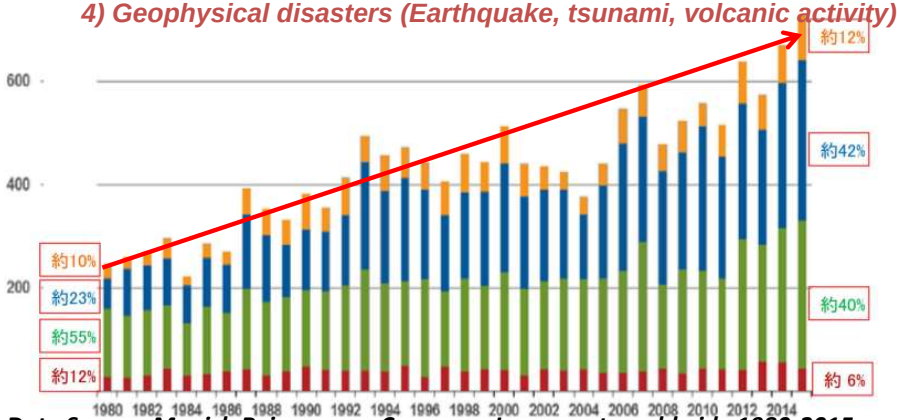
3) Meteorological disasters (Tropical storm, Tornado)

4) Geophysical disasters (Earthquake, Tsunami, Volcanic activity)

- ***These disasters have led to enormous economic and social loss.***

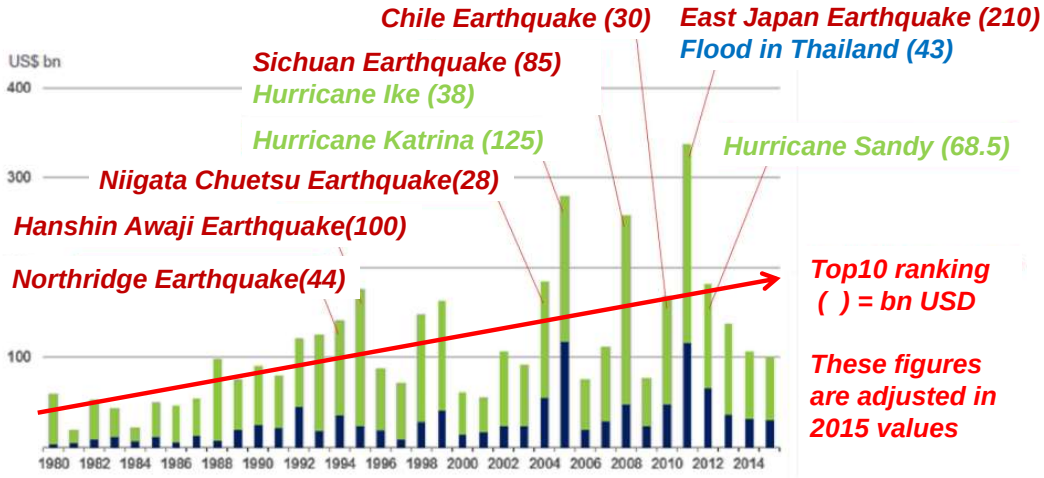
The number of extreme disasters (world)

1) Climatological disasters (Extreme temperature, drought, forest fire)
2) Hydrological disasters (Flood, mass movement)
3) Meteorological disasters (Tropical storm, Hurricane)
4) Geophysical disasters (Earthquake, tsunami, volcanic activity)



Data Source: Munich Reinsurance Company, Loss event worldwide 1980-2015.
Table Source: Cabinet Office, Government of Japan /Author adds words.
Accounted events have caused at least one fatality and/or produced normalized losses > USD 100k, 300k, 1m or 3m (depending on the assigned World Bank income group of the affected country)

Overall losses in 1980-2015 (world)



