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Cost-Benefit Evaluation for Early Warning Systems

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Cost-Benefit Evaluation for Early Warning Systems

Introduction and motivation

- Early Warning Systems
- Challenges and focus
- Application in projects

Example: From WIND to SAFE

- WIND and SAFE
- Context-aware alerting

Cost-Benefit Evaluation

- Model
- Parameters
- Interdependencies

Conclusion

Introduction and Motivation

Definition of Early Warning Systems

Problem:

There is a variety of different notions of what an Early Warning Systems constitutes

Definition of Early Warning:

The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response

(source: UN/ISDR)

Early Warning Systems: Key Elements

Risk Knowledge

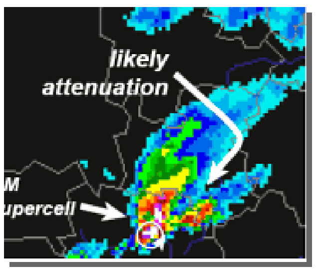
Monitoring and Warning Service

Dissemination and Communication

Response Capability

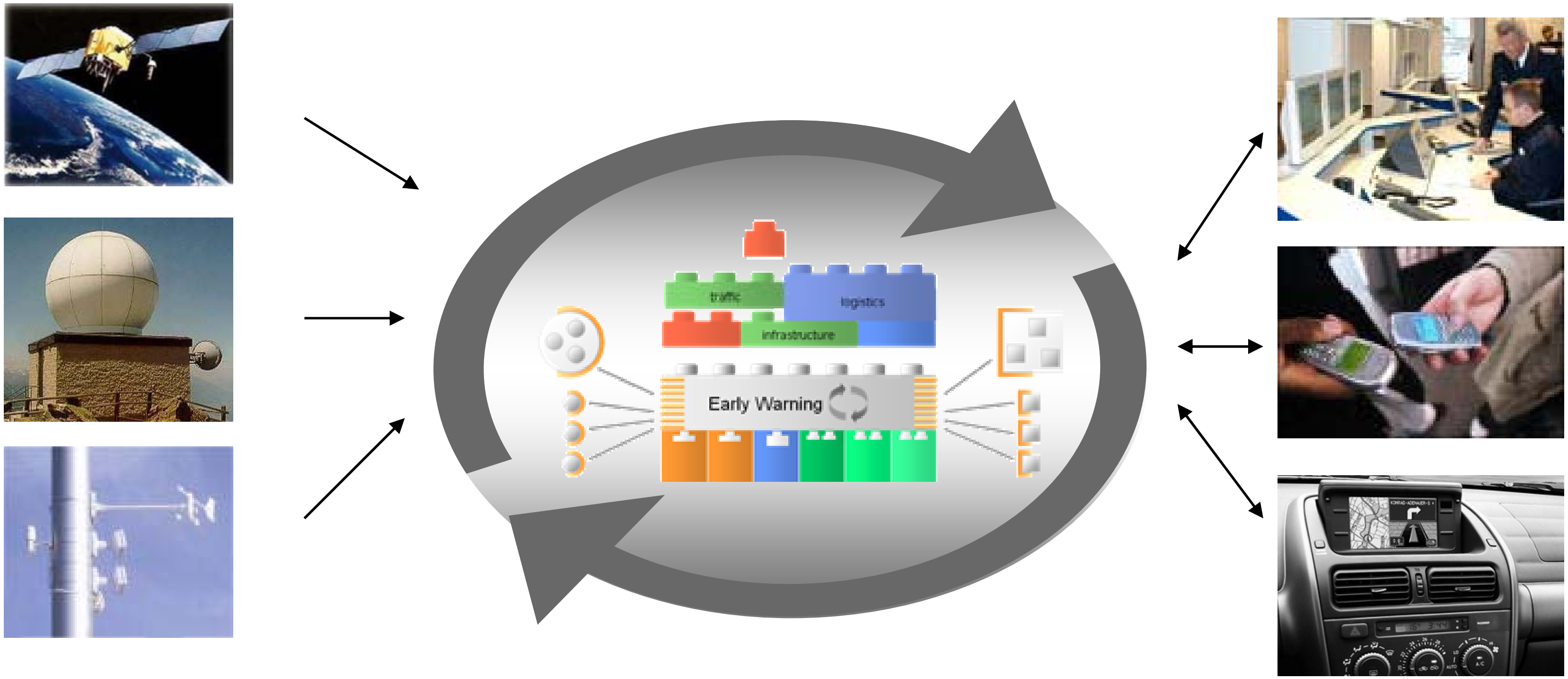
Defined by UN/ISDR

Challenges in Early Warning Systems



- From single-hazard towards **multi-hazard systems**
  (as well as from single-channel towards **multi-channel alerting**)
- From national towards international **coordinated systems**
- From general warnings towards **regional, group specific and individual warnings**
- From systems solely operated by the public sector towards **integration of the private sector**
- Long term **operating costs and new technologies**
- The question of **costs and efficiency**
- Strong need for evaluation methods for EWS

Our context: Multi-hazard and multi-channel EWS



Data | **Prognosis und Logistics** | **Users**

Ensuring timely and targeted information supply

Early Warning Systems: Systems Engineering View

Warning dissemination
Broadcasting the warnings on available communication channels

Warning generation
Transforming hazard information into warnings for the receivers

Information processing
Analyzing the data in order to estimate time, duration and impact of the hazard with a certain probability

Data capture
Providing the necessary data foundation to detect a certain risk

Our focus in Early Warning Systems

Efficient warning dissemination
Optimize the use of available communication channels and prioritize alerting based on the situation of receivers

Targeted warning generation
Transforming hazard information into adapted warnings based on the situations of receivers

Information processing
Analyzing the data in order to estimate time, duration and impact of the hazard with a certain probability

Data capture
Providing the necessary data foundation to detect a certain risk

Experiences from projects

Tsunami Early Warning System as an example for a global/international EWS

WIND as an example for a national EWS

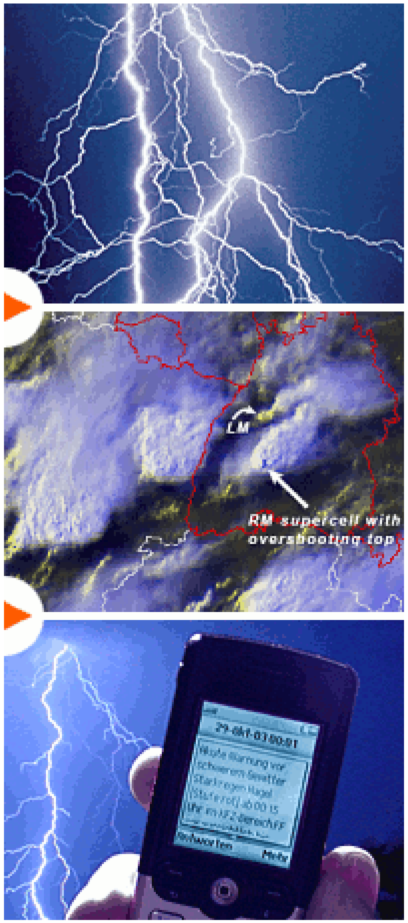
rePAI as an example for a regional/cross-border EWS

SAFE as an example for a local EWS

IMSK as an example for a local/temporal EWS

Example: From WIND to SAFE

WIIND - Commercial weather warning system

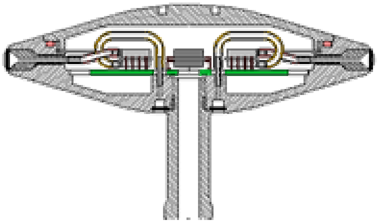


- Service started in 2002
- Alerting service with currently 350.000 subscribed users in Germany, Austria and Switzerland
- Precise warnings based on radar detection
- Financed and operated by insurance companies
- Example of an initiative within the private sector

▶ Extensive studies about warning quality and effects (user-centric !)

