DECISION SUPPORT SYSTEMS FOR PARTICIPATORY FLOOD RISK AND DISASTER MANAGEMENT

SPIN LAB SPATIAL INFORMATION LABORATORY

VU VRIJE UNIVERSITEIT AMSTERDAM

PhD Thesis

Panayiotis Sophronides, Dipl.-Ing., MSc & DIC, PhD Candidate

Advisory committee:

Prof. Maria Giaoutzi (Supervisor), National Technical University of Athens.

Prof. Henk J. Scholten, Vrije Universiteit Amsterdam.

Prof. Demetris Koutsoyiannis, National Technical University of Athens.

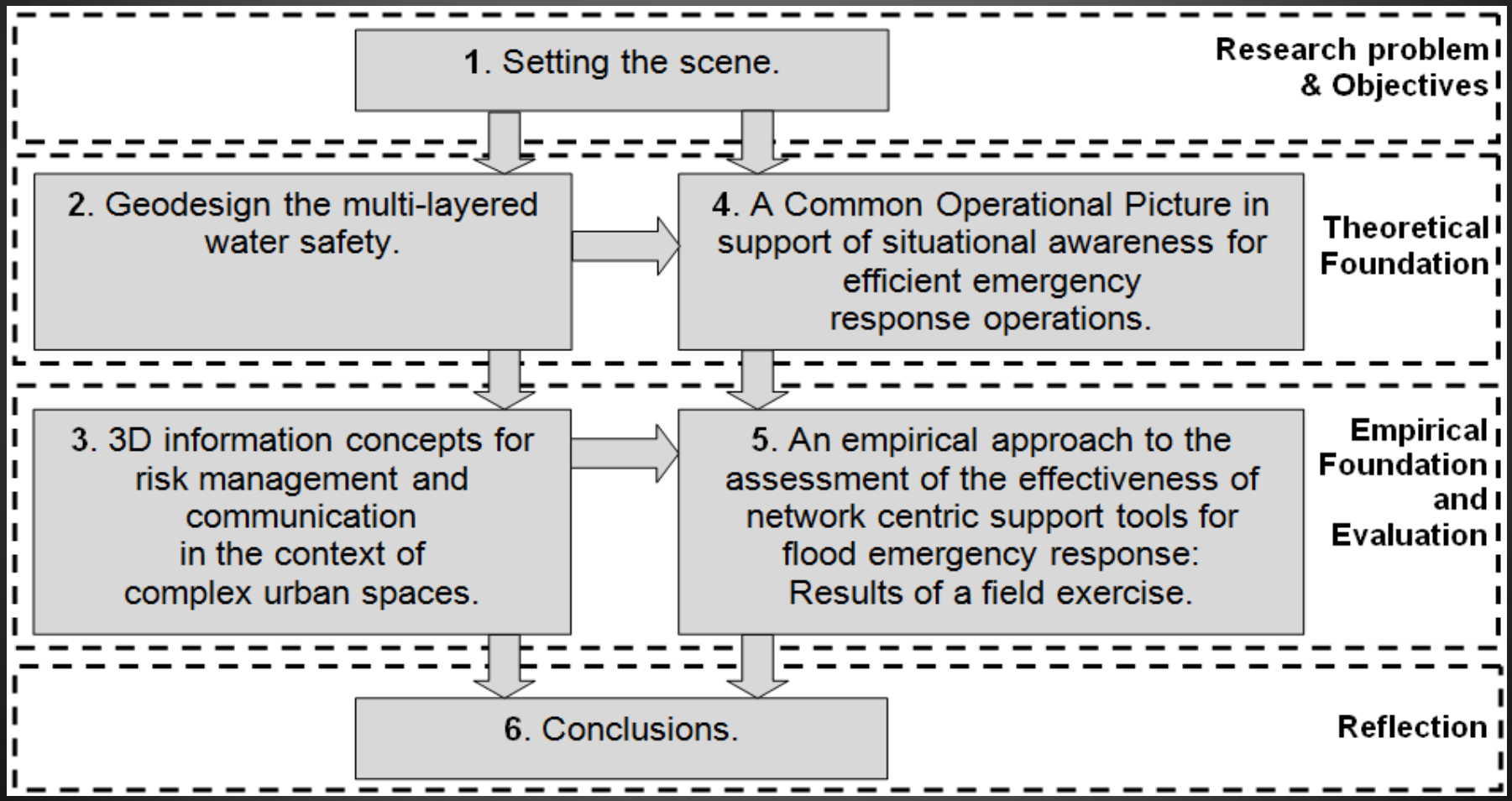
ATHENS

7 OCTOBER 2016

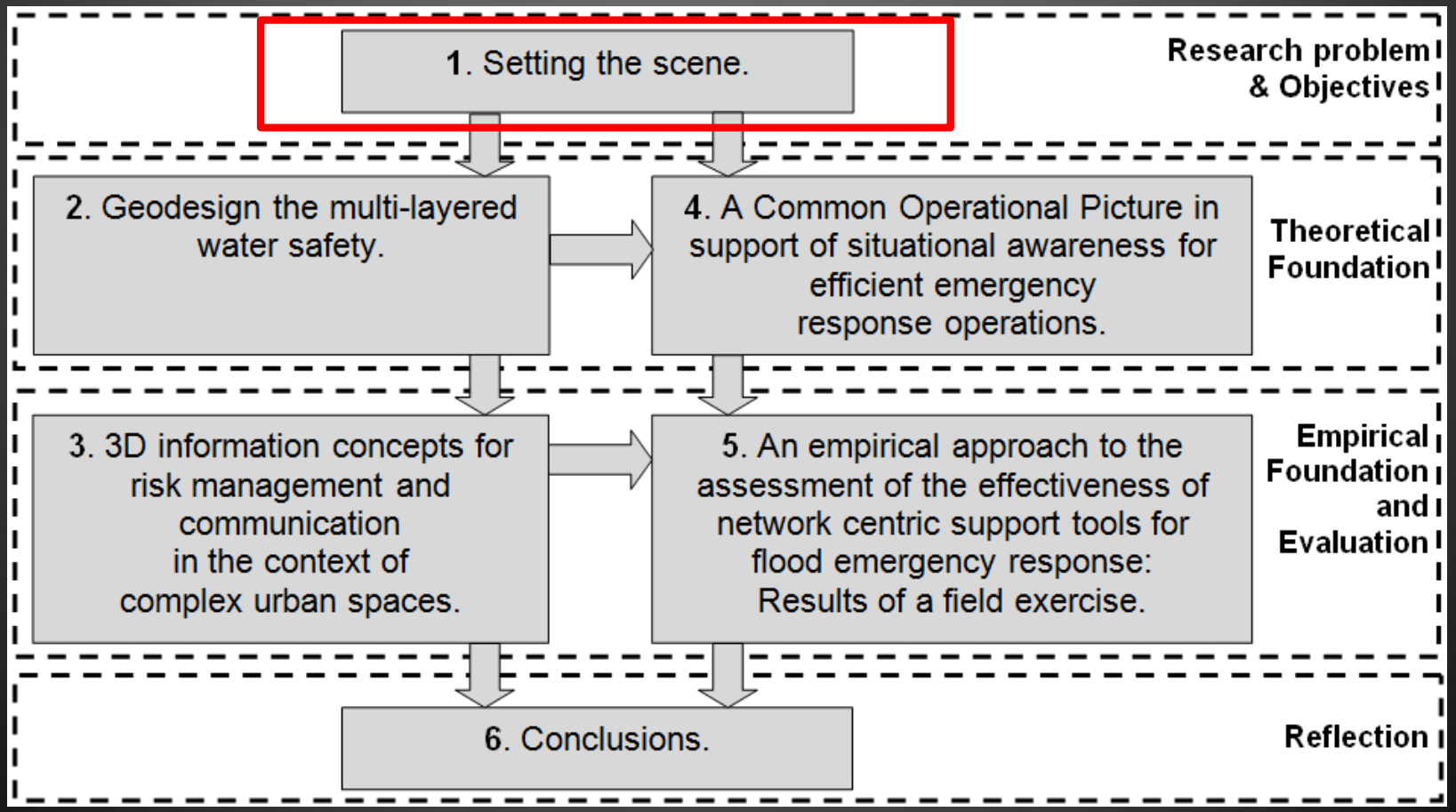
FOCUS OF THE PhD THESIS

IDENTIFICATION AND EXPLORATION OF HOW SITUATIONAL AWARENESS CAN BE IMPROVED TOWARDS BETTER SUPPORTING DECISIONS FOR FLOOD RISK AND DISASTER MANAGEMENT.

