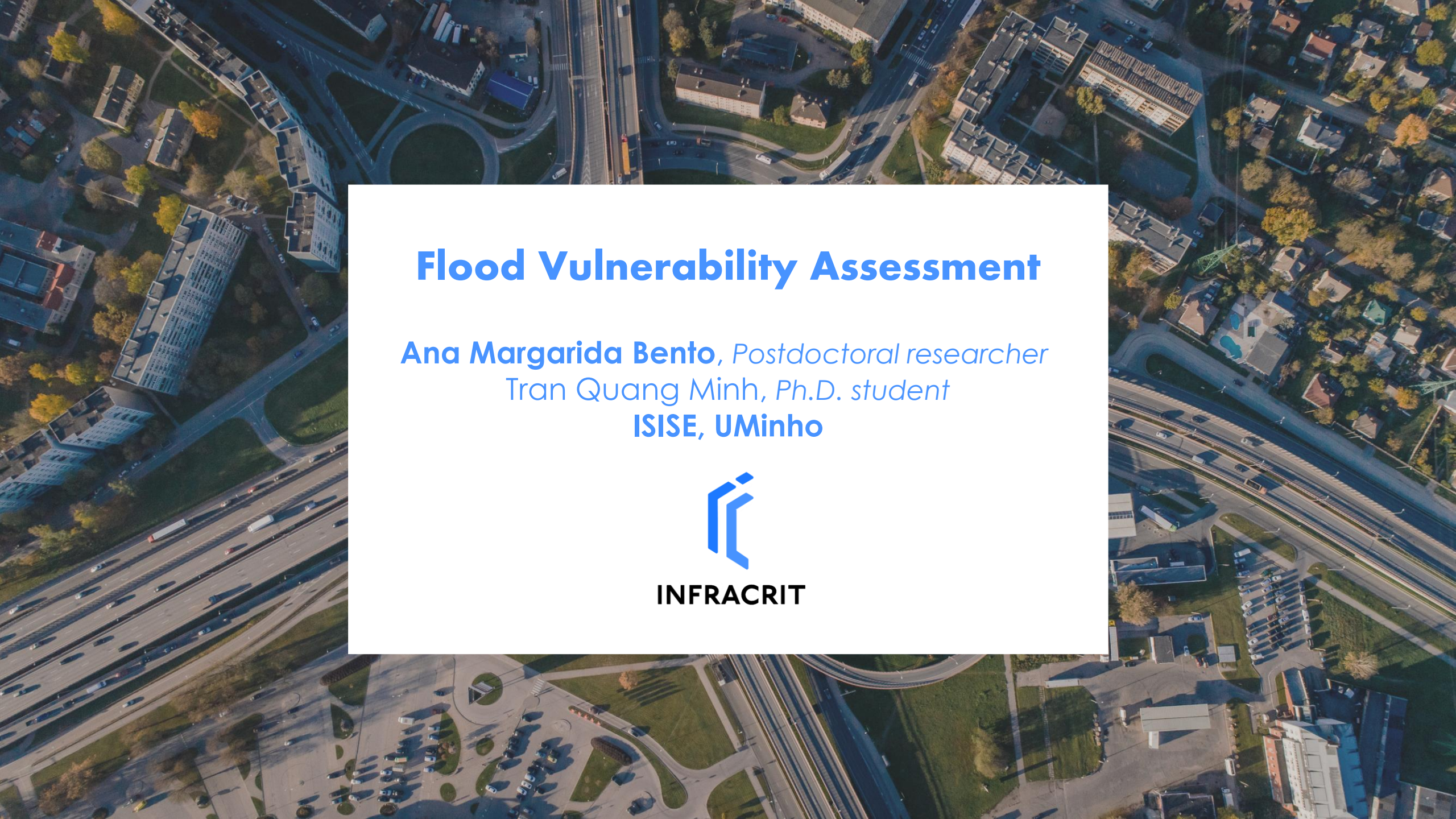

Flood Vulnerability Assessment

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Outline

01. Introduction

- Introduction to flood events and flood vulnerability
- Published studies on vulnerability

02. Conceptual frameworks

- Vulnerability and risk management to flood events
- Vulnerability assessment methods