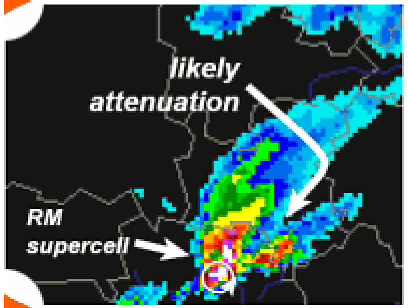
SAFE - Research pilot for an advanced local warning system

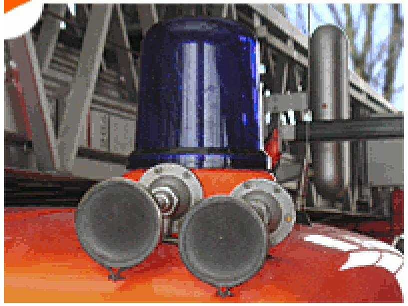
I. New sensor technologies



II. New alerting technologies

SAFE: Focus





- Better data foundation based on specialized sensors in a dense network
- Better prognosis methods based on local measurements combined with radar and satellite data
- Better protection based on targeted information provision for persons and systems

SAFE: Field Tests 2008 - 2009

- Marktgemeinde Mering

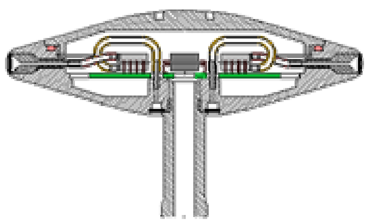
  - Information for fire brigades and local authorities
  - Individual warnings for affected people
  - Alert signals for building automation

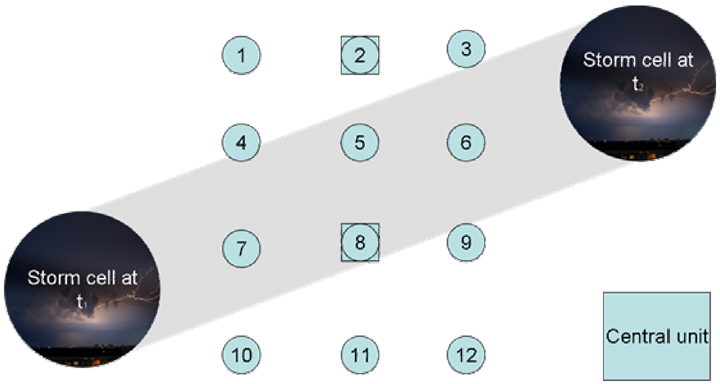
- Wacker Chemie AG, Burghausen

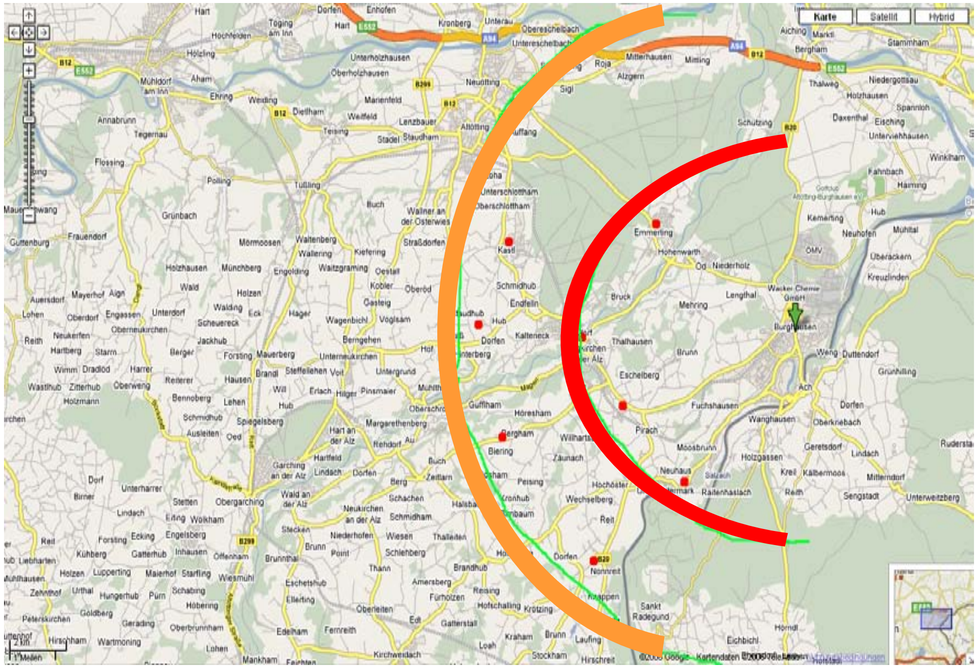
  - Information for operators
  - Individual warnings for affected employees
  - Alerts signals for sensitive production facilities

SAFE: Sensor networks

Additional data from local sensor networks







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SAFE: Pervasive Alerting

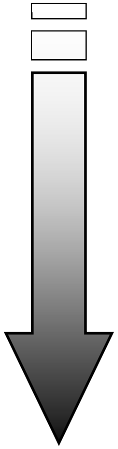
I. Seamless device integration

II. Seamless system integration

Improving the effectiveness via context-aware alerting

Context-awareness: Information layers for EWS

- General and broad warning information
- Location specific warning information
- Group specific warning information
- Individual warning information



Context-awareness

▶ Using context-awareness for better response

Specific dimensions in the context of Early Warning

Focus on the following dimensions:

1. Location:
   - symbolic (e.g:, region, town, ZIP-code) or Geo-coded (e.g. polygons)

2. Environment:
   - in-building, in-traffic (car, public transport, airplane), outside

3. Reachability:
   - available communication channels

4. Action abilities:
   - possible response or mitigation activities (cover, escape, response, informing others, helping others)

Using the model in effective alerting and warning

Example:

Problem of lack of time an scarcity of channels => Efficient alerting strategies

Step 1:

Selecting only receivers first affected by the disaster (time and area), with a specific exposure (outside), reachable with available channels, that can response or inform others

Further steps:

Stepwise relaxation of restrictions

Step n:

Informing that are affected in the future (e.g. people with a car moving into the area) based on available situation sequences