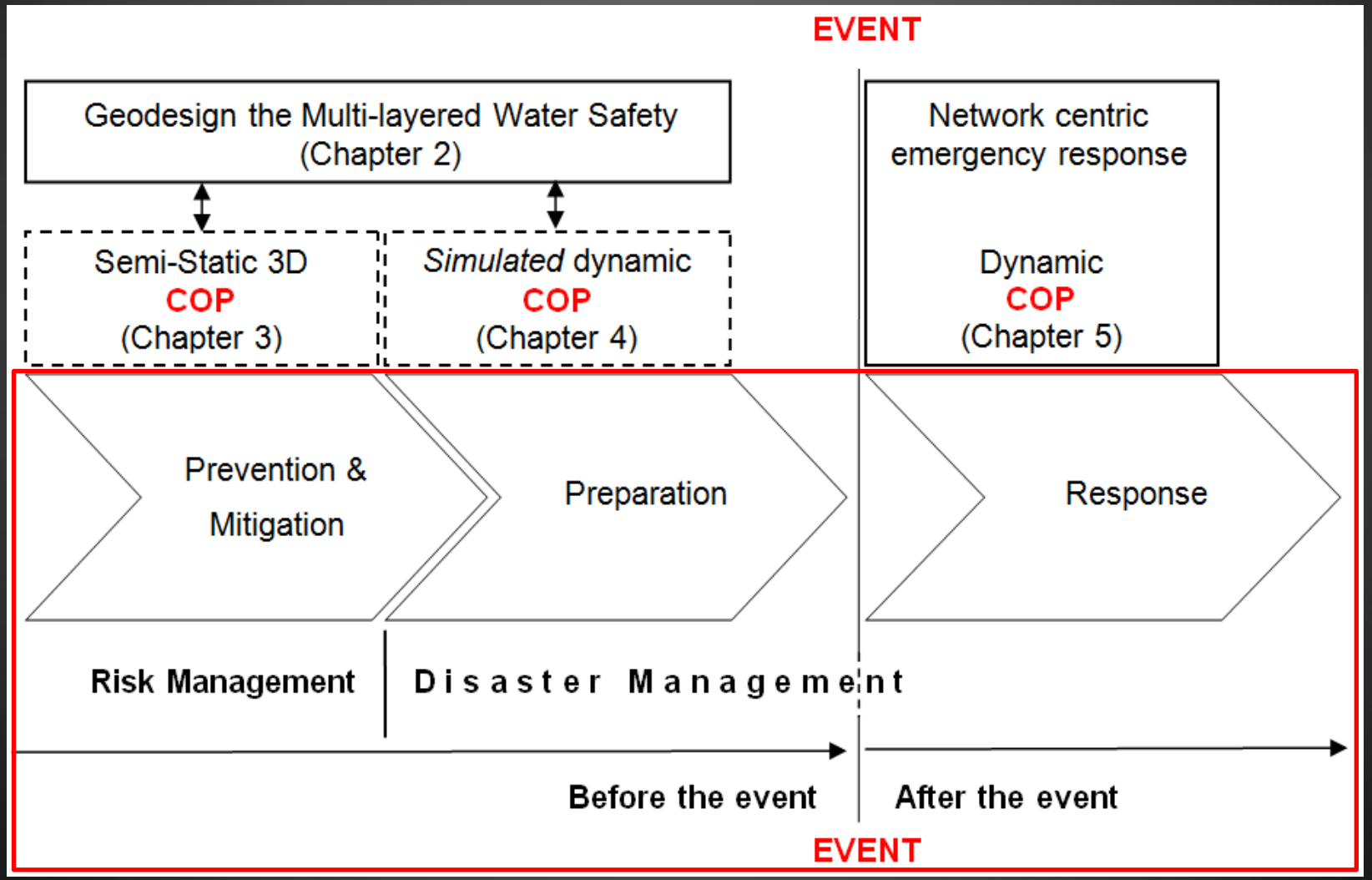
OUTLINE OF THE PhD THESIS



PhD RESEARCH

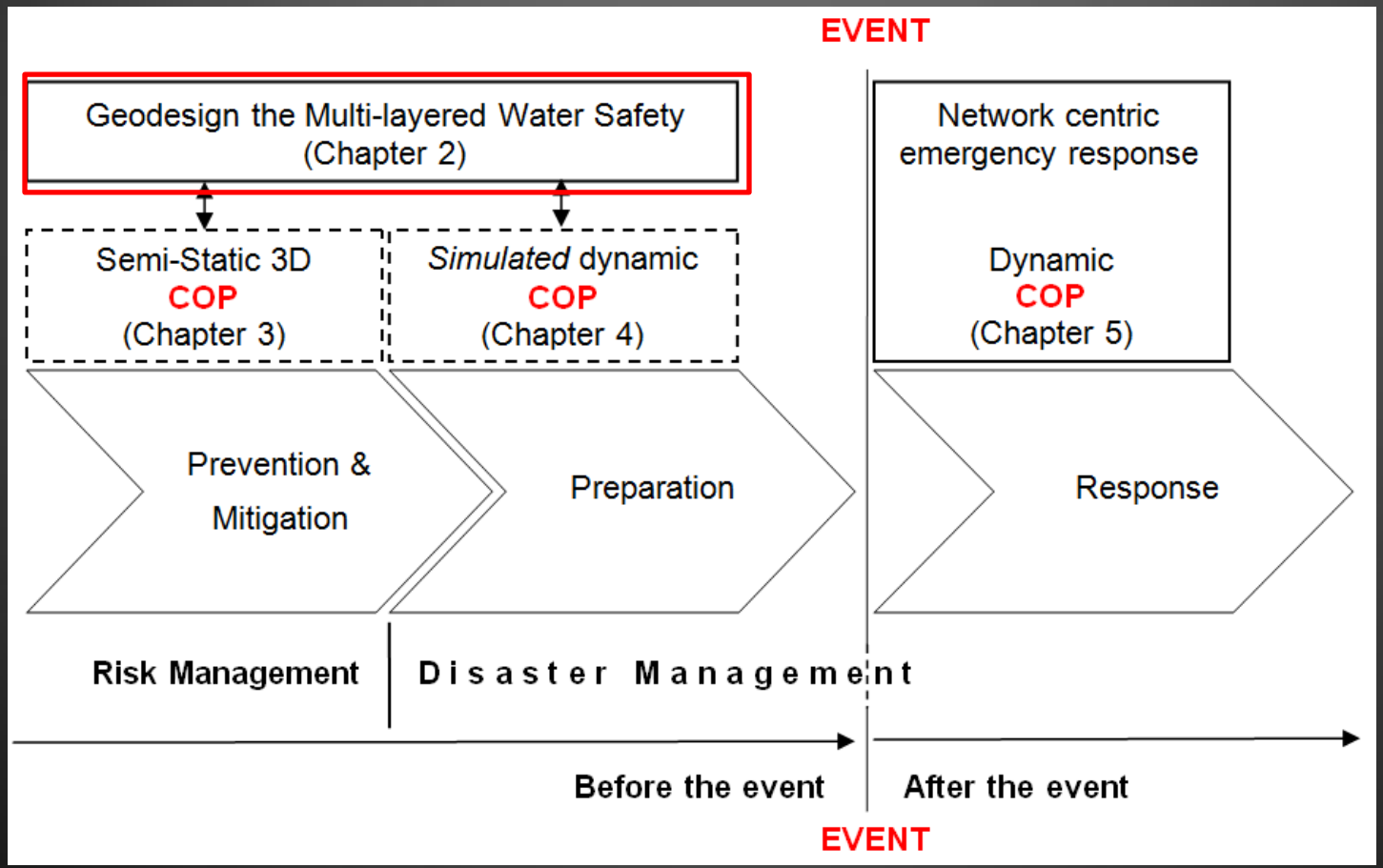


SETTING THE SCENE: THE DISASTER MANAGEMENT CYCLE



CHAPTER 2: AN INTEGRATED FLOOD RISK MANAGEMENT APPROACH

Research question: How can geodesign frame the multi-layered water safety towards improving situational awareness and better supporting decisions in regards to achieving optimal flood security measures?

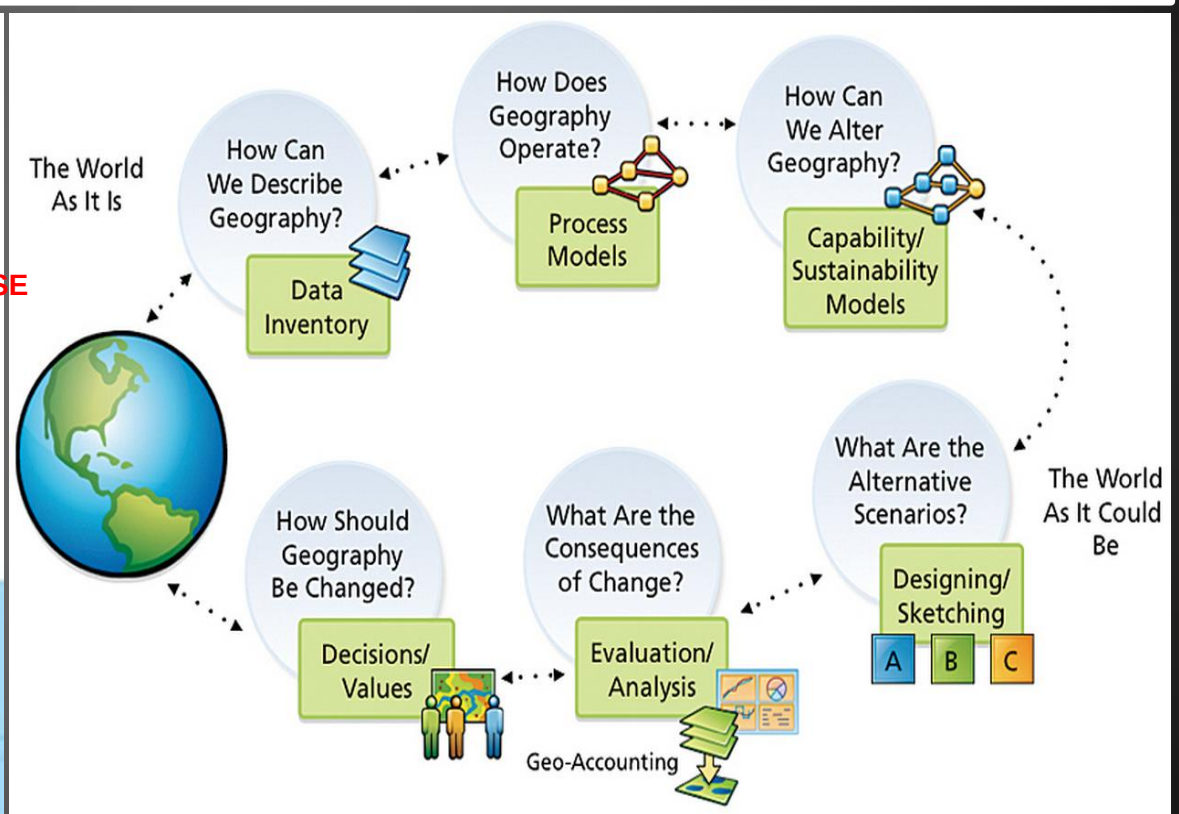


GEODESIGN FRAMEWORK & MULTI-LAYERED SAFETY

Geodesign: The process of changing geography by design. (Steinitz, 2012)

The multi-layered water security concept.

(Kolen *et al*., 2010)



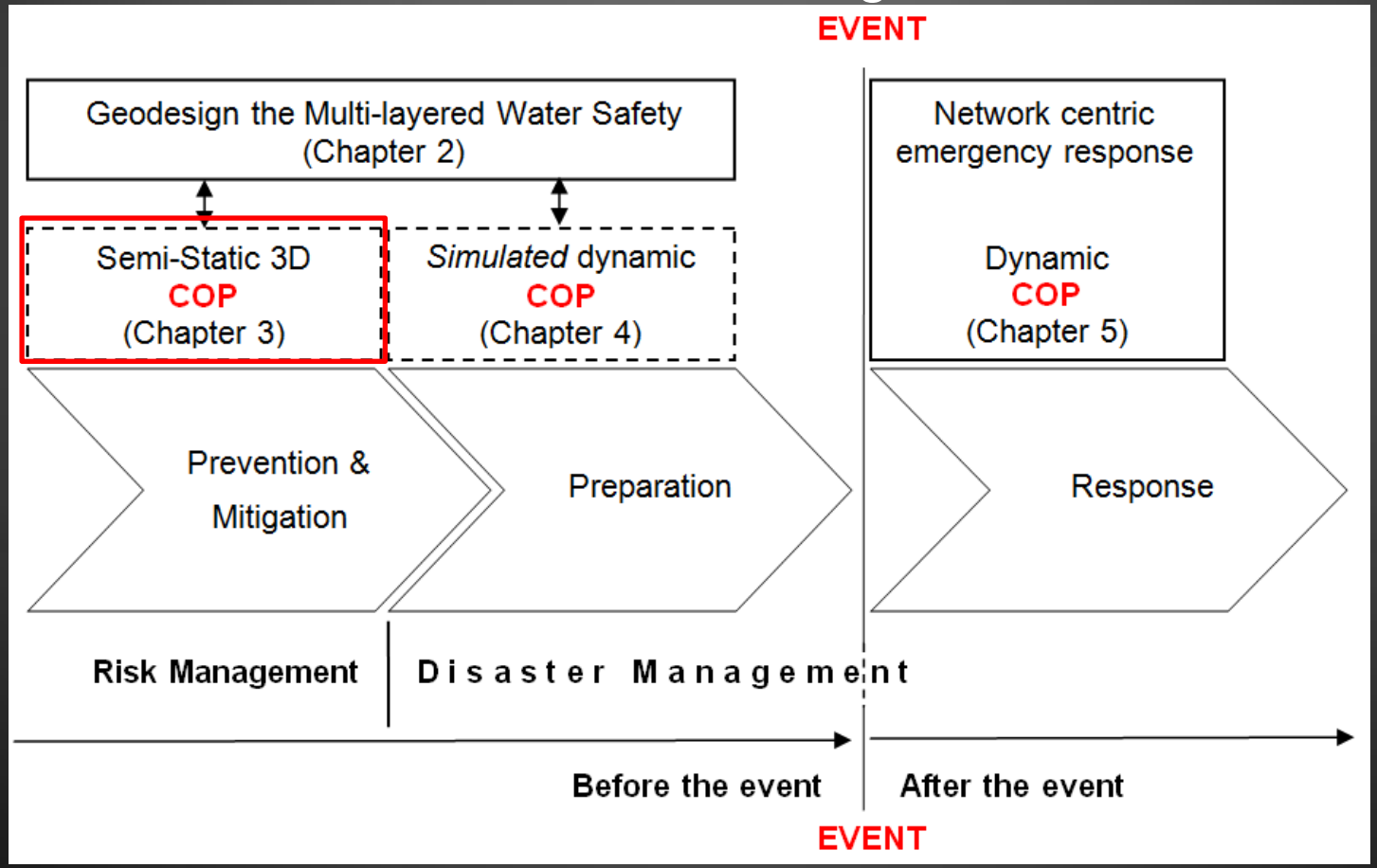
The geodesign framework based on six questions/steps.

Adapted from the Steinitz model of landscape change.