03. Uncertainty

- Uncertainty of the flood event
- Uncertainty in vulnerability method

04. Conclusions

- Conclusion on vulnerability assessment measures
- Proposal for further research

Flood events and its consequences

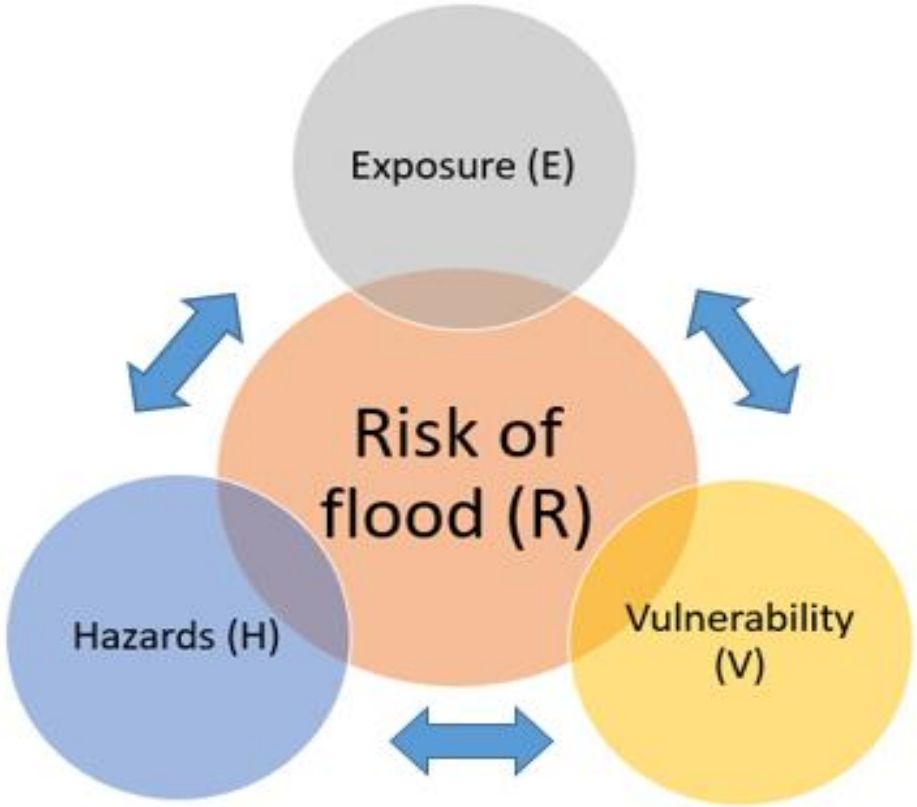
Ngoi Thia Bridge collapsed in Vietnam due to flooding, Dec 2017

Liège, Belgium, 2021

Floods engulf homes in central Vietnam, 2020

Rhineland-Palatinate, Germany, 2021

Flood risk management and its components



The risk of flood (*R*) is composed of three factors: (1) Hazards (*H*), (2) Exposure (*E*), and (3) Vulnerability (*V*).