Using the model in effective alerting and warning (cont'd)

Example:

Problem of targeted warning => Individualized warning generation

Steps:

For each receiver group that has a certain pattern i.e., in terms of location action abilities and exposure individual instructions can be added

Evaluation

Evaluation model

I. Motivation

- Evaluation framework for our context-aware approach
- Towards cost/benefit models for Early Warning Systems

II. Application

- for design, planning and decision making
- for monitoring and quality improvements

Existing quantitative approaches

I. Performance Measures:

- Focused on risk monitoring
  Parameters such as *accuracy*, *response time*, *availability* or *up-time*
  (i.e. DeGroeve2005, or Bayrak2007)

- Focused on dissemination and communication
  Parameters such as *availability*, *coverage*, *delivery time*, or *attention*
  (i.e. Held2001, or Sillem2006)

II. Cost-benefit models

- Only on the macro-economic level
  (i.e. CEDIM 2004)

Our evaluation model

Top-down approach starting from the main parameters:

- *Frequency*
  Average occurrence of a specific disaster for a certain location
- *Accuracy*
  Probability of correct detection/prediction in given response time corridors
- *Response*
  Probability of correct and efficient response
- *Mitigation*
  Mitigation potential

Example: Application in SAFE

Statistical data from WIND

Scenarios from users and insurances
(time corridor!)

Ex-post analysis from Meteorologists

First estimation based on performance model

Statistical data from insurances

Statistical data from insurances

Risk Scenarios	Frequency	Response action	Accuracy	Response	Prevent prob.	Damage cost	Benefit
d	2	Fix loose items	87 %	37 %	0,1000000%	500,00 €	0,32 €
iolett	0,25	Fix loose items	93 %	39 %	0,5000000%	500,00 €	0,23 €
	0,25	Car in garage	93 %	30 %	0,0100000%	10.000,00 €	0,07 €
	0,25	Stay in buildings	93 %	42 %	0,0000005%	500.000,00 €	0,00 €
m							
d	15	Fix loose items	92 %	37 %	0,1000000%	500,00 €	2,55 €
	15	Close windows	92 %	37 %	0,0100000%	1.000,00 €	0,51 €
	15	Unplug electronic devices	92 %	25 %	0,0100000%	1.000,00 €	0,35 €
	15	Car in garage	92 %	30 %	0,0010000%	5.000,00 €	0,21 €
	15	Stay in buildings	92 %	45 %	0,0000005%	100.000,00 €	0,00 €
	15	Close valvets in cellar	92 %	37 %	0,0010000%	20.000,00 €	1,02 €
olet	1,5	Fix loose items	94 %	39 %	0,1000000%	500,00 €	0,27 €
	1,5	Close windows	94 %	39 %	0,0100000%	1.000,00 €	0,05 €
	1,5	Unplug electronic devices	94 %	30 %	0,0100000%	1.000,00 €	0,04 €
	1,5	Car in garage	94 %	35 %	0,1000000%	2.500,00 €	1,23 €
	1,5	Stay in buildings	94 %	50 %	0,0000005%	100.000,00 €	0,00 €
	1,5	Close valvets in cellar	94 %	42 %	0,0050000%	20.000,00 €	0,59 €
Local flooding							
Risk level red	0,5	Close valvets in cellar	82 %	37 %	0,0050000%	20.000,00 €	0,15 €
Risk level violet	0,2	Close valvets in cellar	88 %	39 %	0,0100000%	20.000,00 €	0,14 €
	0,2	Install barriers	88 %	10 %	0,0050000%	20.000,00 €	0,02 €
	0,2	Secure oil and gas	88 %	15 %	0,0050000%	250.000,00 €	0,33 €
Sum:							8,09 €

Note: Prevent. Prob. and Damage Costs have been changed

Improving the effectiveness of an EWS

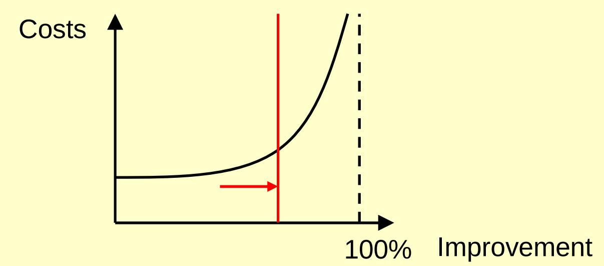
Actual status in WIND

Accuracy: appr. 80-95%
(Ex post analysis of Meteomedia)
Response: appr. 10-30% (=> improvement potentials!)
(surveys of insurance companies)

Aim in SAFE

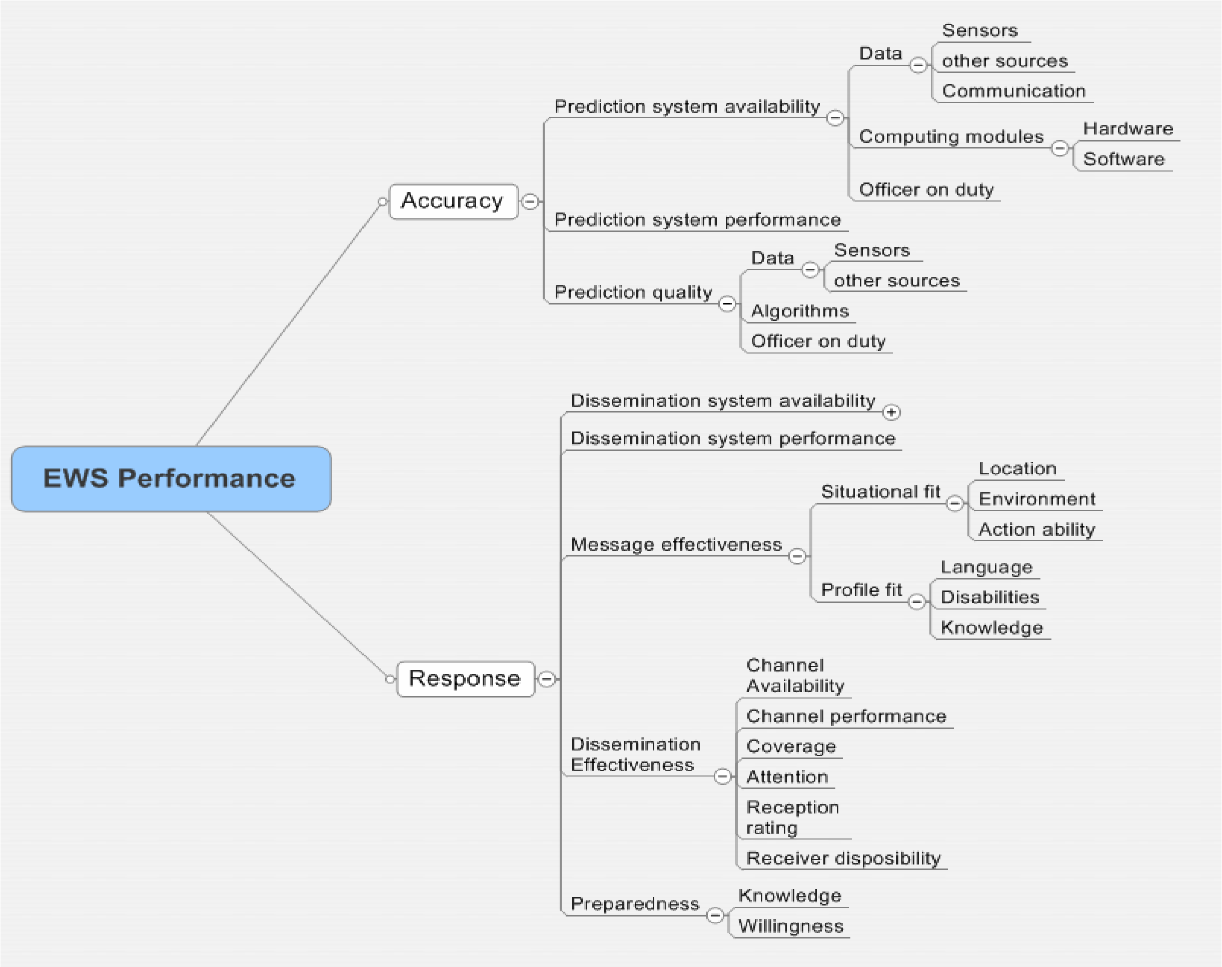
Accuracy: over 90%
Response: towards 50%