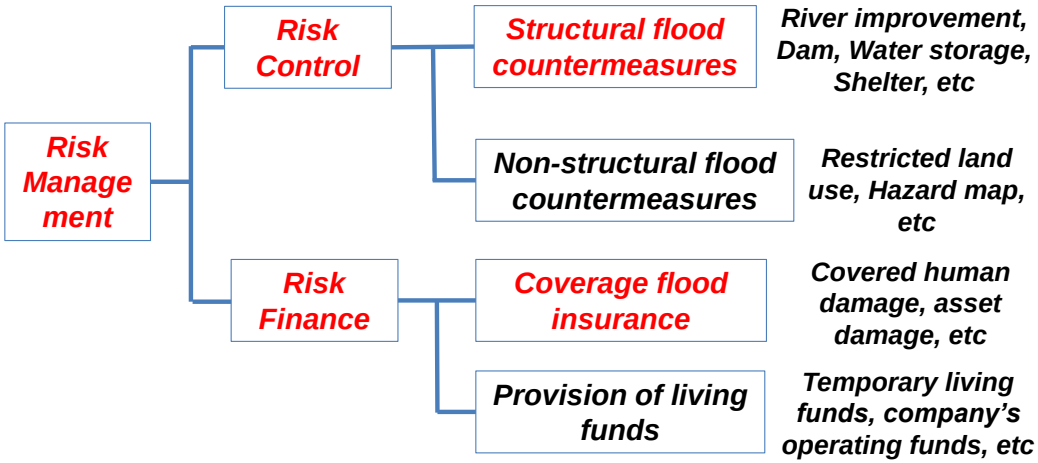
Data Source: Munich Reinsurance Company, Loss event worldwide 1980-2015.
Table Source: Cabinet Office, Government of Japan /Author adds words.
Inflation adjusted via country-specific consumer price index and consideration of exchange rate fluctuations between local currency and USD

The tendency of extreme disasters (world)

- As former two tables (P3, P4) are shown, the number and overall losses of extreme disasters may have increasing, in particular hydrological disasters and meteorological disasters (flood damage).

- How can we protect ourselves from flood damage?
- What would be the better thing to prepare for flood damage?

Risk management against flood damage



Data Source: Yoshioka, Comparison and consideration of flood insurance system with other countries, 2002 / Author adds words.

The purpose in this paper

1. We organize "the current situation and problems surrounding flood disaster risk management" in Japan and river-flooded area.(Chapter 1)
2. We suggest "the new insurance system" by combining flood countermeasures as a risk control method and flood insurance as a risk finance method. (Chapter 2)
3. We show the calculation's method of the insurance product value by the new insurance system and estimate the insurance fee in river-flooded area. (Chapter 3,4)

1. The current situation and problems surrounding flood disaster risk management in Japan and river-flooded area

The most risky city about natural disasters

- 1st : Tokyo and Yokohama (Japan)
- 5th : Osaka and Kobe (Japan)
- 6th : Nagoya (Japan)

In 616 cities or metropolitan areas around the world

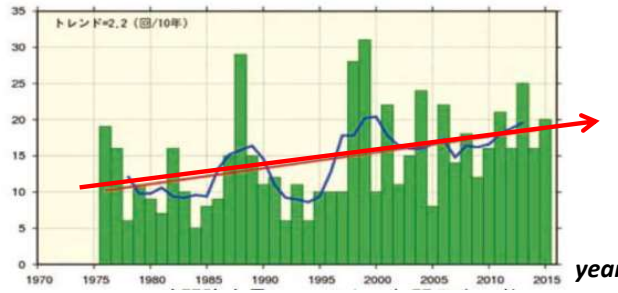
- Hydrological disasters (Flood) and meteorological disasters (Tropical storm) occur frequently.
- Geophysical disasters (Earthquake, Tsunami, Volcanic activity) will occur with high probability.

Data Source: Swiss Re:
Mind the risk: A global ranking of cities under threat from natural disasters
https://media.swissre.com/documents/Swiss_Re_Mind_the_risk.pdf (English)

Rainfall's trend

- In Japan, the times recording over 80mm/hr rainfall is increasing year by year.

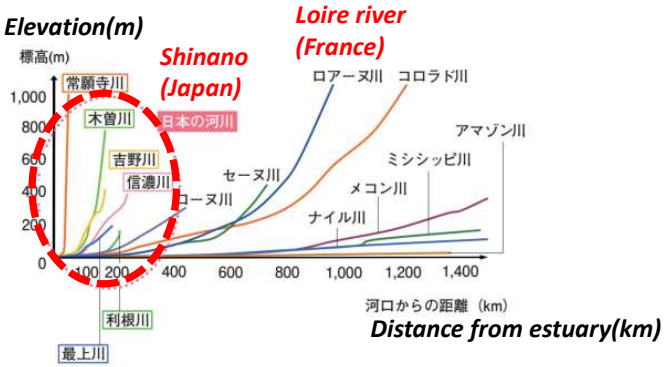
The times recording over 80mm/hr rainfall per 1,000 observatories



Data Source: Japan Meteorological Agency
Monitoring report of climate change in Japan(2016)

River's situation

- In Japan, the river has a short distance and a steep gradient. So the river-flooded period is very short and flood flow per basin area is very high.