(Dangermond, 2010)

CHAPTER 3: 3D INFORMATION CONCEPTS

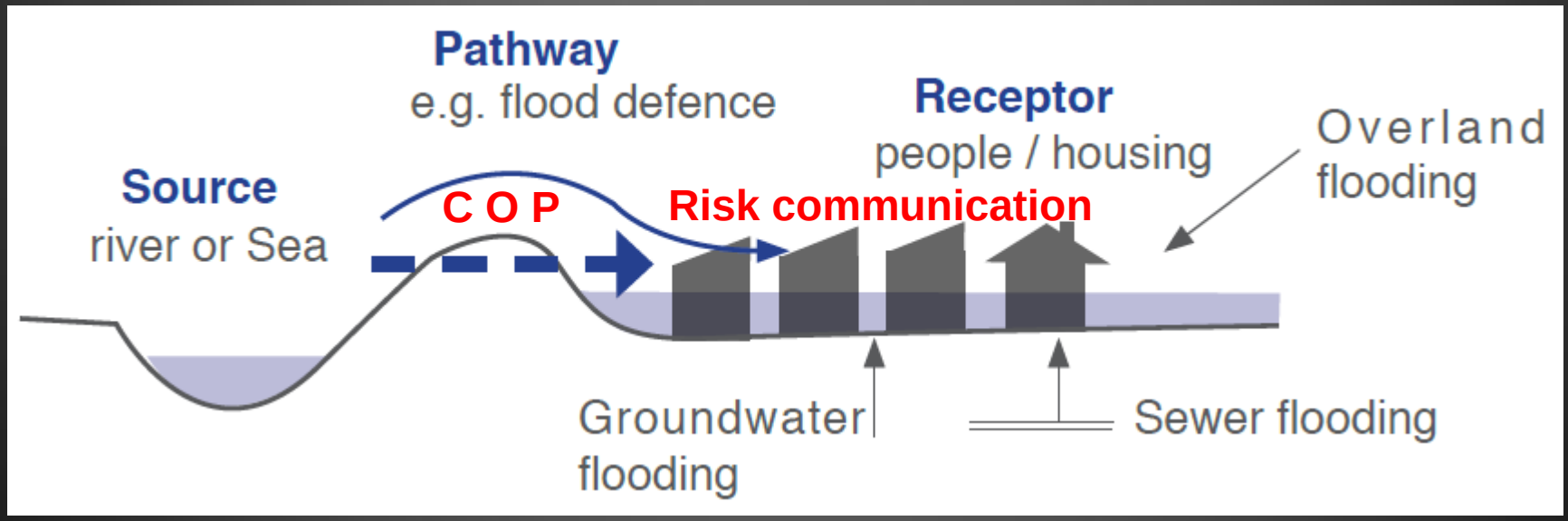
Research question: How can 3D information concepts support information dissemination and visualization towards improving flood risk communication, awareness and management?



ROAD MAP FOR IMPROVING FLOOD RISK COMMUNICATION AND MANAGEMENT

Conceptual flood risk model I	+	Virtual 3D city model of Heerhugowaard II	+	Conceptual 3D information system III

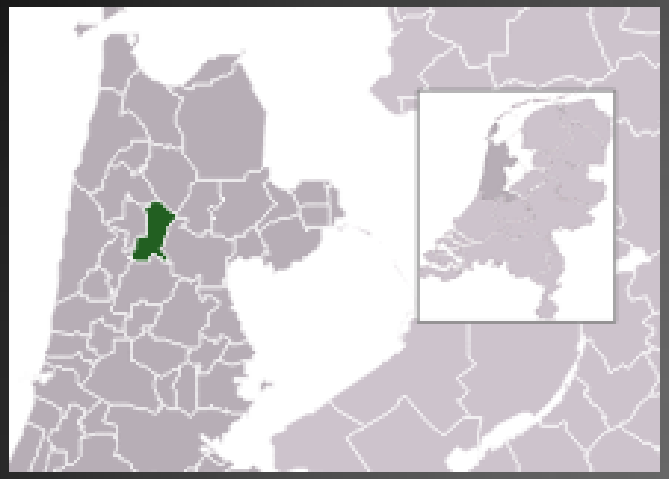
I. FLOOD RISK MODEL



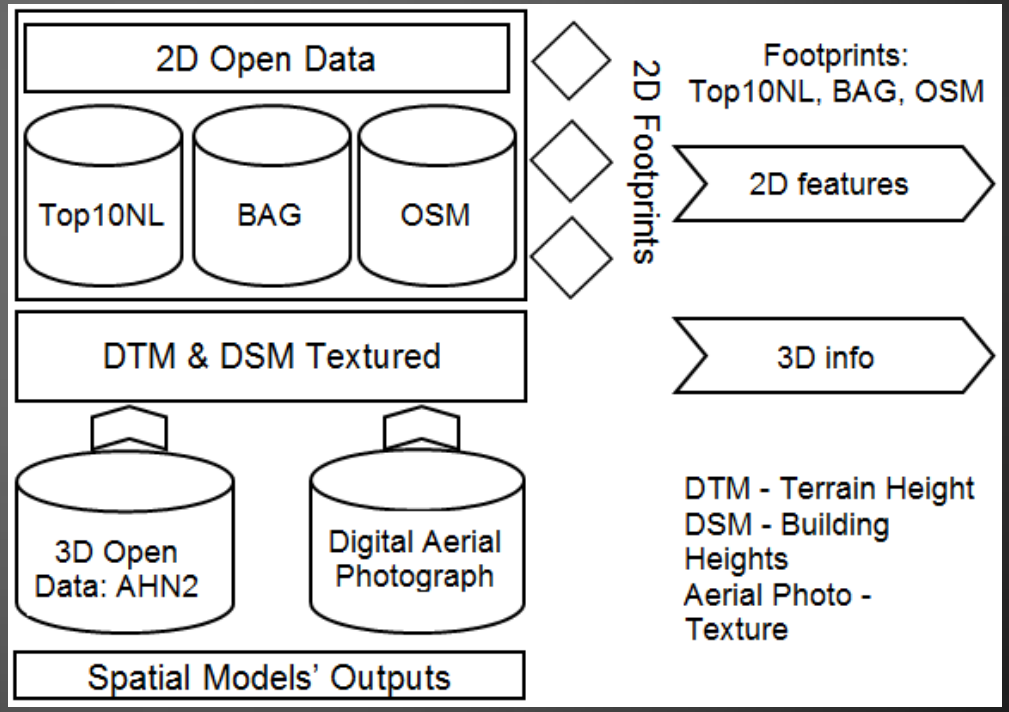
Risk (Source – Pathway – Receptor) Conceptual Model

(Government of Ireland, 2009)

II. CASE STUDY: THE VIRTUAL 3D CITY MODEL OF HEERHUGOWAARD



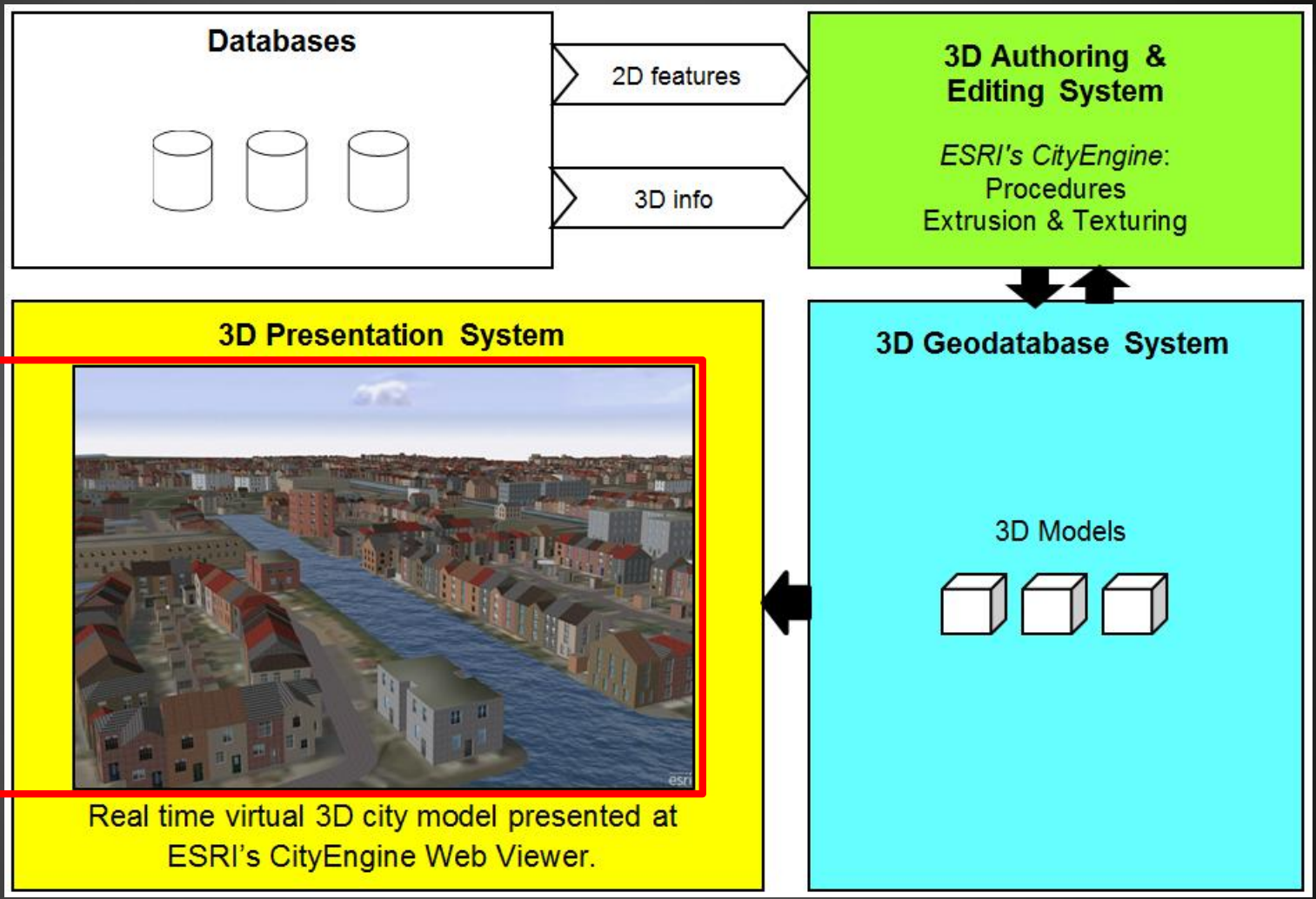
Heerhugowaard area



Databases

II. CASE STUDY: THE VIRTUAL 3D CITY MODEL OF HEERHUGOWAARD

3D C O P

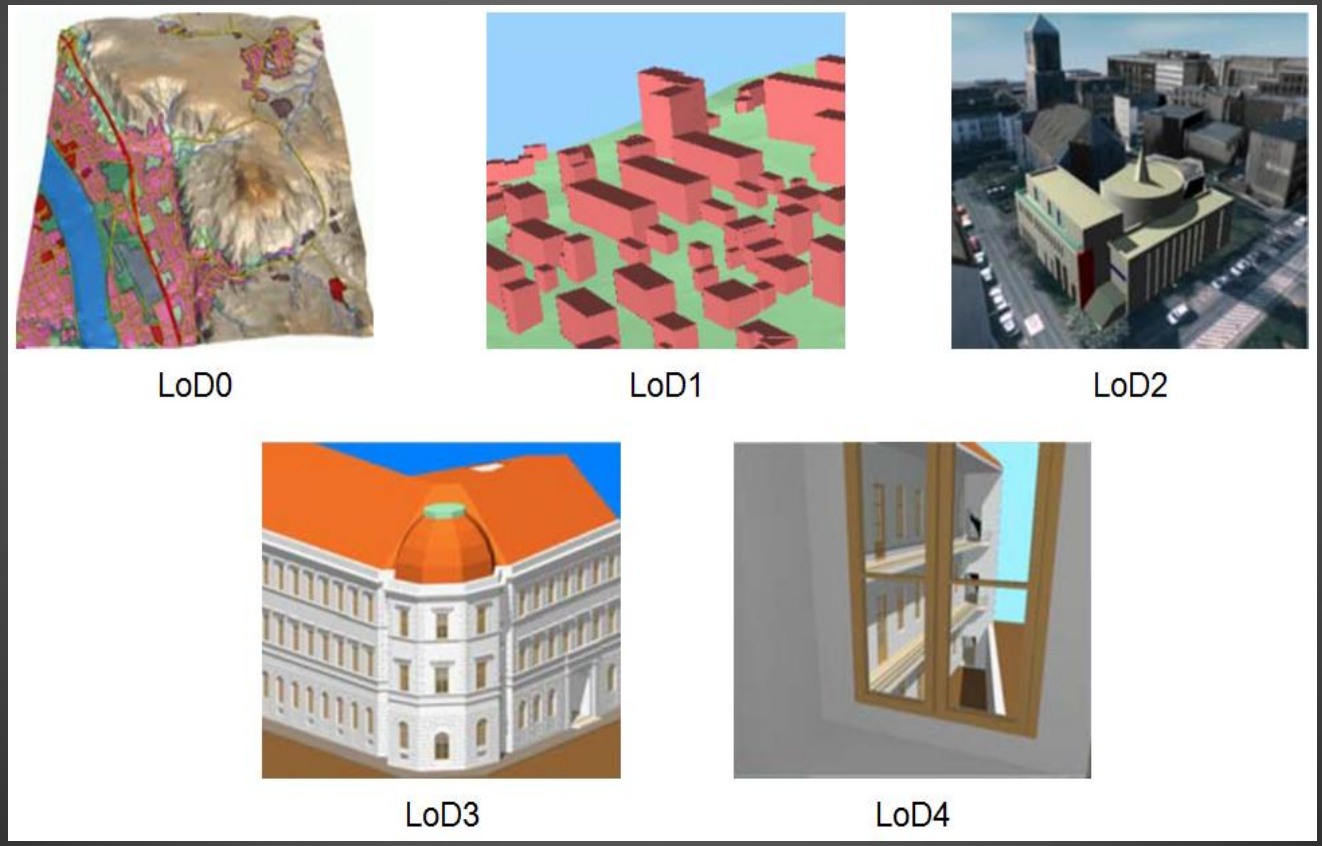


Enables:

Visualization(3D); Awareness; Participation; Transparency; Interactivity.