Consideration of cost-effectiveness:

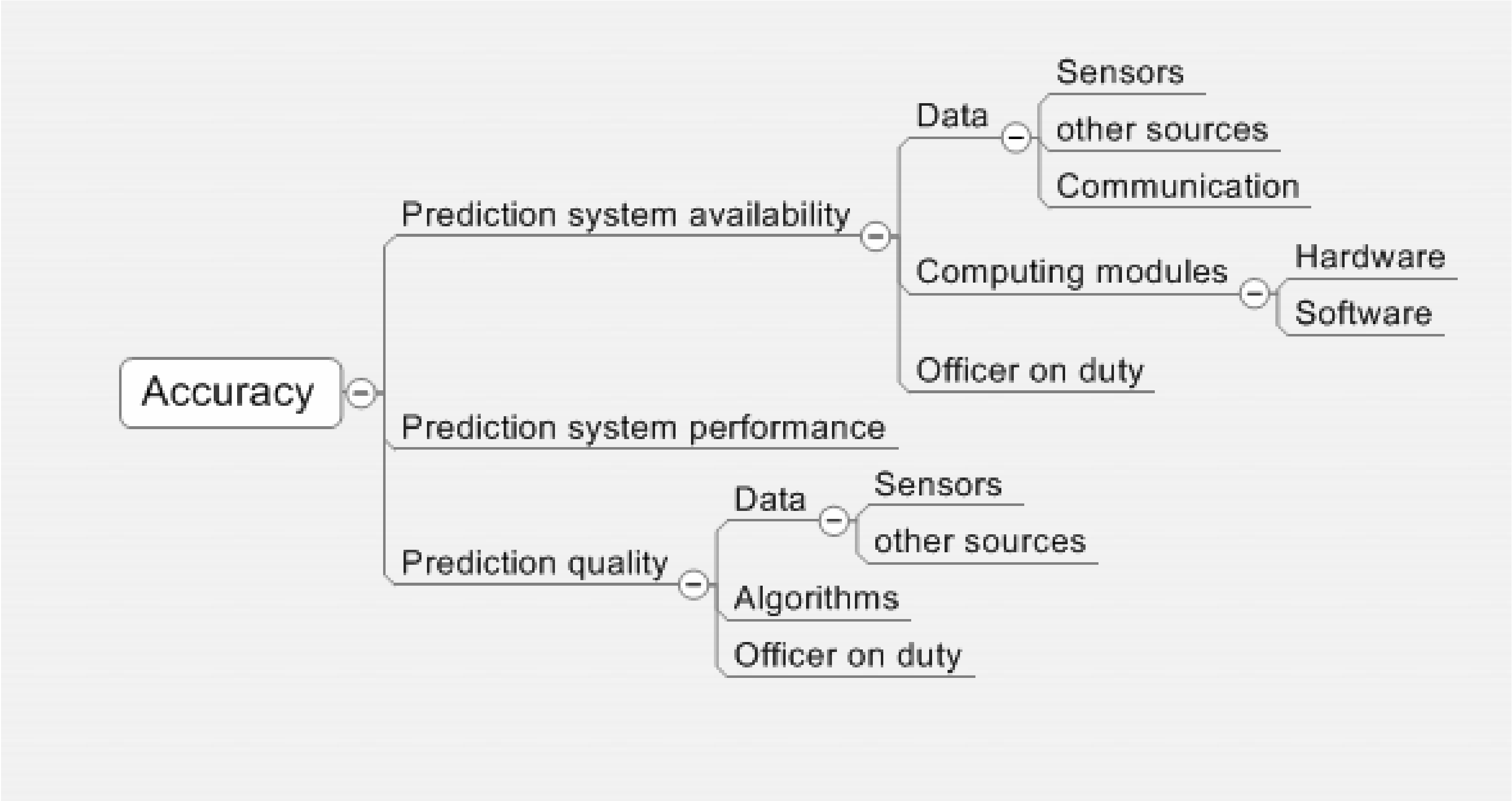


How do I estimate and measure this in detail?