Data Source: Ministry of Land, Infrastructure, Transport and Tourism
http://www.mlit.go.jp/river/toukei_chousa/kasen_db/pdf/2019/all.pdf (Japanese)

People and Assets concentrating the river-flooded area

- In Japan, the river-flooded area accounts for only 10% of the land, but 50% of Japan's population lives on such land and the assets in this area account for 75% of Japan's assets.

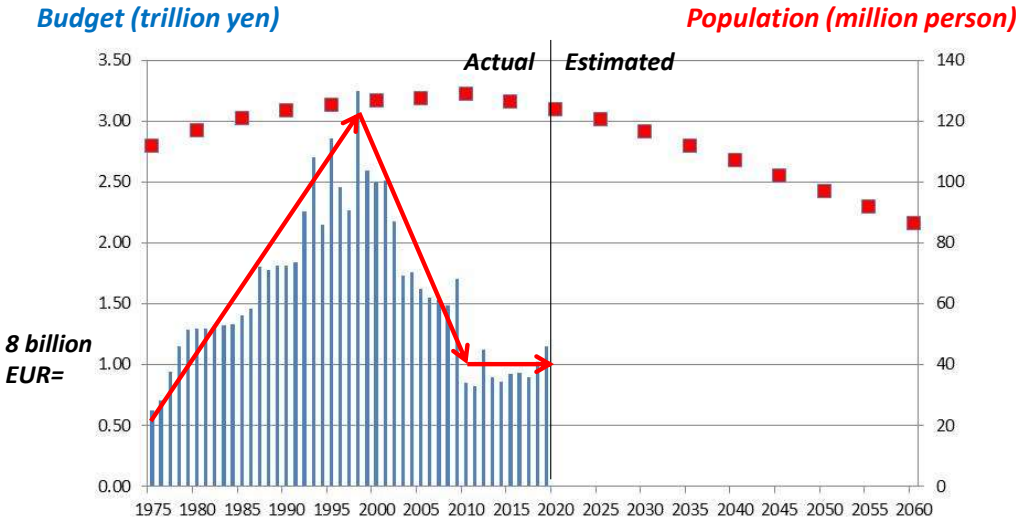
- Therefore, the damage caused by torrential rain and typhoons is very extensive in terms of humans and assets.

Data Source: Ministry of Land, Infrastructure, Transport and Tourism
http://www.mlit.go.jp/river/toukei_chousa/kasen_db/pdf/2019/all.pdf (Japanese)

Investment of flood countermeasures(1)

- To help reduce these damages, flood countermeasures such as widening the river channel have been implemented.
- But as the population decreases and infrastructure renewal efforts become concentrated, these conventional flood countermeasures will be more difficult to implement in the future.

Investment of flood countermeasures(2)



Data Source: Ministry of Land, Infrastructure, Transport and Tourism
http://www.mlit.go.jp/river/toukei_chousa/kasen_db/pdf/2019/all.pdf (Japanese)
Author makes table based on the data source.

The situation of coverage flood insurance

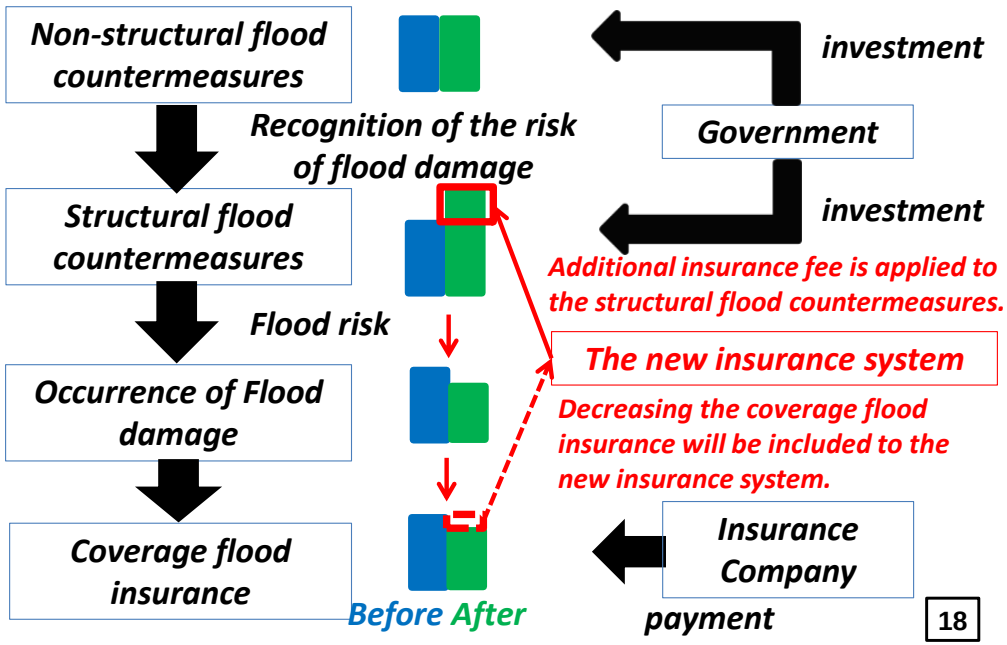
	America	UK	Germany	France	Switzerland	Japan
Forms of insurance	Flood insurance	House Insurance	House Insurance	House Insurance	House Insurance	House Insurance
Insurance rate	By risk map	By risk map	By risk map	Constant rate	Constant rate	Constant rate
Insurer	FEMA*	Private Company	Private Company	Private Company+ Government	Private Company	Private Company
Degree of participation	Optional 14%	Optional 70-90%	Optional 32%	Compulsory	Compulsory	Optional 57%

