Vulnerability to torrent processes

Sven Fuchs

Torrent processes...
Torrent processes...

Situation 1954  Situation 1997  Situation 2000

The concept of vulnerability

An asset is not vulnerable unless it is threatened by something
A hazard is not hazardous unless it threatens something

Hazard  Risk  Vulnerability  Elements at risk
Intensity  Exposure
Multidisciplinary approaches:

- (Natural) Scientist: $v = 0.5$ in both cases, but absolute values different.

Multidisciplinary approaches:

- Social scientist: Vulnerability in Hong Kong considerably higher than in Germany…

Quo vadis?

- Vulnerability as a multi-dimensional phenomenon, what might result in high vulnerability for social scientists might be negligible for engineers…

**Consensus**: Vulnerability has a spatial dimension
Alternative vulnerability indices?

- Physical vulnerability sub-index
  - construction materials of the buildings (masonry vs. reinforced concrete, ...)
  - building strength and resistance to processes

- Economic vulnerability sub-index
  - unemployment rate in flood prone areas
  - gives an idea of real life conditions and the economical recovery capacity after the hazard occurred
  - illiteracy rate of the population in flood prone areas
  - capacity to access information and to adopt civil protection preparedness measures (training and education)

- Demographic vulnerability sub-index
  - percentage of children and old people living in flood prone areas
  - translate the mobility capacity of most vulnerable people
  - number of social equipments and civil protection infrastructures localised in flood prone areas
  - identifies the contact points, also evaluating the reaction time of civil protection organisations

...
Torrent events matter…

Oberndorfer et al. 2007

N = 5,000 (1972-2004)
Torrent events matter…

Events [N] and damage [%] related to recurrence intervals

Introduction | Method | Results | Conclusion

Torrent events matter…

object-specific damage extent (relative)
number of events (relative)
number of events (absolute)
Linear (object-specific damage extent (relative))
Linear (number of events (relative))
Therefore: Risk analyses

- Risk dependent on
  - the probability of occurrence of a specific process
  - the height of the damage potential exposed

\[ R_{i,j} = f(p_{Si}, A_{Oj}, v_{Oj, Si}) \]

- \( R_{i,j} \) = risk
- \( p_{Si} \) = probability of scenario \( i \)
- \( A_{Oj} \) = value at risk of object \( j \)
- \( v_{Oj, Si} \) = vulnerability of object \( j \), dependent on scenario \( i \)
### Methods to determine vulnerability

- With respect to exposed buildings

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Intensity</th>
<th>Method</th>
<th>Results</th>
<th>Conclusion</th>
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**Fuchs et al. 2007**
Methods to determine vulnerability

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Vulnerability

- Fuchs et al. 2007
- Kimmerle 2002
- Cardina et al. (2002)
- Pal and Mathai (1997)
- Dal and Coale (2005)
- Roming (2014)
- Giller (1999) (for channel debris flows)

Methods to determine vulnerability

- With respect to exposed buildings
Methods to determine vulnerability

- Lack of data linking intensity to exposure

1. Vorderbergerbach (29 August 2003)

2. Wartschenbach (16 August 1997)

Method

- Analysis of the events:
  - Event documentation (aerial photos, documents of Austrian Torrent and Avalanche Control Service)
  - Back-calculation using FLO-2D
  - Flow depths and accumulation heights as a proxy for intensity*
Method

- Analysis of values at risk:
  - Spatially explicit analysis of buildings
  - Assessment of values according to Keiler et al. (2006) (classification, floor space, height, reconstruction value, real estate appraisal)

- Analysis of losses

\[ \nu = \frac{\text{loss}}{\text{value}} \]

Results [detached houses]

\[ y = 0.12x^2 - 0.04x \]
\[ R^2 = 0.97 \]
Results

- Appropriate solution for process intensities < 2.5 m
- Mathematically, valid between 0.33 m and 3.06 m

\[ f(x) = \begin{cases} 
0 & \text{if } x < 0.33 \\
0.12x^2 - 0.04x & \text{if } 0.33 \leq x \leq 3.06 \\
1 & \text{if } x > 3.06 
\end{cases} \]

- Converges to the value of 1: \( \lim_{x \to \infty} f(x) = 1 \)

Conclusion

- Range is still considerable, in particular related to small process intensities \( \rightarrow \) strong dependence on local structural protection

- Vulnerability values below suggestions in literature

- More data needed for a validation…
Conclusion

- E.g., validation by data from Italy (Univ. of Trento), see presentation of Matteo Dall’Amico

References

Thank you for your attention!

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