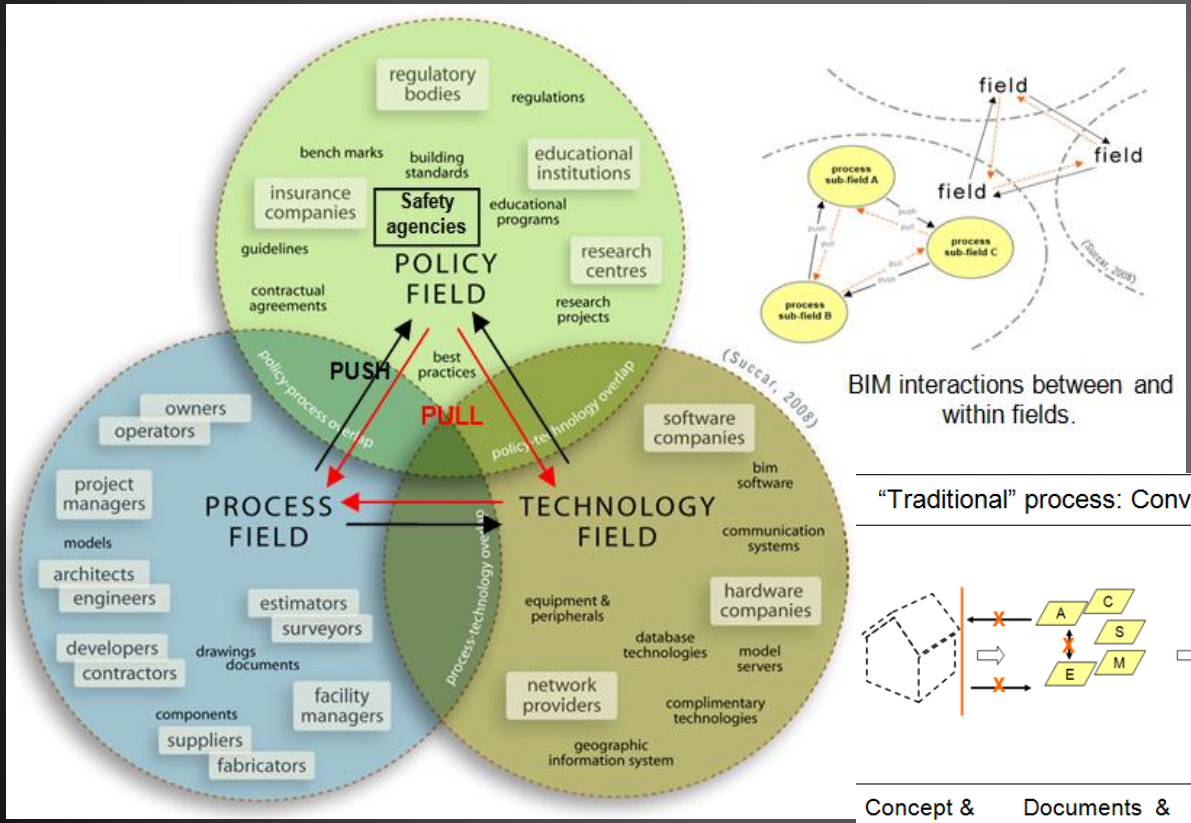
Is it enough?

II. CityGML STANDARD FROM GIS DOMAIN



The 5 Levels of Detail (LoDs) of CityGML standard.
(Gröger *et al.*, 2007)

II. BIM DOMAIN & STANDARDS



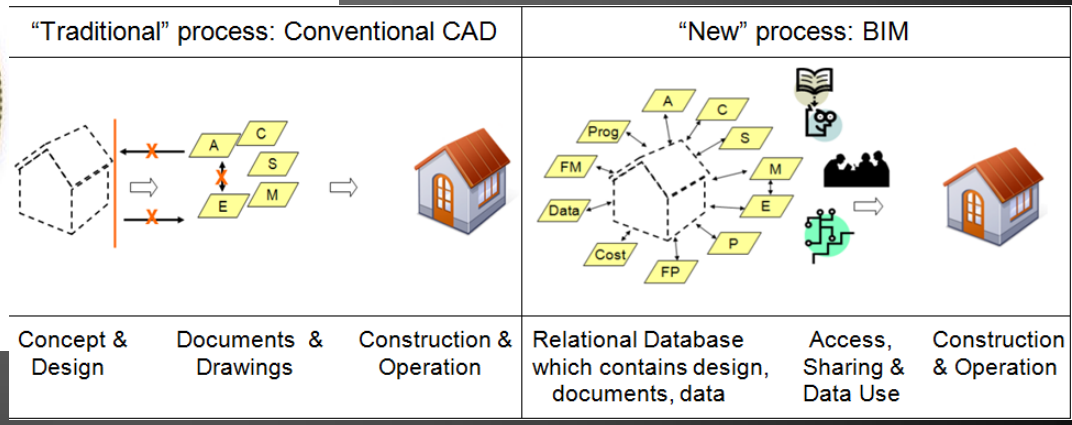
The interlocking **BIM** fields. (Adapted from Succar, 2009)

BIM interactions between and within fields.

Standards:

CIMSteel Integration Standards 2 (**CIS/2**);

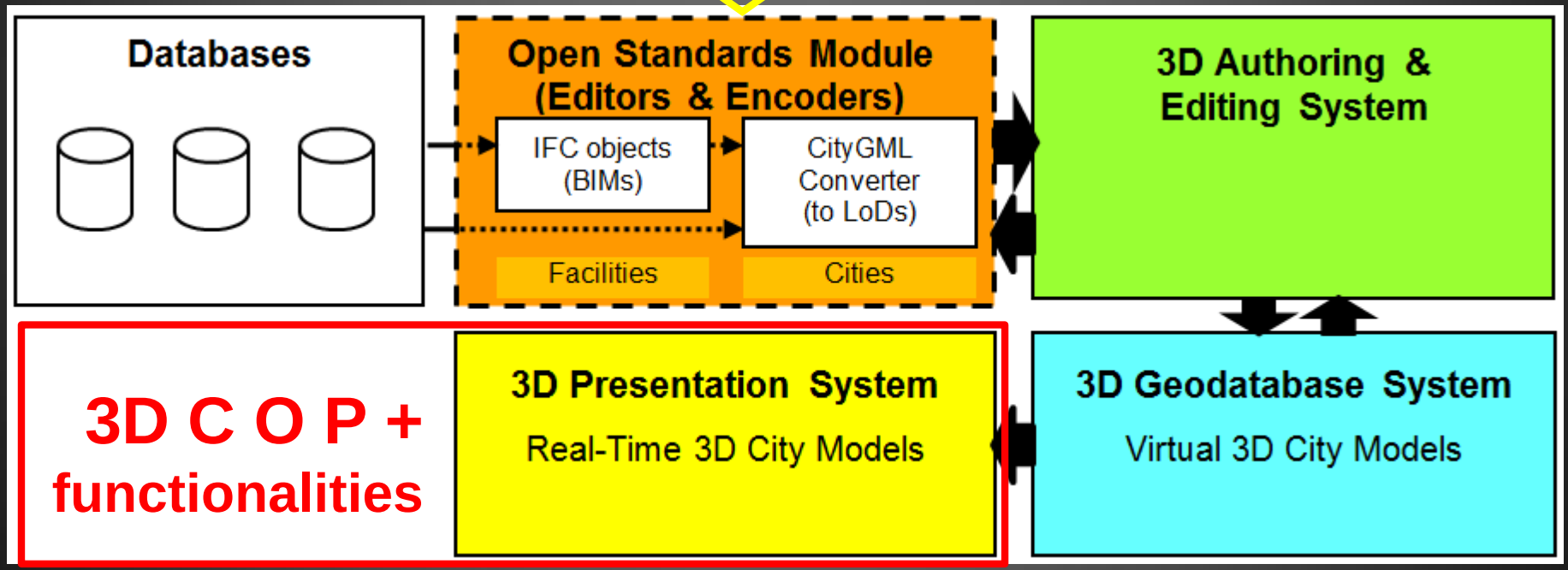
Industry Foundation Classes (**IFC**).



(Azhar *et al.*, 2012)

III. A CONCEPTUAL 3D INFORMATION SYSTEM BASED ON VIRTUAL 3D CITY MODELS

Virtual 3D city (risk) model + Standards + Workflows =
Conceptual 3D information system for risk communication and management.



- Interoperability
- Querying and analysis
- Internal and external alternative evacuations routes