Performance parameters in detail

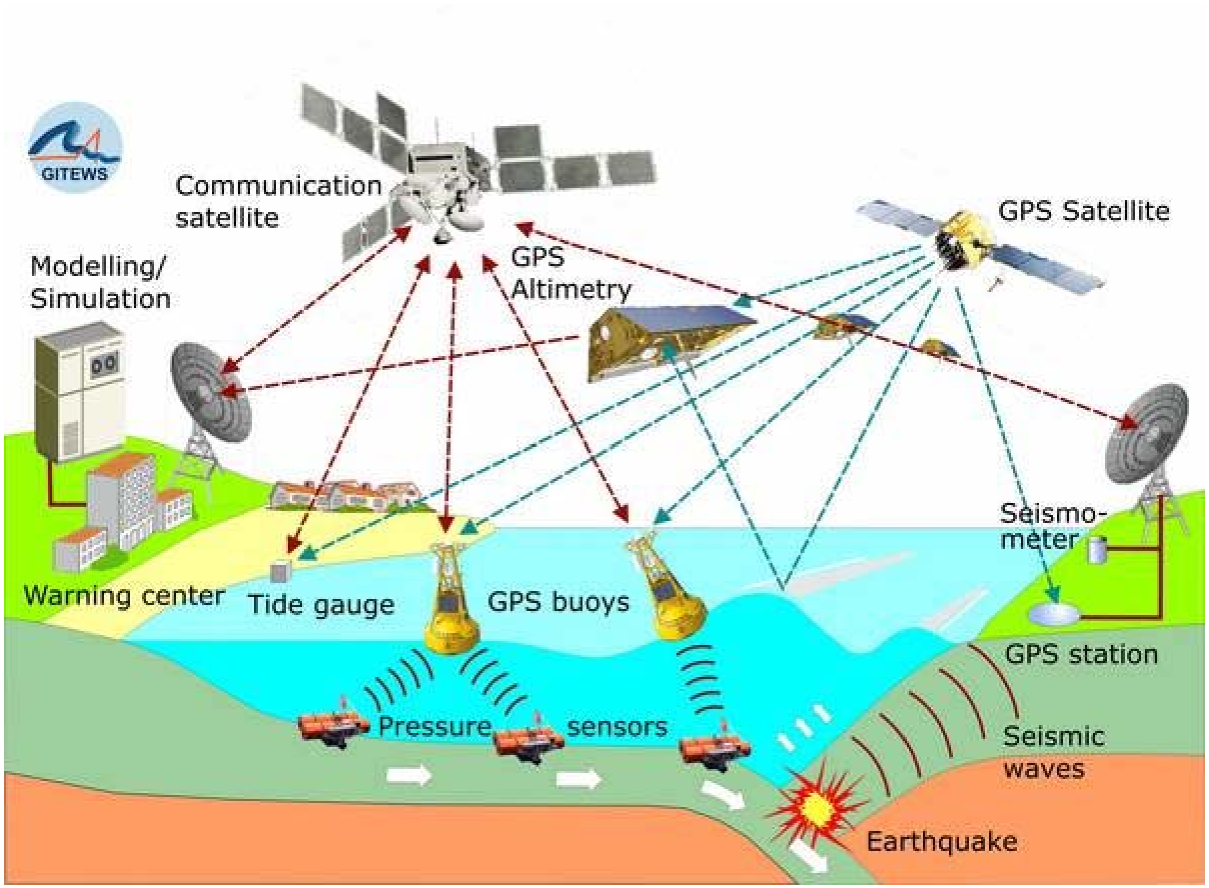


Performance parameters in detail: Accuracy



Interdependencies: Sensor system availability - Accuracy

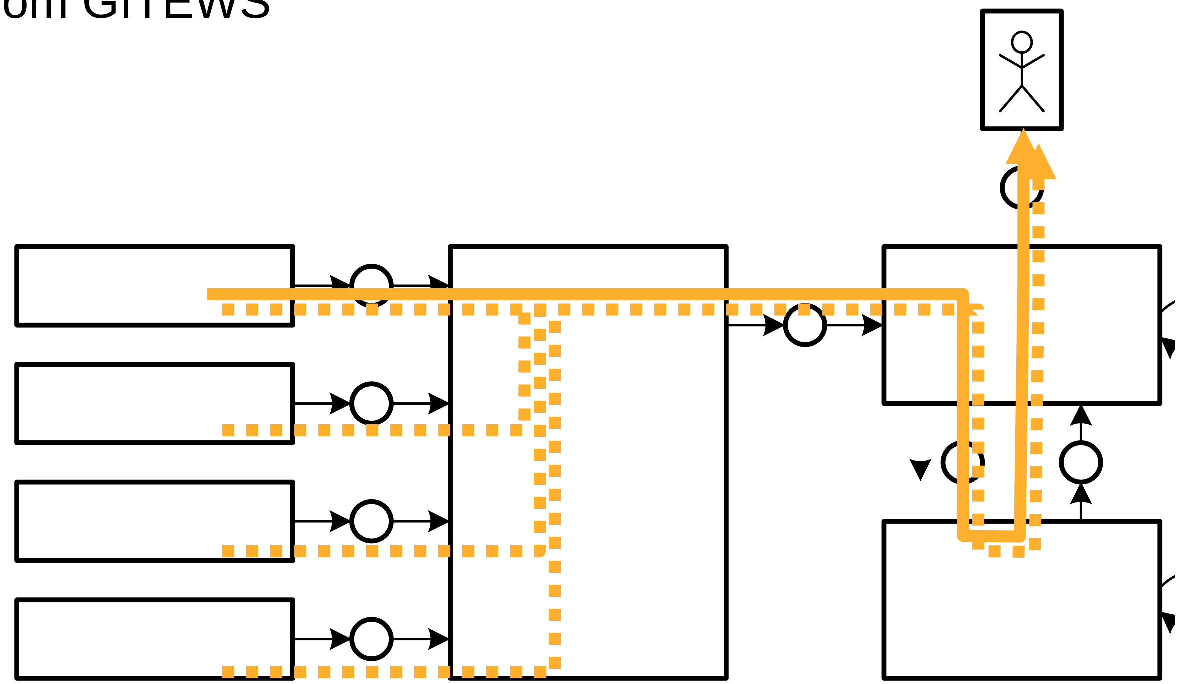
Example from GITEWS



Source: Geoforschungszentrum Potsdam (GFZ)