$$R = f(H, E, V)$$

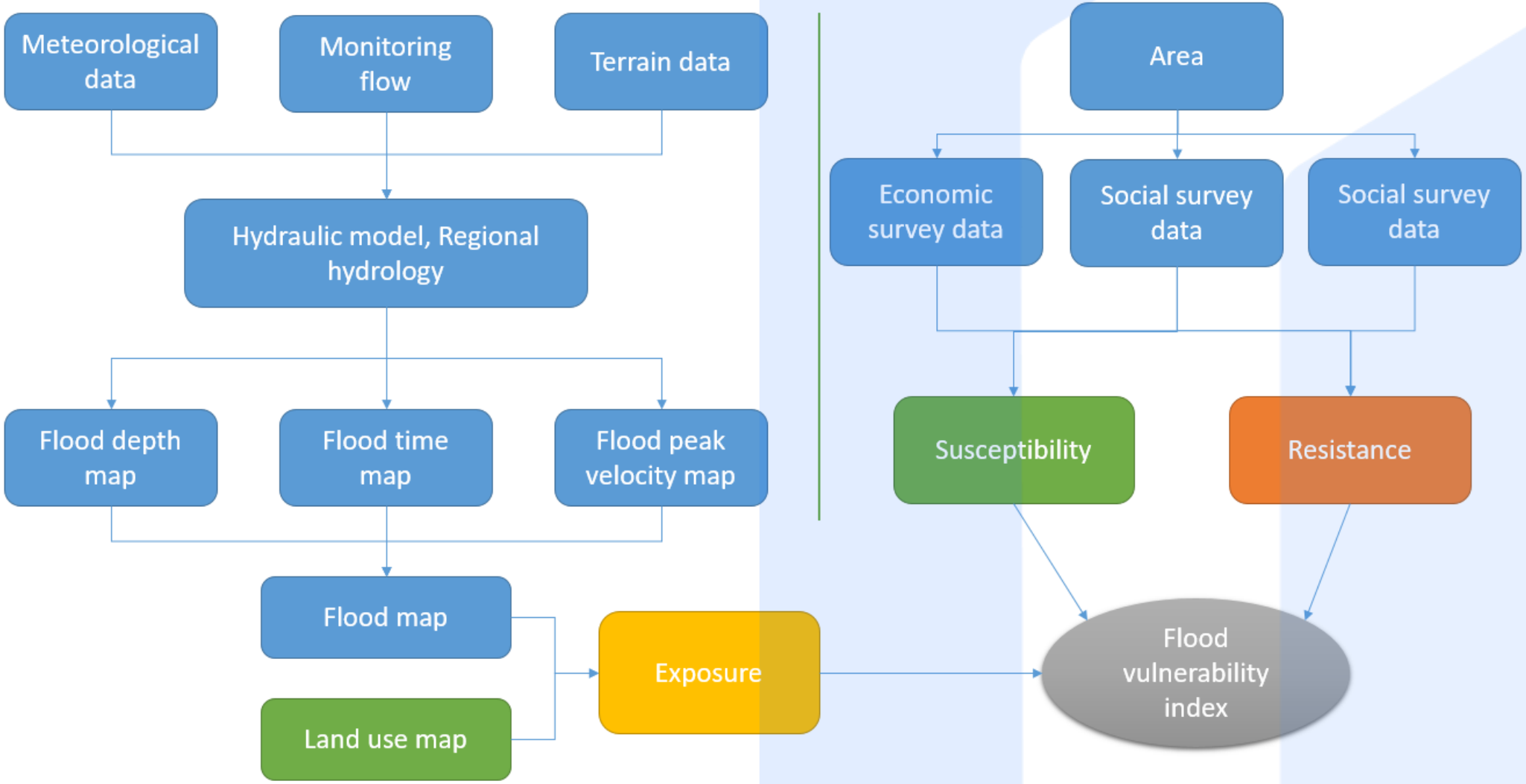
- Hazard (*H*) is an inevitable part
- Exposure (*E*) to floods of human activities is natural, people must appear in economic zones to participate in production activities, build new infrastructure
- Flood risk management, the most important factor is related to **vulnerability (*V*)**