THE NEED FOR NOVEL INFORMATION CONCEPTS

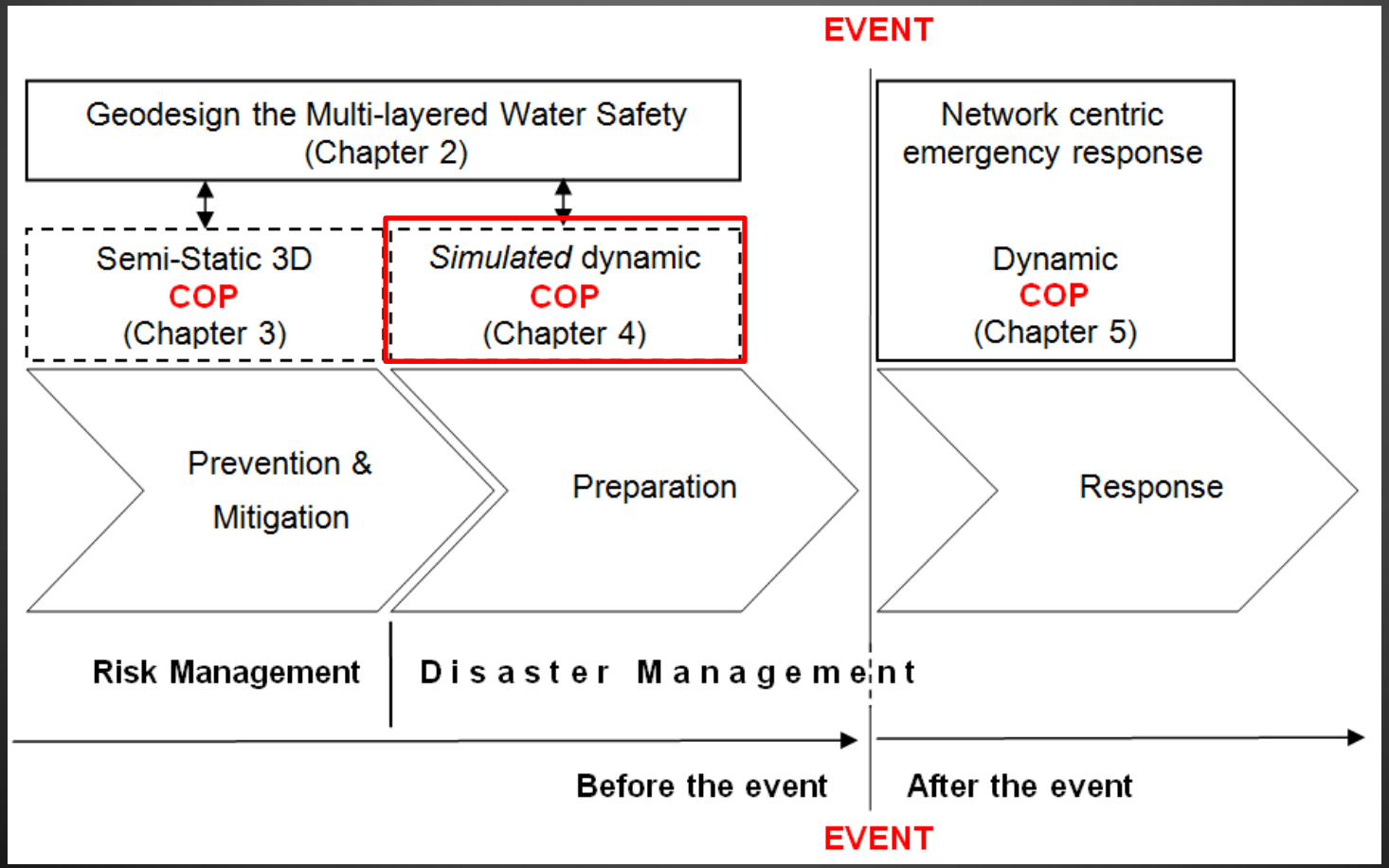
Risk related information + Model information + Emergency response information

There is a need for effective information sharing through

a C O P

CHAPTER 4: NOVEL INFORMATION CONCEPTS

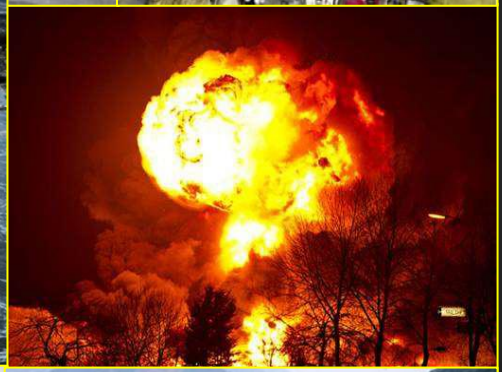
Research question: How can novel concepts in information technology contribute to the improvement of information sharing, communication, awareness and co-operation between safety agencies?



THINGS CAN GO WRONG!

'Prediction is very difficult, especially about the future'

Niels Bohr (1885-1962)



RESPONSE OPERATIONS?

Road Blockage

Rescue

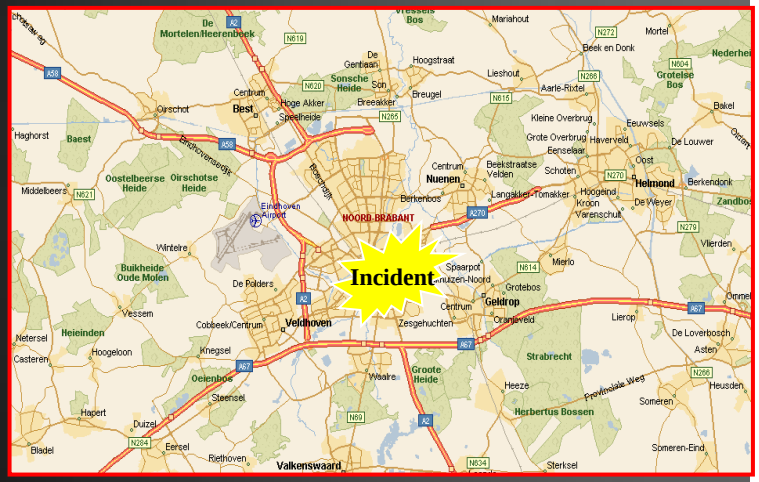
Medical assistance

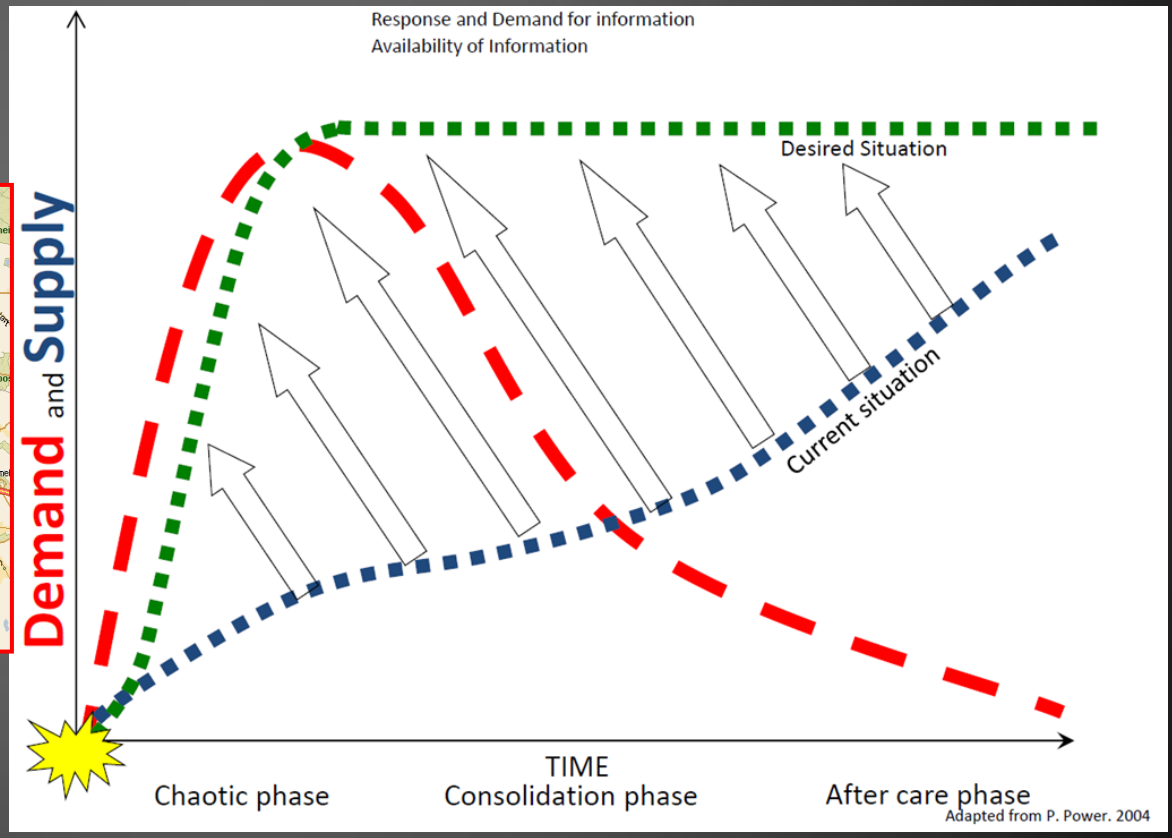
Provide shelter

Regulation of traffic

Evacuation

THE NEED FOR NEW INFORMATION CONCEPTS FOR EMERGENCY RESPONSE

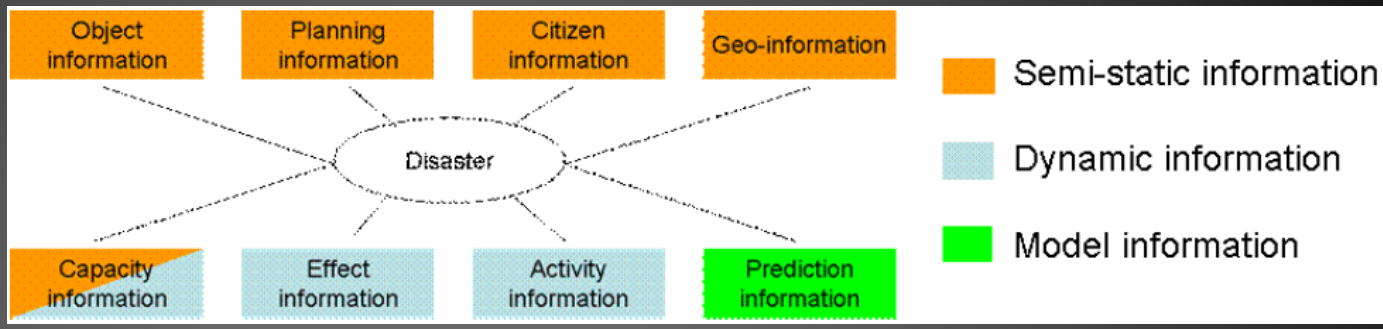


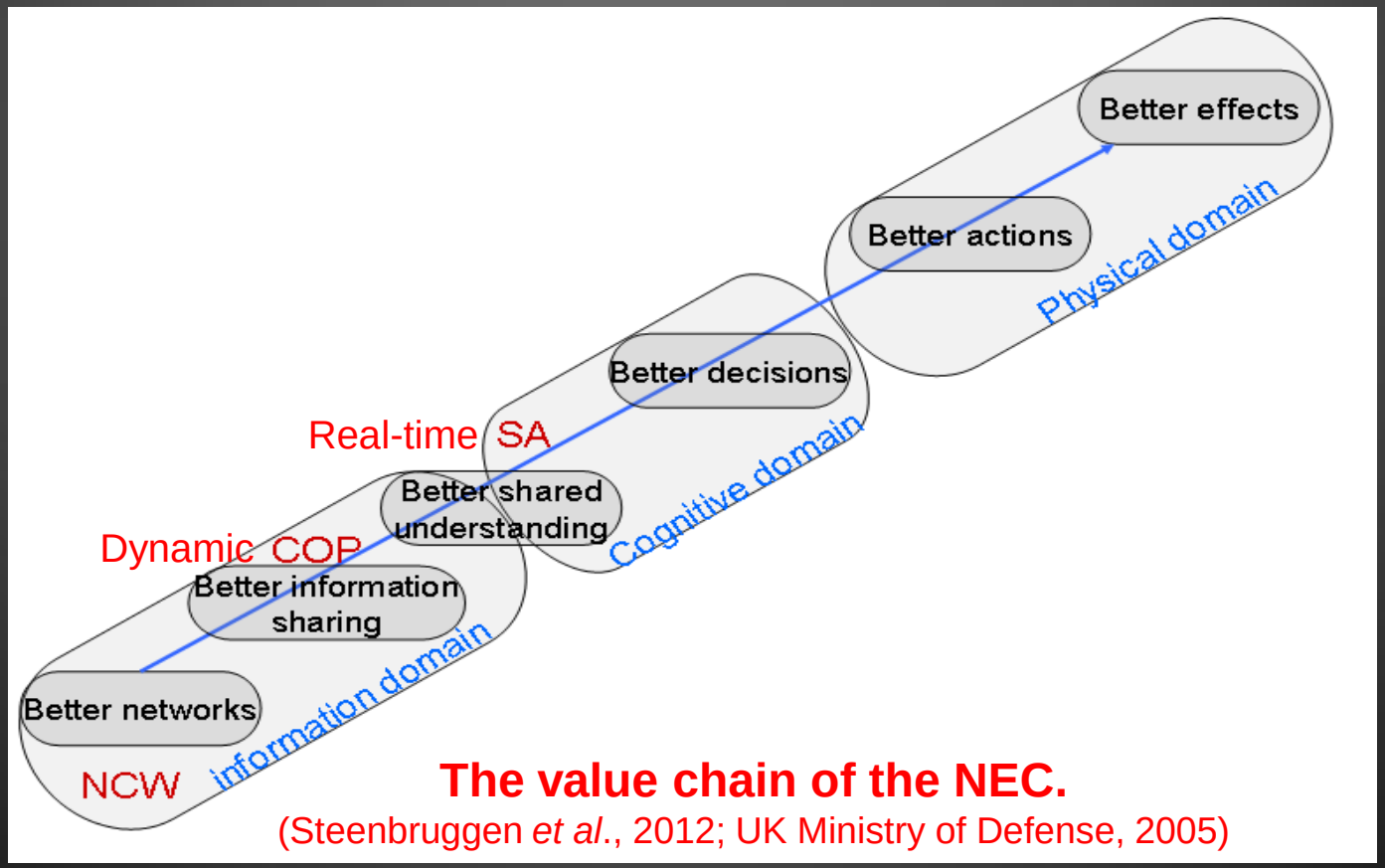


Information often does not reach the right people at the right time.