By compulsory insurance, those who the risk feels low are dissatisfactory with the payment. The incentives of decreasing flood risk are hard to work.
By optional insurance, those who the risk feels low hesitates the payment.

Data Source: Cabinet Office, Government of Japan /Author adds words.
FEMA* = Federal Emergency Management Agency

2. The new insurance system by combining flood countermeasures as a risk control method and flood insurance as a risk finance method

The new insurance system

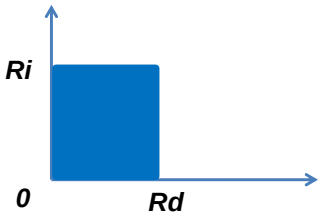


Benefits by the new insurance system

- In this system, a portion of the flood counter-measures' project costs is covered by insurance product sales, so people who have losses due to flood damage are able to receive flood insurance payments if unanticipated flood damage is suffered.
- At the same time, inhabitants in disaster areas will benefit from damage relief implemented through the flood countermesures' project. Finally, this system is expected to reinforce resilience from flood damage in the river-flooded area.

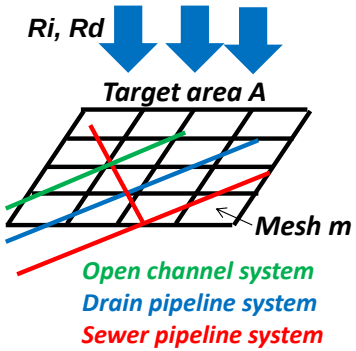
3. The calculation's method of the insurance product value by the new insurance system

Calculation's method (1)



- Ri : Rainfall intensity (mm/hr)
- Rd : Rainfall duration (hr)

⇩ Fair formula
Flooded Simulator (NILIM2.0)
with 3 systems



- T : return period
- D(m) : Maximum inundation depth

⇩ The relation between D(m) and L(m):
Data Source: Ministry of Land, Infrastructure, Transport and Tourism
Manual of survey in flood countermeasures' economy (2005)

- L(m) : Rate of damage

Calculation's method (2)

- θ : subsidy rates
- I(m) : Price of asset

⇩ $S(m) = (1+\theta)\, L(m) / 0.6(1-\theta) \times I(m)$
$K(m) = \theta\, L(m) \times I(m)$

- S(m) : Price of insurance goods
- K(m) : Payment of compensation by asset damage

⇩ Black-Scholes equation

- $f(S(m), t)$: the price of a European call option

Calculation's method (3)

where

$$f(S(m), t) = S(m) \cdot N(d1) - K(m) \cdot e^{-r(T-t)} \cdot N(d2)$$

$$N(d) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{d} e^{-\frac{z^2}{2}}\, dz$$

$$d1 = \frac{log\left(\frac{S(m)}{K(m)}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}, \quad d2 = \frac{log\left(\frac{S(m)}{K(m)}\right) + \left(r - \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}$$

r : the risk free rate (=1%)

σ : the volatility of returns of the underlying asset (=L(m)/(1-θ))

Calculation's method (final)

- T : return period (= 30, 50, 100 years)
- θ : subsidy rates (= 5, 10, 15, 20 %)

⇩ Calculation's method (1)(2)(3)