Flood vulnerability assessment methods

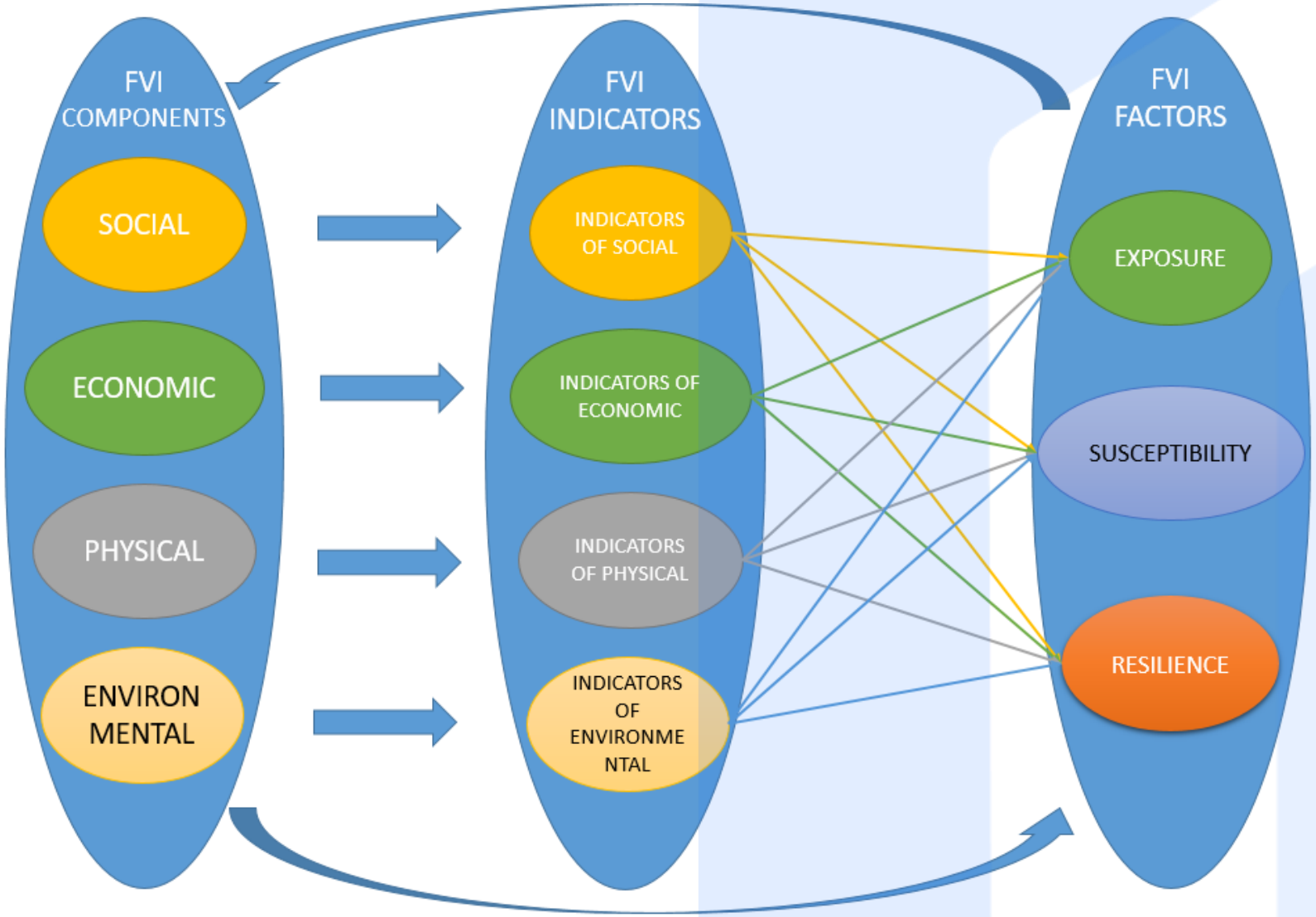
Methods	Vulnerability indicator methods	Vulnerability curve methods	Disaster loss data methods	Modeling methods
Advantages	- Has specific, intuitive categorical value; - Widely researched and used; - Can evaluate in general or specific to each area;	- Precise on the area under consideration because it was established on the basis of actual investigation.	- Simple, easy to do thanks to finding open sources.	- Very well applied to a specific area with full parameters.
Disadvantages	- Depends on many variables of many fields. - The choice of weights for the factors is controversial	- Takes a lot of time and effort; - Not applicable to different areas.	- No significant accuracy.	- Low accuracy in the absence of survey data; - Difficult to implement in a large area.

Combined method for determining flood vulnerability

Flood vulnerability index method enhanced by modeling



Flood vulnerability index (FVI)



Flood vulnerability indicators

Database of the World Bank, up to 1200 indicators were used to calculate and assess vulnerability (1993-1997)

In 2007, Balica et al. selected 40 indicators from 80 considered indicators

In 2014, Balica et al. selected 20 for river basin scale, 22 for sub-catchment and 27 for urban area