THE VALUE CHAIN OF NETWORK ENABLED CAPABILITIES

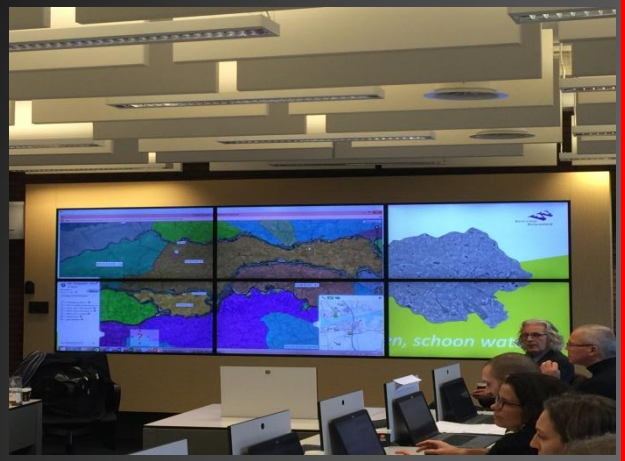
8 information categories distinguished by **3 types.**
(Steenbruggen *et al*., 2012; ACIR, 2005)



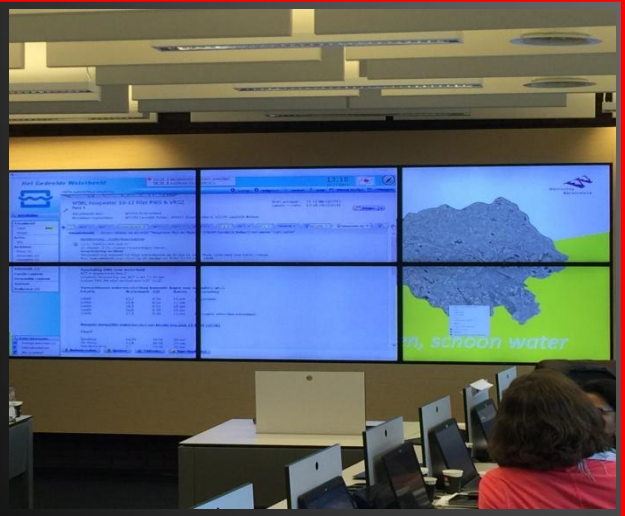


The value chain of the NEC.
(Steenbruggen *et al*., 2012; UK Ministry of Defense, 2005)

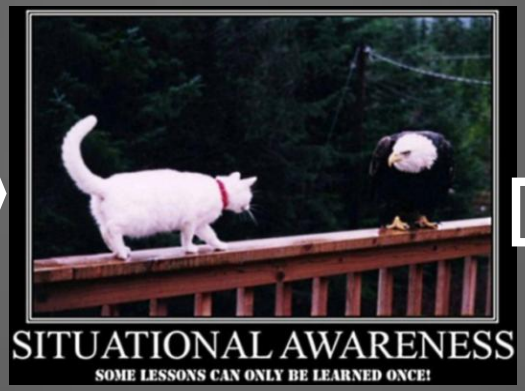
COMMON OPERATIONAL PICTURE & SITUATIONAL AWARENESS



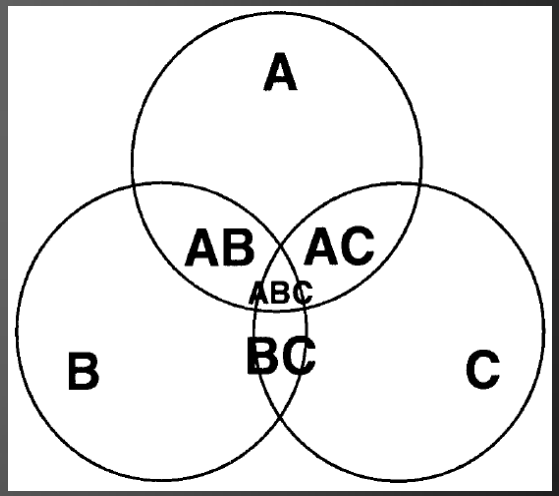
COP in map form



COP in text form

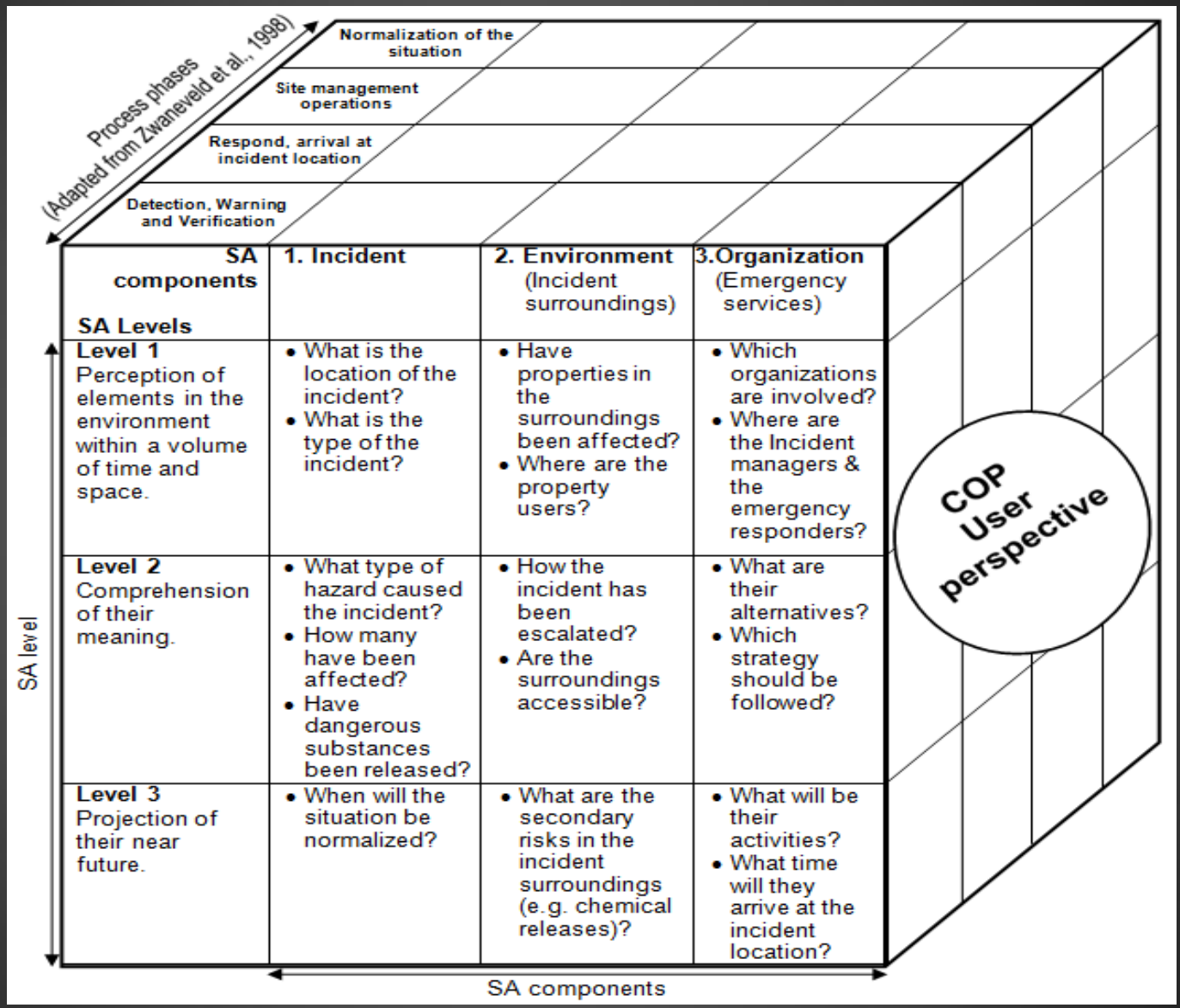


Overlap in SA = Shared SA



(Nofi, 2000)

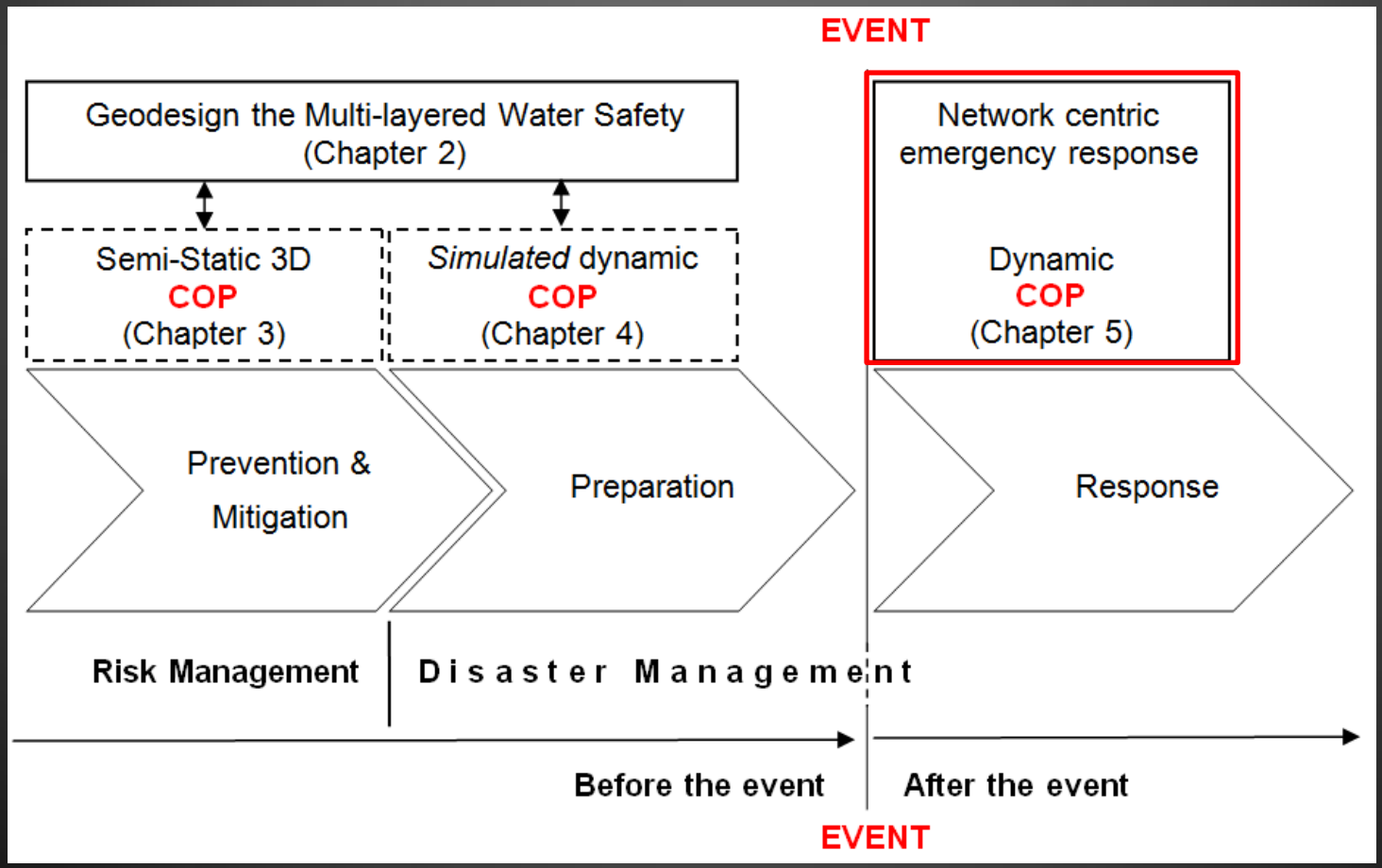
THE ADDED VALUE SERVICE OF A COP



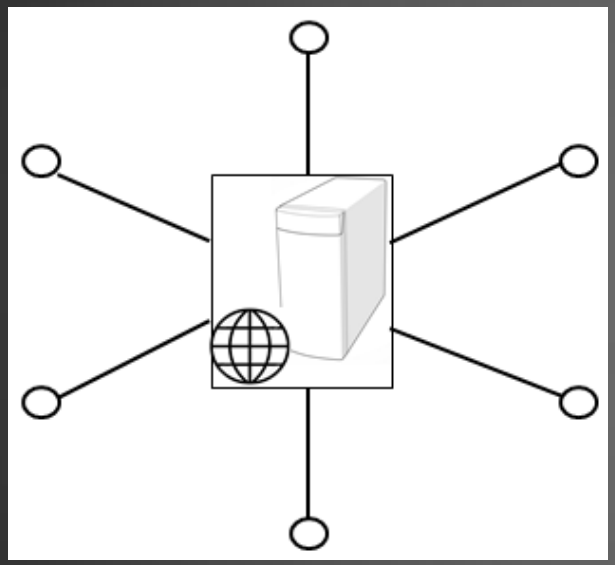
The added value service of a COP in emergency response operations (Adapted from Steenbruggen *et al*., 2012)

CHAPTER 5: THE ADDED VALUE OF THE NETWORK CENTRIC OPERATIONS

Research question: What is the effect of employing network centric information systems in terms of information and system quality towards improving situational awareness and flood emergency response operations?