Interdependencies: Sensor system availability - Accuracy

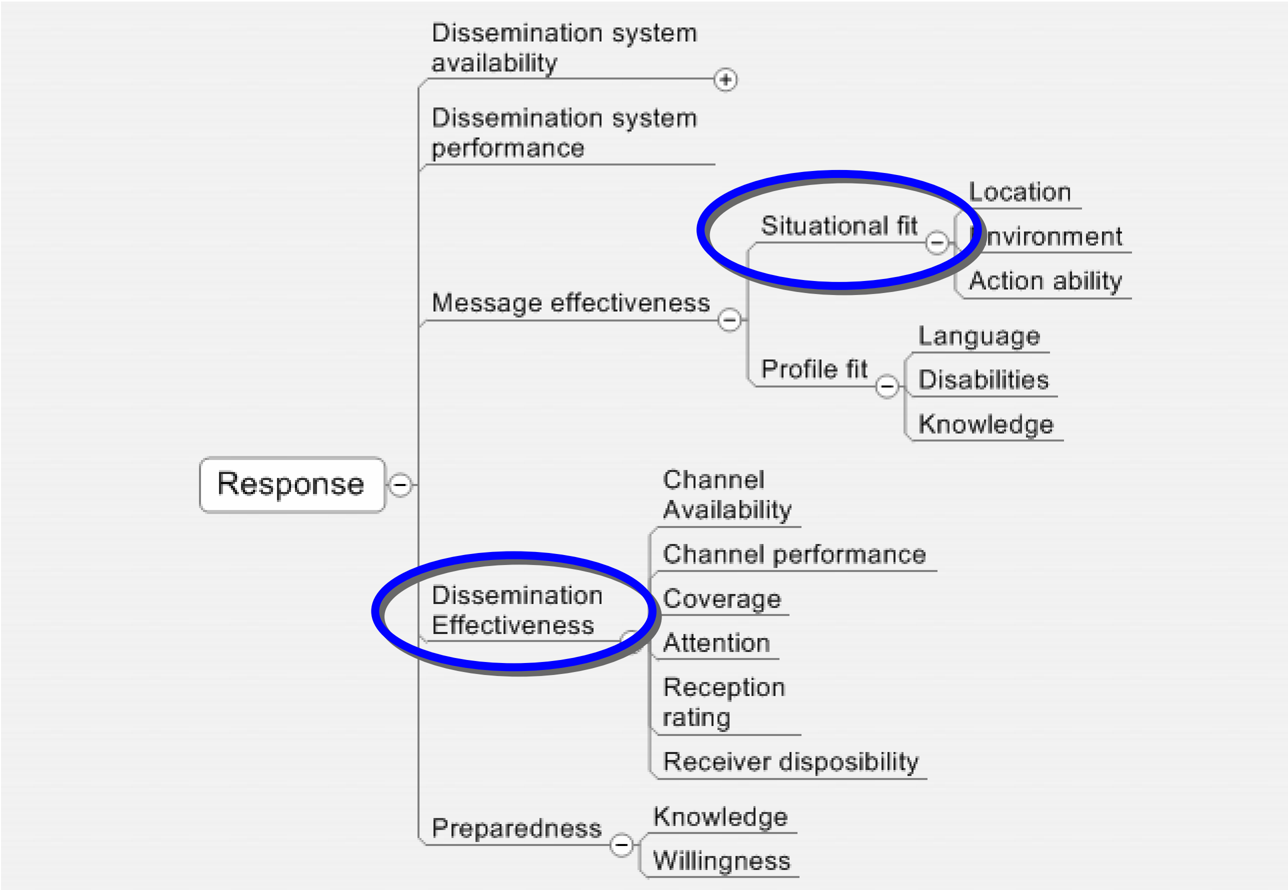
Example from GITEWS



Main path (critical)

Secondary paths (compound events)

Performance parameters in detail: Response



Evaluation criteria for effective dissemination

Technical Coverage *C*:
Percentage of users in reception area (i.e. siren coverage, cell coverage)

Receiver Availability *V*:
Percentage of users with receivers (i.e. mobile phone)

Reception rating *R*:
Percentage of users with activated receivers

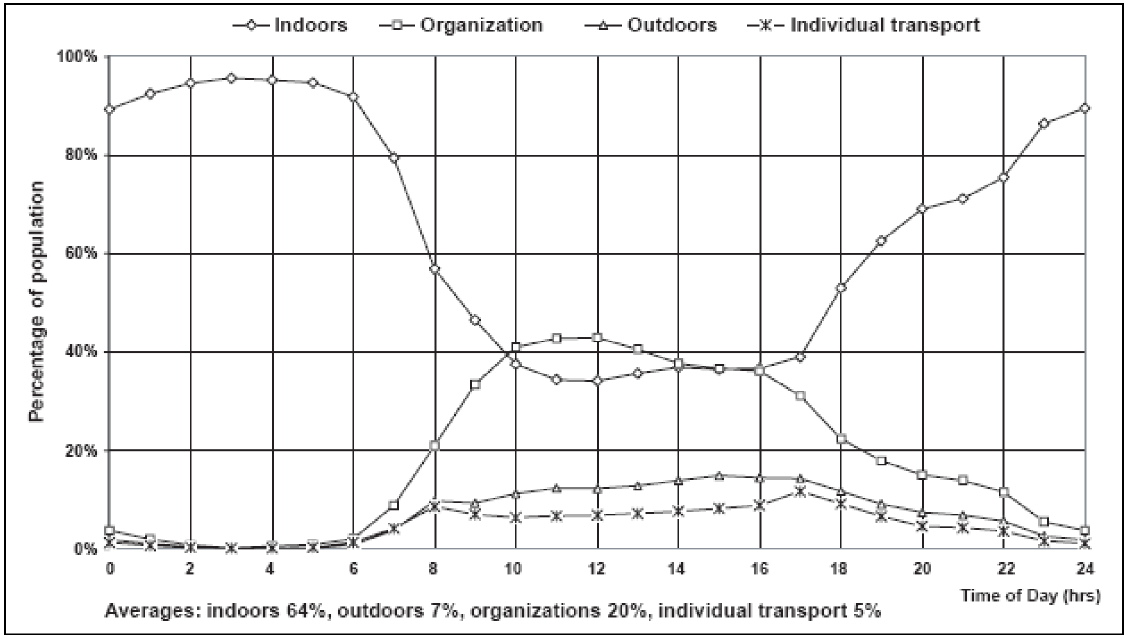
Attention *I*:
Percentage of users noticing the warning

Calculating the effectiveness of dissemination (static):

$$D = C \cdot V \cdot R \cdot I$$

Dynamic aspects

I.e., Population pattern
(Source:Held2001)



Calculating the effectiveness of dissemination (dynamic):

$$D(a,u,t) = C_t(a,u) \cdot V(a,u,t) \cdot R(a,u,t) \cdot I(u,t)$$

a: area, *u*: user group, *t*: time

=> Optimization via situation-based alerting strategies

Calculating situation fit (example)

Location L:
Probability of warning area corresponding to the location of the user/object

Environment E:
Probability of advice corresponding to the environment of the user

Action ability A:
Probability of advice corresponding to the action ability of the user

Calculating the situation fit:

$$S_{fit} = L \cdot E \cdot A$$

(Remark: Scenario-specific thresholds and weights!)

=> Optimization via situation-based message adaptation

Conclusion and Outlook

Results: Evaluation Model for Early Warning Systems

- To our knowledge, the first integrated and detailed EWS evaluation model

- Applicable for cost-benefit estimations (e.g., SAFE)

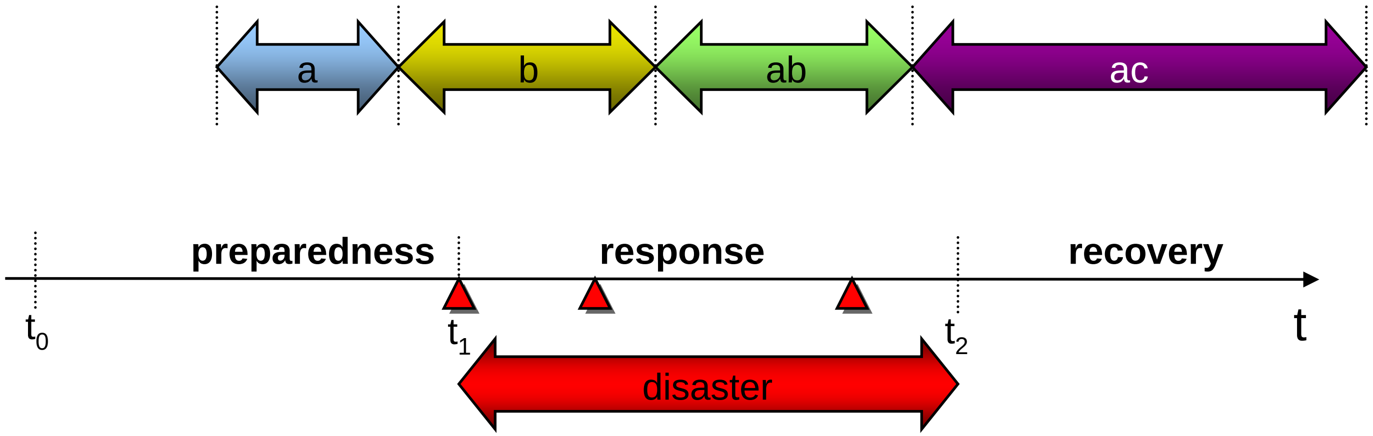
- Further challenges:
  - Aggregation rules (interdependencies, weights, thresholds are partly scenario-dependent)
  - Monitoring in field tests
  - Adaptation to other EWS applications

Thank you very much!