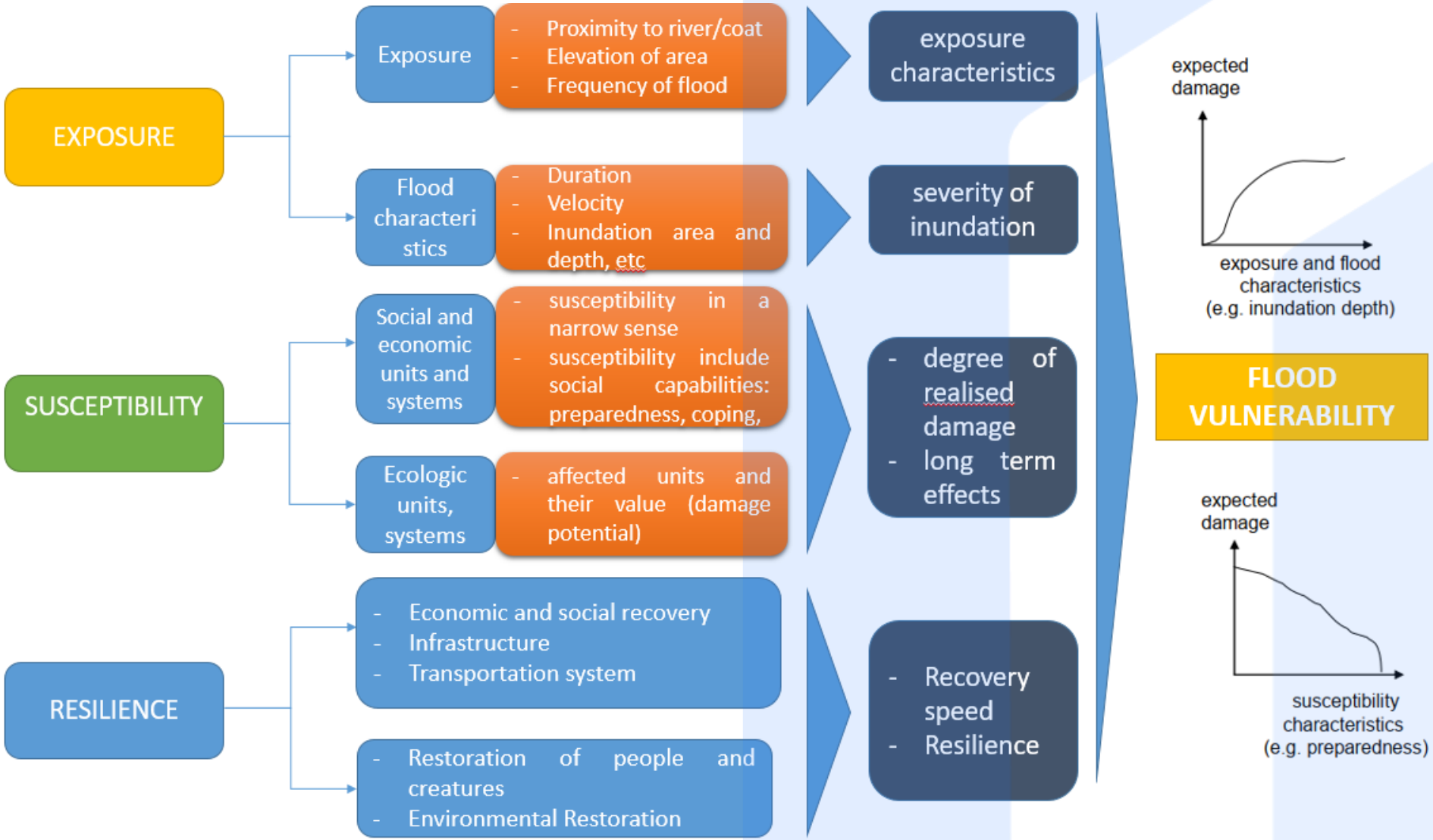
Nguyen et al. 2014 proposed a weight-based flood using 44 indices of components

select

Components	Indicators	Factors	Abb.	Units
Social	Population density	Exposure	P_D	People/km^2
	Flood map	Resilience	$flood_{map}$	-
Economic	Commercial units	Susceptibility	C	Hec
	Industries	Susceptibility	I	Sp^2
Environmental	Rainfall amount	Exposure	R_a	m/year
	River No.	Susceptibility	R	Number
	Open space land use	Resilience	O_{LU}	Hec
	Runoff amount	Exposure	S_t	m^3/s
Physical	Drainage length	Resilience	D_L	Km
	Low-cost building	Exposure	L_{CB}	%

Indicators for consideration in the proposed method

Flood vulnerability factors (1/3)