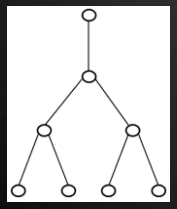


HIERARCHICAL VS. NETWORK CENTRIC INFORMATION SYSTEMS FOR EMERGENCY RESPONSE

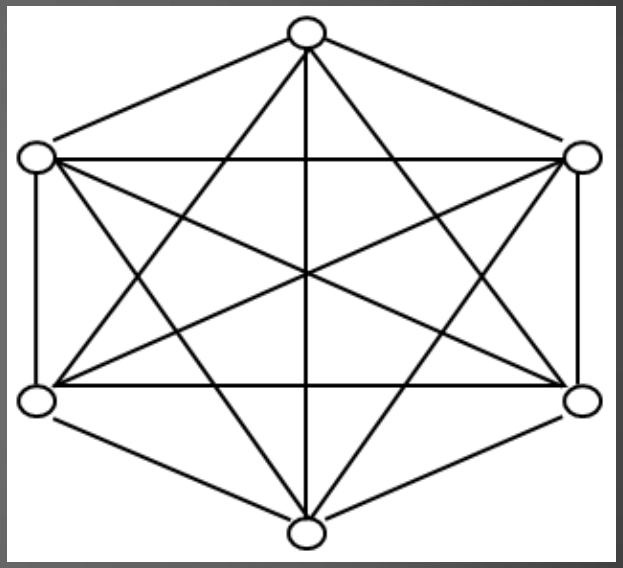


Client server network

Traditional (Hierarchical) approach of information sharing – once with each.



Vs.



Peer-to-peer network

Network centric approach of information sharing – once with all.

HIERARCHICAL VS. NETWORK CENTRIC INFORMATION SYSTEMS FOR EMERGENCY RESPONSE

The same information is made available to everyone at the same time.

INTRODUCING THE PARTICIPATORY ASPECT

FIELD EXERCISE:

- ✓ Date: 10 December 2015.
- ✓ Place: Headquarters of Rivierenland water board in the **city of Tiel**.

EXPERIMENTAL INSTRUMENTS:

- **Panel of experts** for judging the added value service of network centric systems;
- **Realistic flood scenarios:**
  - ✓ **Scenario 1**: Dyke failures and evacuation;
  - ✓ **Scenario 2**: Dam failure, dyke failures, hazardous gas networks in the radius of effect and evacuation.
- **Research methods**:
  - ✓ Questionnaires;
  - ✓ Shadowing.
- **Network centric system** specially designed to support flood emergency response.

EXPERT PANEL

Number of participants	**8**
Average age	**48.6 years**

Gender	**n**
Male	4
Female	4

Organisation	**n**
Rijkswaterstaat's VWM (Traffic and water management services)	3
Rijkswaterstaat Oost-Nederland (Regional information and crisis management center)	3
DCC-IenM Departmental Coordination Center for Crisis management of the Dutch Ministry of Infrastructure and the Environment.	2

Education		**n**
Primary education	Lager onderwijs (Basisschool)	0
Secondary education	LBO, LAVO, MAVO, MULO	1
	MBO, VMBO, HAVO	0
	MMS, HBS, Atheneum, Gymnasium	0
Higher education	HBO, Universiteit	7

Experience	**n**
0-1 year	1
1-5 years	0
5-10 years	4
10-20 years	3
20-30 years	0
More than 30 years	0

Experience emergencies at GRIP 2 level or higher	**n**
0 times	0
1-5 times	3
5-10 times	1
10-20 times	3
20-40 times	1
More than 40 times	0

FLOOD SCENARIO 1

Scenario 1: Dyke failures and evacuation (GRIP 2).

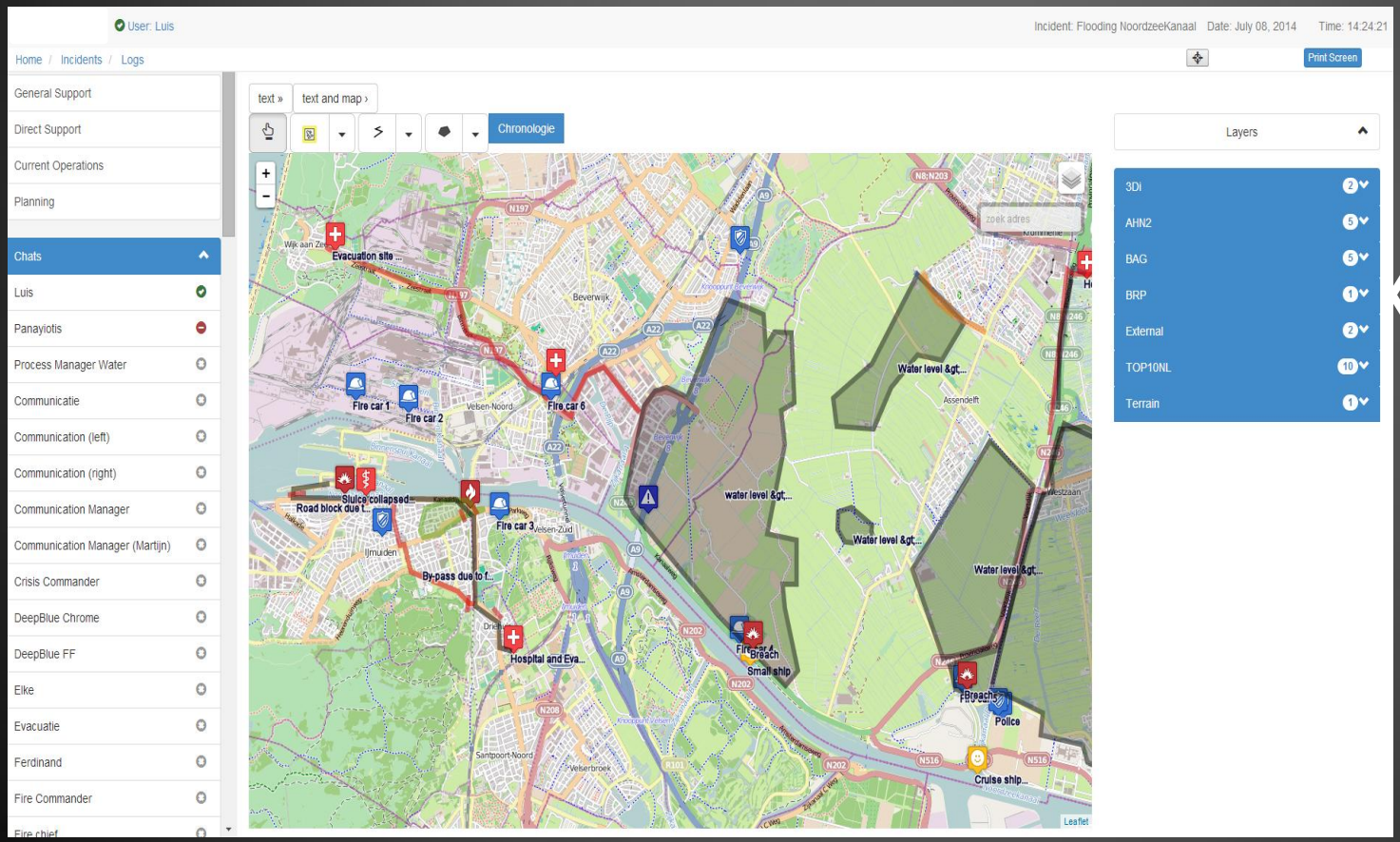
- ✓ Dyke failures are visible in the Zaltbommel municipality;
- ✓ The water depth is increasing and the area in the vicinity of the dyke is flooding progressively;
- ✓ Schools and healthcare facilities which host vulnerable population have to stop functioning immediately;
- ✓ The emergency response agencies have to decide about and organise the evacuation of all the people giving priority to the most vulnerable.

FLOOD SCENARIO 2

Scenario 2: Dam failure, dyke failures, hazardous gas networks in the radius of effect and evacuation (GRIP ¾).

- ✓ A dam failure is observed in the municipality of Culemborg;
- ✓ The embankment has subsided over a depth of approximately 16 meters;
- ✓ The water depth is increasing and the area in the vicinity of the dam is flooding progressively;
- ✓ Because of extensive water overflow and overtopping, the risk of dyke failure in the Zaltbommel area is high;
- ✓ Due to high water pressure, pipes of the gas network near Gamersedijk in Zaltbommel area are in danger of exploding;
- ✓ Several municipalities are affected;
- ✓ 1000 field workers, such as policemen and firemen, are deployed in the area of the emergency;
- ✓ It is necessary to organize the evacuation of all the people located within the radius of effect from the dam and the gas networks;
- ✓ Ground (police vehicles, fire trucks) and aerial means (helicopters and aircrafts) will be used for the evacuation;
- ✓ The shortest evacuation paths have to be identified, given that network blockages and traffic jams occur progressively as the flood escalates.

