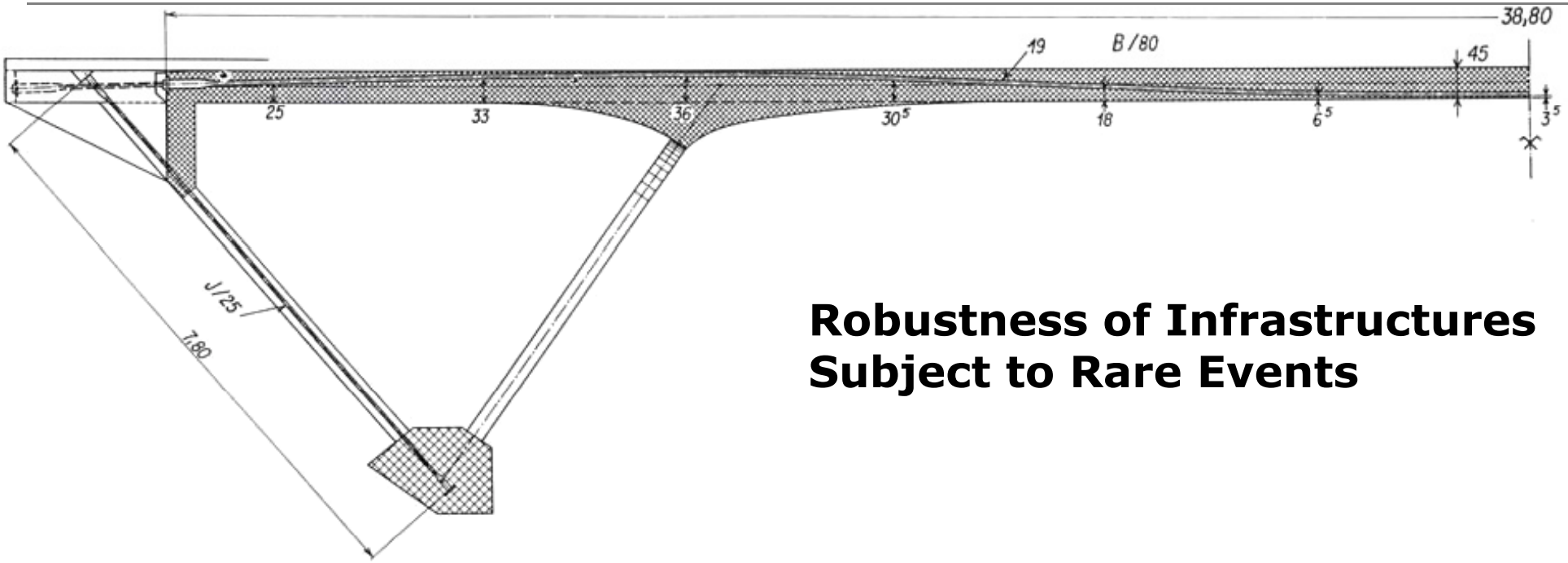
10th International Conference on Applications of Statistics and Probability in Civil Engineering



Robustness of Infrastructures Subject to Rare Events

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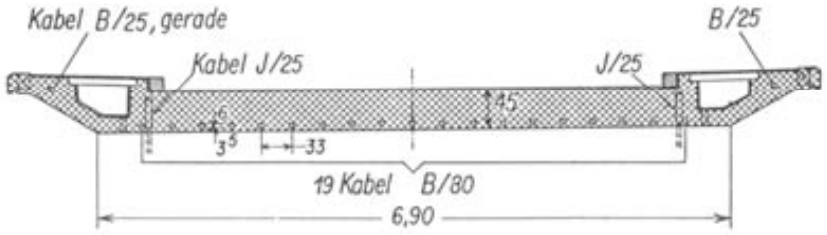
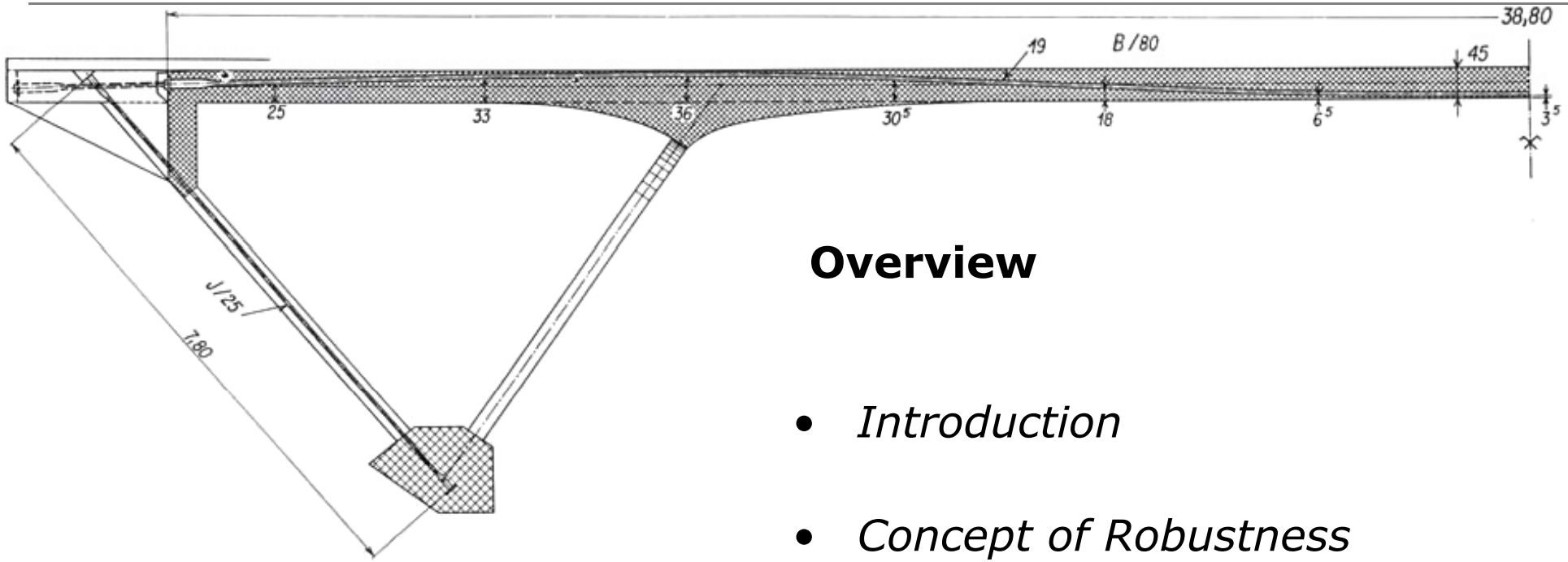
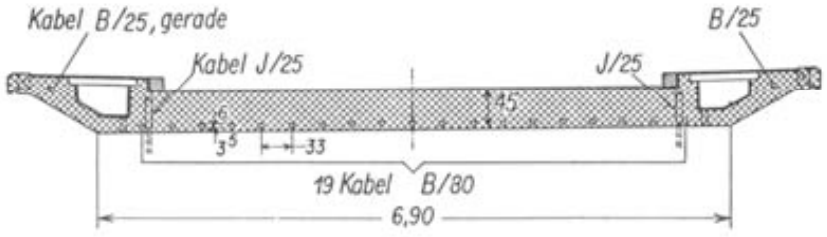