Factors for consideration in the proposed method

Flood vulnerability factors (2/3)

$$Vulnerability = \text{Exposure} + Susceptibility - Resilience$$ ➡ Less used

$$Vulnerability = \frac{\text{Exposure} \times Susceptibility}{Coping\ capacity\ (\text{or } Resilience)}$$ ➡ Widely used and easier to evaluate

$$FVI_{total} = \frac{\left(\frac{E \times S}{R}\right)_{social} + \left(\frac{E \times S}{R}\right)_{economic} + \left(\frac{E \times S}{R}\right)_{envitonment} + \left(\frac{E \times S}{R}\right)_{physical}}{4}$$

As expected, the parameters and indicators have different dimensions, and the weights of the components also need to be evaluated based on their importance to vulnerability. After normalizing the parameters and getting dimensionally homogenous parameters…

$$y = \sum_{i=1}^{n} \mathrm{W}_i X_i$$ ➡ $$FVI = \frac{\sum_{E=1}^{n} X_E \mathrm{W_E} \times \sum_{S=1}^{n} X_S \mathrm{W_S}}{\sum_{R=1}^{n} X_R \mathrm{W_R}}$$

Flood vulnerability factors (3/3)

$$FVI_{social} = \frac{0.165 P_D}{0.143\, flood_{map}}$$

$$FVI_{Economic} = 0.076 I + 0.09 C$$

$$FVI_{Evironmental} = \frac{0.782 R_a + 0.774 S_t \times 0.219 R}{0.154 O_{LU}}$$

$$FVI_{Physical} = \frac{0.203 L_{CB}}{D_L}$$

Flood vulnerability components

$$FVI_{total} = \frac{FVI_{social} + FVI_{economic} + FVI_{envitonment} + FVI_{physical}}{4}$$

No.	FVI_{total}	Designation
1	< 0.01	Little or no vulnerability to floods
2	0.01 – 0.25	Low vulnerability to floods
3	0.25 – 0.5	Vulnerable to floods
4	0.5 – 0.75	High vulnerability to floods
5	0.75 - 1	Very high vulnerability to floods

FVI_{total}

Uncertainty in vulnerability method (1/2)

- Given the current state of climate change, **disaster predictions based on historical data are highly uncertain.**
- The **impact** of these **extremes events** also depends on the **resilience and adaptation capacity** of the region, the community and each individual.
- **Socio-economic** factors **fluctuate in both space and time**, globally as well as regionally, nationally, and even locally.
- It is worth noting that **vulnerability also depends on the interaction of the above factors** as well as on disasters and crises, accumulation of risks, and dynamics of vulnerability.
- **Vulnerability** expressed in the ability to respond to changes in environmental factors such as physical, chemical, biological, economic, social, institutional, policy, among others will **change drastically across time and space within the locality and community**.

Uncertainty in vulnerability method (2/2)

- The **degree of impact of factors**, such as weather phenomena, extreme climate and disasters on people, communities, infrastructure, industrial parks, urban areas, natural resources (environment) **will be increased**, but vulnerability increased in one area but decreased in another.
- Vulnerability is **both affected by factors of floods or climate change and other factors related and not directly related**, especially the development path of each country, territory and mankind.
- These factors **fluctuate complicatedly from time to time** and therefore the trend of vulnerability changes is **difficult to predict with high confidence**.

Conclusions

- Vulnerability is an important aspect of **assessing and mitigating** the negative impacts of **flooding events**.
- To minimize damage from floods or other negative events, it is necessary to **reduce the vulnerability of communities** and **critical infrastructures** by providing early warning measures, strengthening infrastructure, and taking countermeasures in the worst-case scenario.
- There are **many methods of assessing flood vulnerability**, but each method has its own **advantages and disadvantages**. By analyzing the components and indicators of flood vulnerability, this research **proposes a method to assess vulnerability by combining two methods** of FVI and numerical modeling, at the same time, **provide a set of indicators to assess vulnerability**.
- The proposed vulnerability method **contributes to mitigate the negative impacts of floods**, however it also has **uncertainties due to the influence of many factors**. These factors **vary over both space and time**, making it **difficult** to predict with **complete accuracy**.

Thank you for your attention!

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