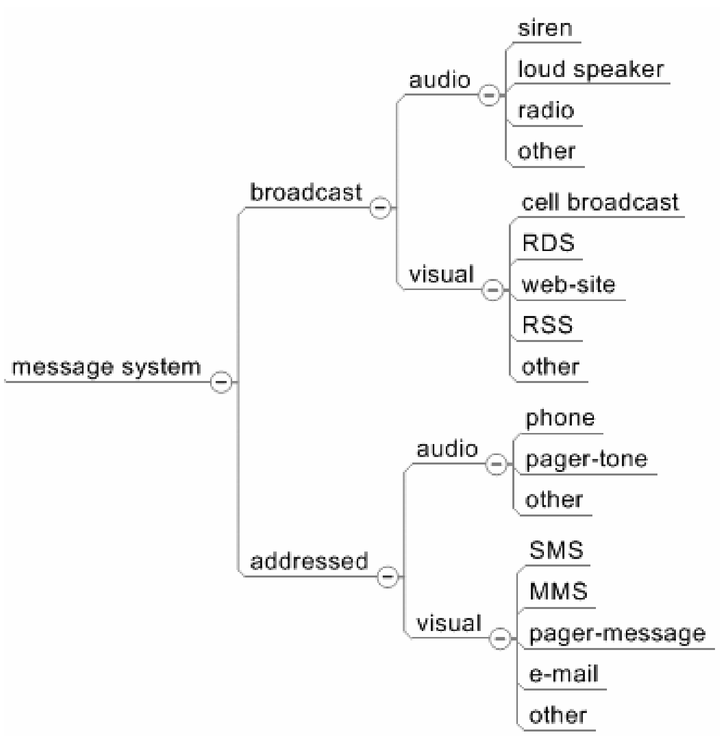
Situation sequence

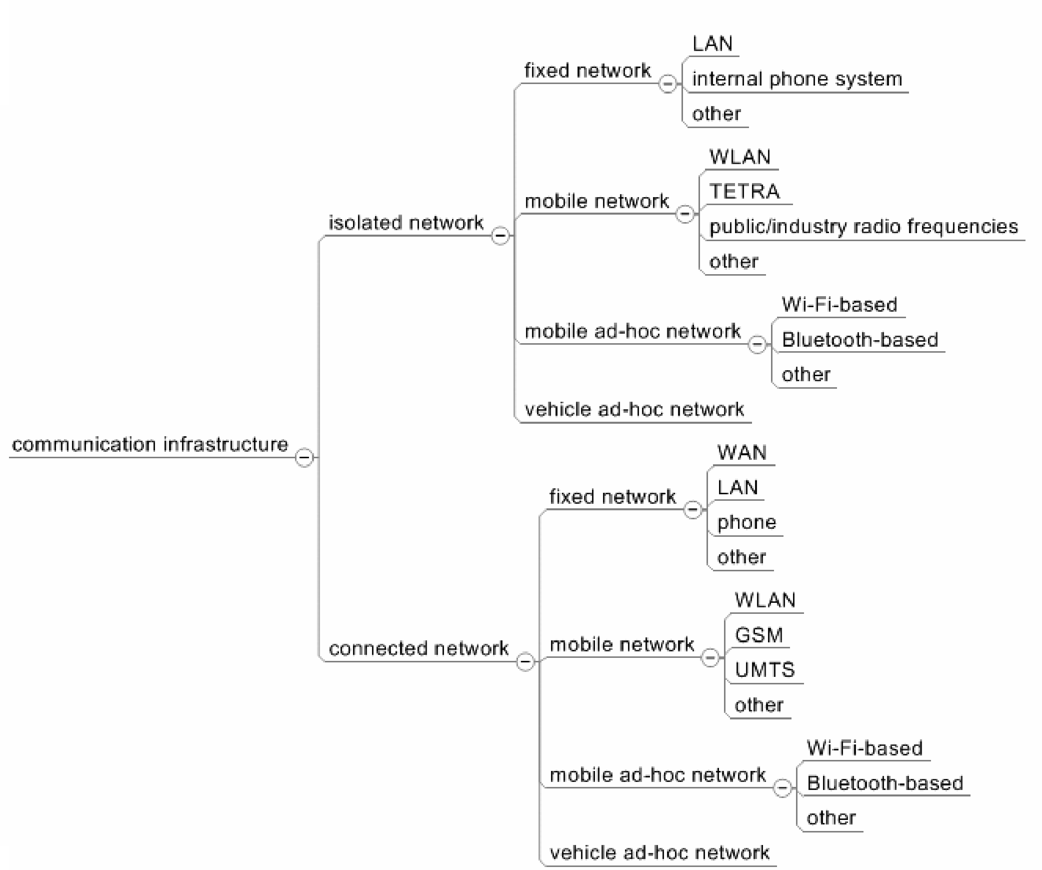
A situation sequence is a well-ordered set of non-overlapping situations. The order is given by the time intervals.