THE INTERFACE OF THE NETWORK CENTRIC TECHNOLOGY



DATA LAYERS

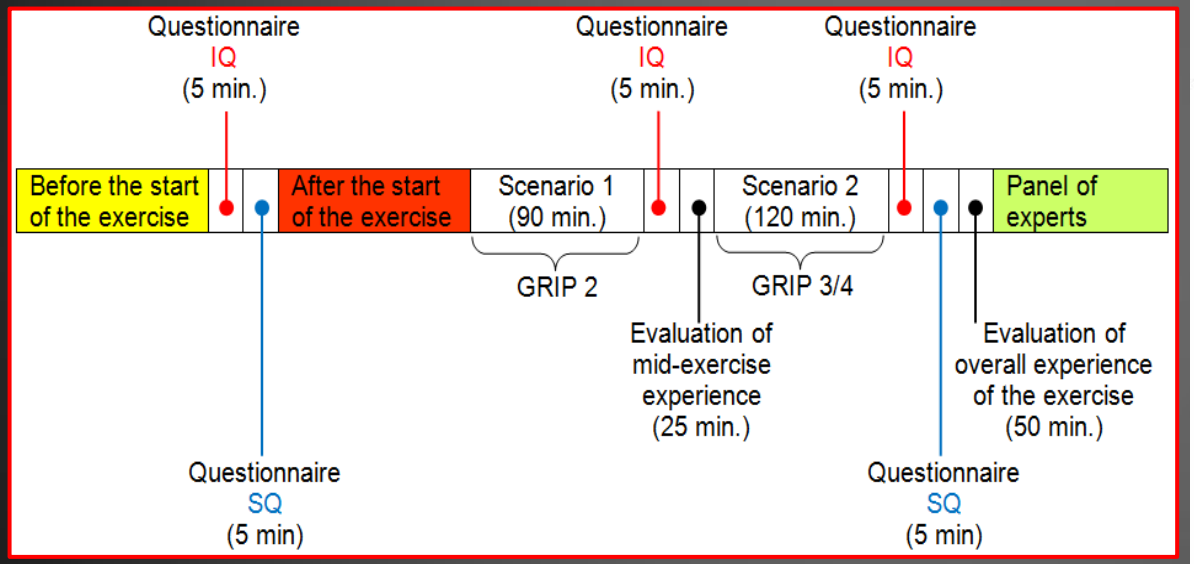
RISK ANALYSIS RESULTS

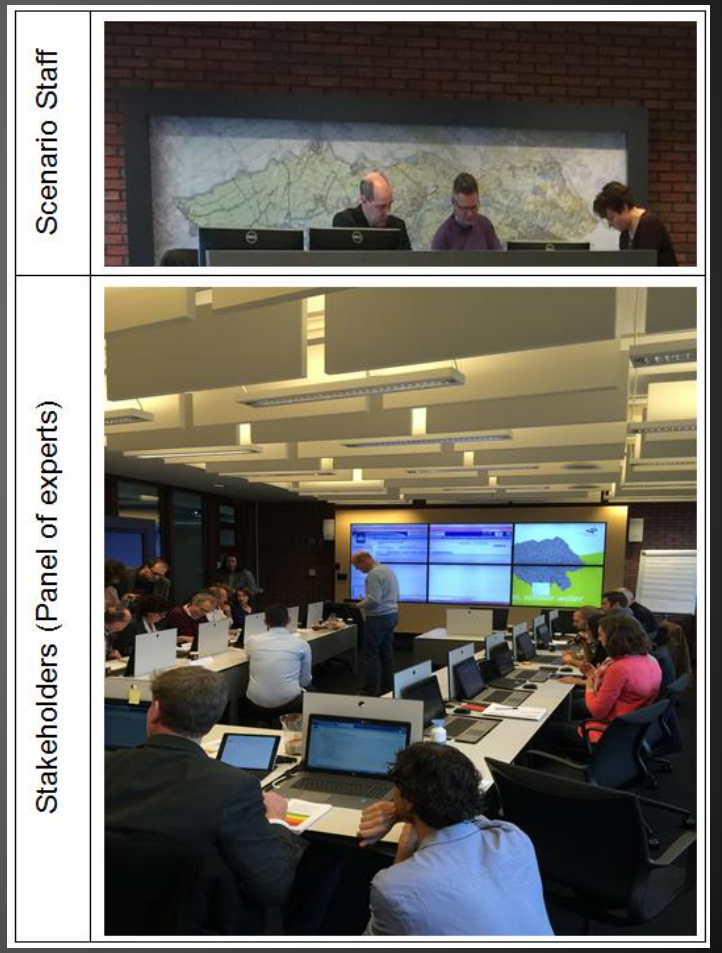
MODEL OUTPUTS

(*E.g.* ***Floods, evacuation routes, population*** etc.)

The interface of the network centric system.

EXPERIMENTAL PROTOCOL





Layout of field exercise.

QUESTIONNAIRES BASED ON INFORMATION QUALITY CONSTRUCTS

IQ category	IQ Construct
Contextual	Timeliness (Currency)
	Completeness
	Quantity (Information Overload)
	Relevance
Representational	Consistency
Others	Correctness
	Reliability (Validation)

QUESTIONNAIRES BASED ON SYSTEM QUALITY CONSTRUCTS

SQ category	SQ construct
System related	Accessibility
	System reliability
	System response time
Task related	Format
	Integration
	Memory
	Situational awareness
Perceived operational satisfaction	Ease of use
	Usability

RESULTS REGARDING INFORMATION QUALITY

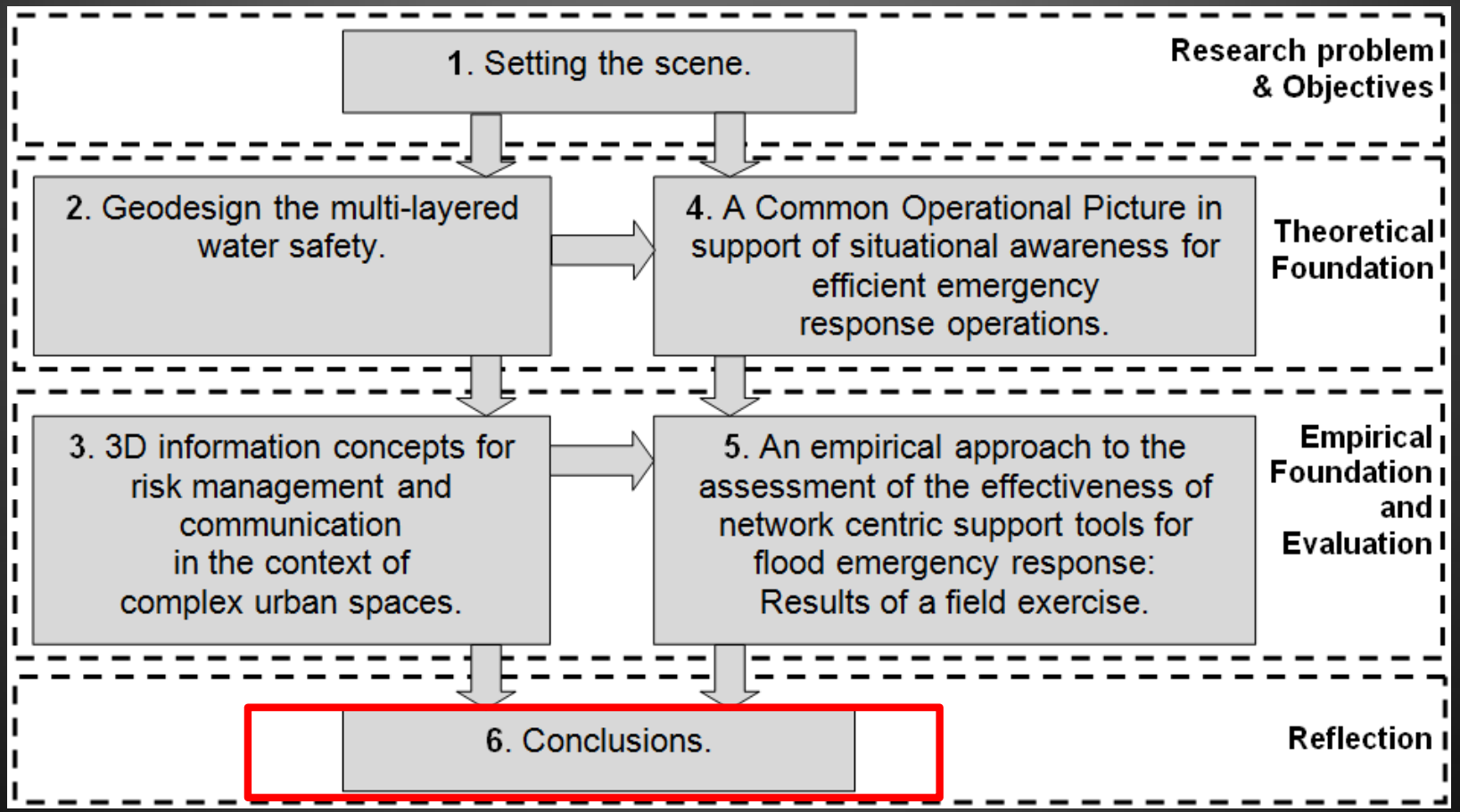
- IQ constructs that showed increase in terms of appreciation by the experts when the response operations were in a network centric environment:
  - ✓ Timeliness and
  - ✓ Reliability.
- Stakeholders suffer from lack of information availability awareness.
- Learning effect has been observed.
- As the complexity of the scenarios is increasing and the need for more information escalates, the appreciation of the experts on the quality of the information shared in a network centric environment also tends to rise.

RESULTS REGARDING SYSTEM QUALITY

- SQ constructs that showed increase in terms of appreciation by the experts when the response operations were in a network centric environment:
  - ✓ System related: Accessibility;
  - ✓ Task related: Integration and Situational Awareness;
  - ✓ End users' perceived operational satisfaction: Usability and ease of use.

- Based on the experts' judgment, these SQ dimensions can be viewed as the design principles of an adaptive emergency response system which can better be supported by network centric tools.

PhD RESEARCH: CHAPTER 6



INNOVATIONS OF THE PhD THESIS

1. How geodesign frames the multi-layered water safety towards improving situational awareness and better decisions.

2. How 3D information concepts support information dissemination and visualization towards improving flood risk communication, awareness and management.

3. How novel concepts in information technology contribute to the improvement of information sharing, communication, awareness and co-operation between safety agencies.

4. The added value of employing network centric information systems towards improving situational awareness and flood emergency response operations.

CONCLUSIONS

- The **theoretical systematization** of the **multi-layered water safety concept** in a **geodesign-oriented methodological framework** has the potential to support participatory designed alternatives (most desirable and balanced water safety measures) with known consequences (awareness).

- **Geo-information** is an important **prerequisite** for flood risk management and emergency response (location awareness).

- **Effective** flood risk and disaster management rely on flexible **information and communication systems**.

- A **common operational picture** can contribute to the development of **situational awareness** by sharing information in an effective manner.

CONCLUSIONS

- A **3D information system forms an ambitious concept** that can provide the stakeholders with **a level field for equal access to information** towards facilitating the **cognition of risk related situations (awareness)** through a **real-time adjustable 3D common operational picture**.

- Based on the experts' judgement of the field exercise of this thesis, the network centric systems have the potential to **enable better information sharing, development of a common operational picture** and **improvement of situational awareness** which in turn can **better support decisions** with **better effects** in flood emergency response operations.

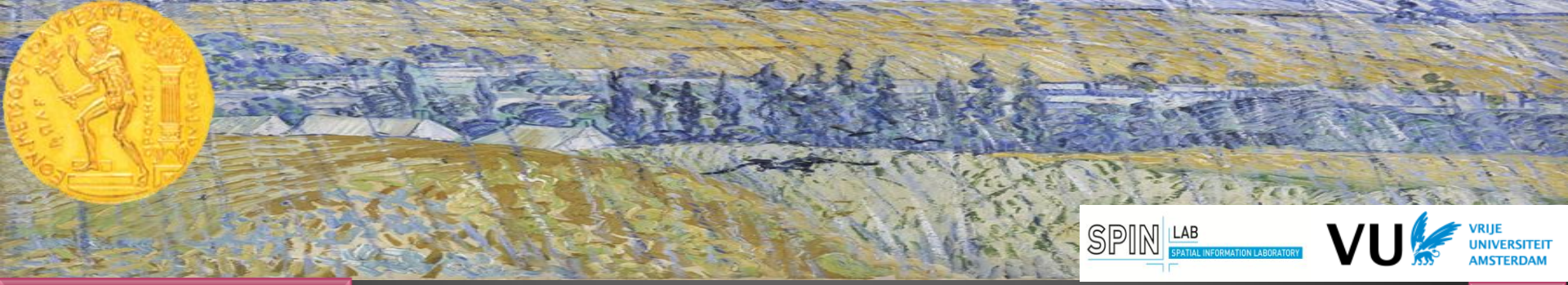
- The **roles and capabilities** regarding **information sharing and coordination** are currently set for hierarchical operations and **they do not adapt to situational requirements**.

FUTURE DIRECTIONS

- Transfer the implementation of geodesign on multi-layered safety **from theory to practice.** The concept can be **experimented** in workshop settings **engaging safety agencies** and **employing technology driven tools** towards identifying optimal measures regarding water safety in an area of interest.

- For **fully setting the framework of a system** that **support decisions** for **flood risk management** as well as for extending the potential and the academic and institutional standing of the proposed conceptual 3D information system, further investigations in collaboration with interested stakeholders are needed.

- The **effectiveness of the network centric support tools** has been **assessed** in the context of simulated flood scenarios. In order to verify their **usefulness** and extend the results of the experimental research, these can be utilized in **real flood emergencies' response environment**.



PhD Thesis

Thank you for your attention!