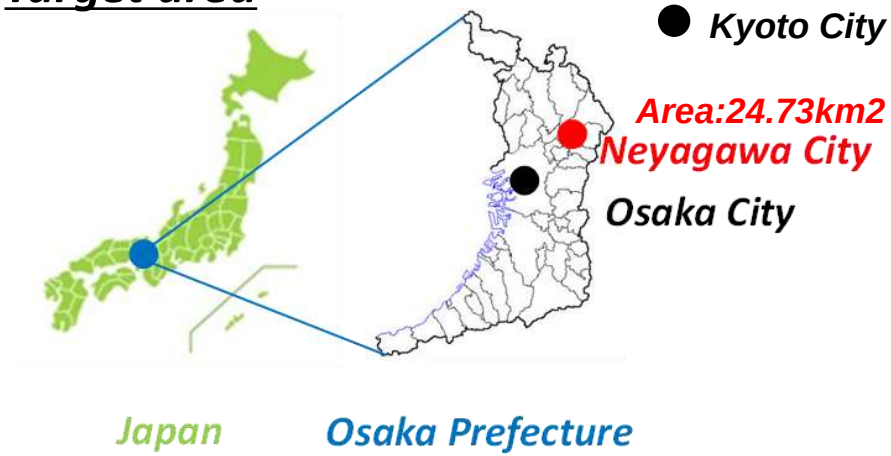
- $f(S(m), 0)$: the price of a European call option in t=0

⇩ $\sum_{m \epsilon A} f(s(m), 0)$/The number of households in A

- The insurance fee in target area (yen/household/year)

4. Estimation of the insurance fee in river-flooded area.

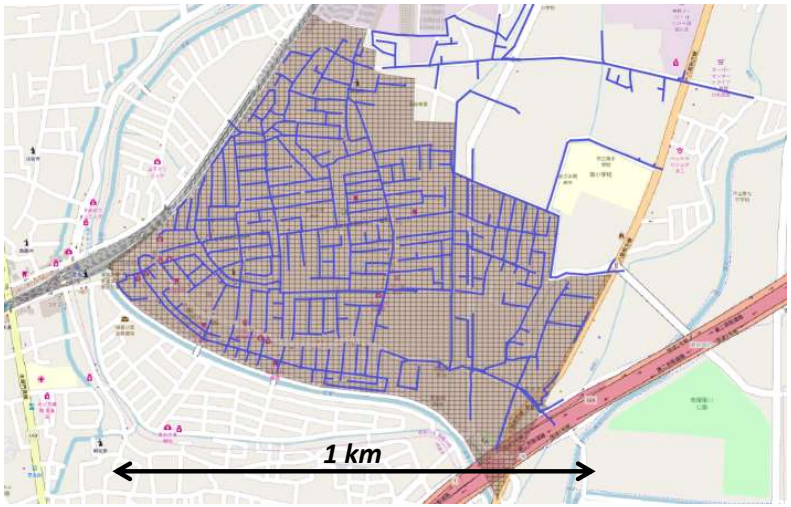
Target area



Population:50,000(in 1960)→250,000(in 1975) →234,373 (in 2018)

This rapid population growth created a densely populated urban area with narrow roads, which is one factor that creates vulnerable land about flood damage

Detailed map in target area



The number of household = 4,758

The number of mesh = 4,790

Result of calculation

The insurance fee in target area (yen/household/year)

	θ=5%	θ=10%	θ=15%	θ=20%
T=100	15,000	16,600	18,400	20,300
T=50	1,760	1,950	2,160	2,400
T=30	76	84	93	103

- We calculated the insurance fee based on the condition that θ% of the insurance product sales are assigned to the flood countermeasures' project and all households purchase insurance that expires in T years, to target the flood damage caused by heavy torrential rains that occurred in some areas of Neyagawa City in Osaka prefecture.
- The maximum of insurance fee per household was calculated to be approximately 20,000 yen (about 160 EUR) per year.

5. Conclusion and future tasks

Conclusion

- *We show the situation of flood damage, natural disaster, investment in flood countermeasures, and flood insurance. (Introduction, Chapter 1)*
- *We propose the method of flood risk management using the new insurance system for flood damage combined with flood control. (Chapter 2)*
- *We estimate that the total value of insurance products will rise even if the insurance fee increases, because it is possible to promote disaster prevention and reduction by allocating funds to the flood countermeasures' project. (Chapter 3,4)*

Future tasks

- *What is the better form of flood insurance?*
  Optional and Compulsory, Insurance and Tax, Government and Private insurance company , …
  Evaluation of flood risk and damage (area, time, flood type) , Inhabitant's behavior, …
- *How we inform people who the risk feels low that the risk of flood damage is higher than ever and the participation of flood insurance is more important.*
  Education, More attractive insurance, …
  Consensus building, …