symbolically $(S, \prec:)$

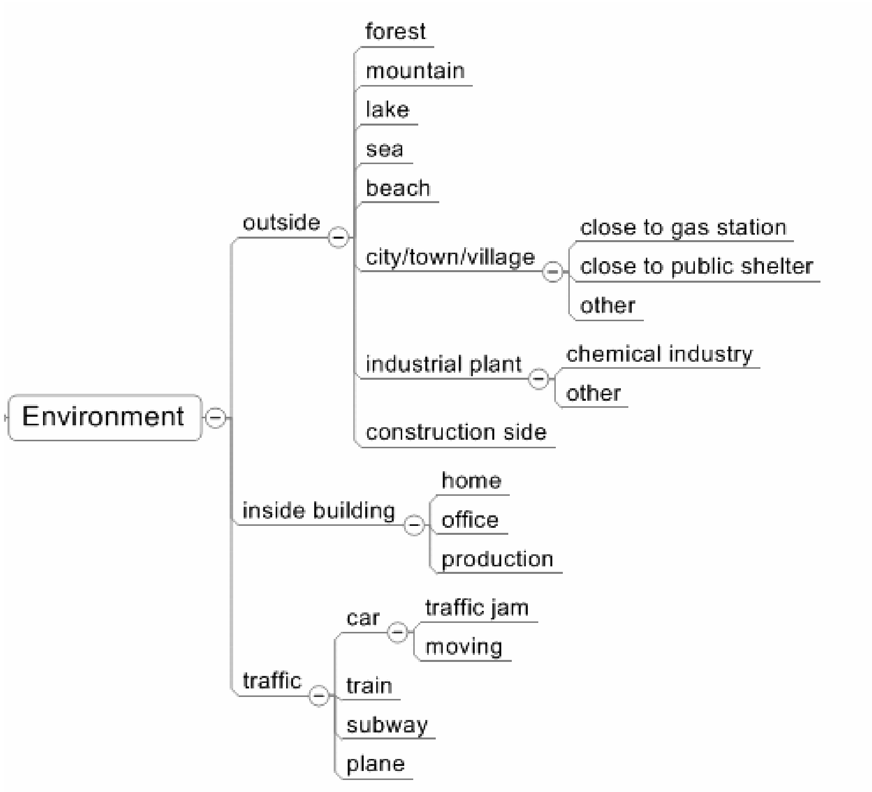


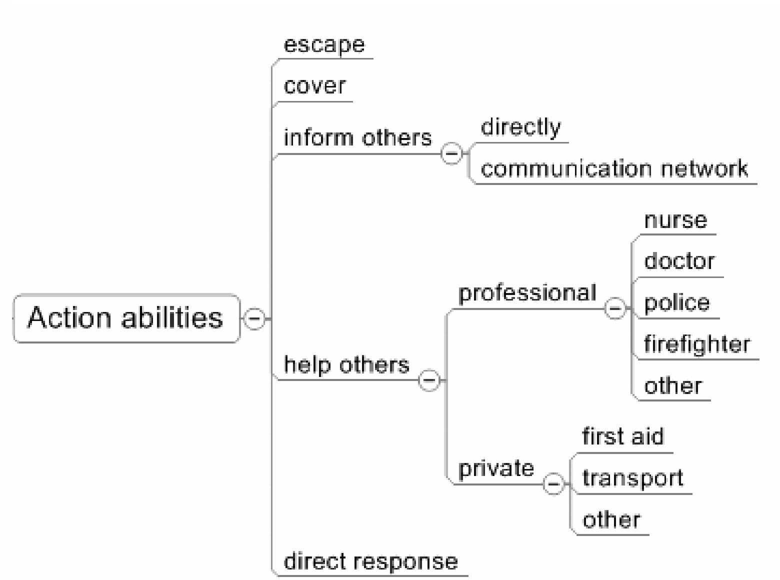
Taxonomies for reachability





Taxonomies for environment and action abilities





Benefits for effective alerting and warning

A general selecting and filtering mechanism based on situation patterns

i.e.,

$$s_{\mathrm{P1}} = (01/25/2007-14:00:00, 01/25/2007-14:30:00, \\ C_{\mathrm{l}}(\text{"13,1829-53,6792-15000-0-10000"}), C_{\mathrm{e}}(\text{"outside"}), C_{\mathrm{a}}(\text{"cover"}))$$

$$S_{\mathrm{P1}} = \{S \in S_{\mathrm{all}} \mid partof(s_{\mathrm{P1}}, S)\}$$

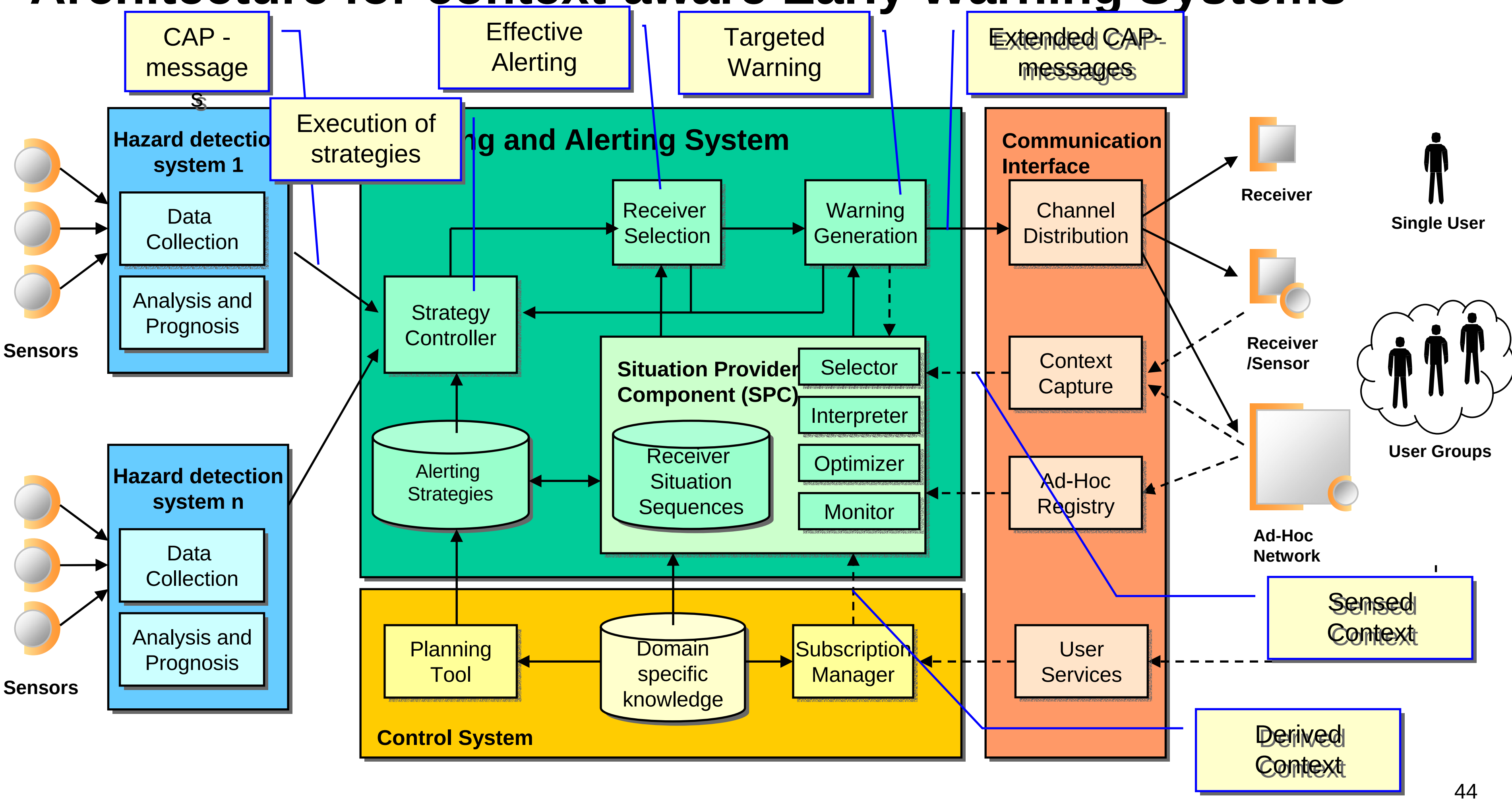
I. Flexible implementation effective alerting strategies:

The alerting of receiver groups can be prioritized along an optimization strategy based on situation patterns.

II. Flexible implementation of effective warning adaptation:

For each receiver group that has a certain pattern i.e., in terms of location action abilities and exposure individual instructions can be added.

Architecture for context-aware Early Warning Systems



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