Overview

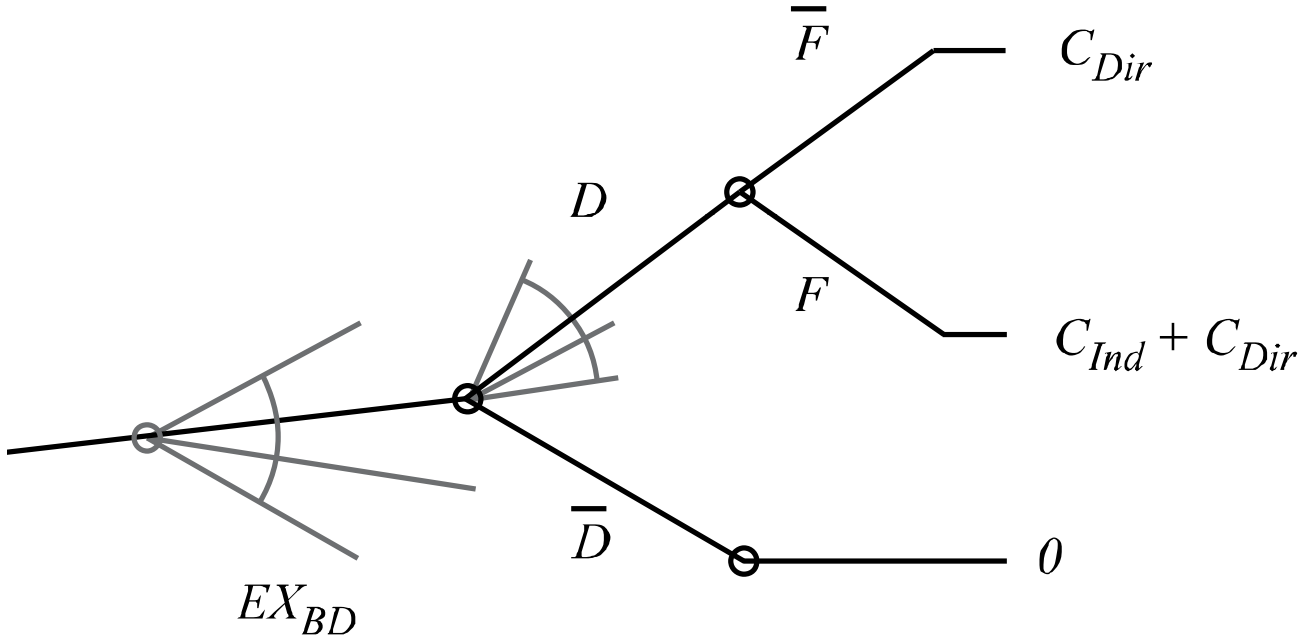
- *Introduction*
- *Concept of Robustness*
- *Risk assessment using Influence Diagrams*
- *Results*
- *Conclusions*

Introduction

- Robustness is generally accepted as a characteristic of a good system design
- Objective quantification of robustness is needed
- Robustness is interpreted here as damage tolerance:

  The consequences of structural failure should not be disproportional to the effect causing the failure

Concept for the quantification of robustness



$$I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk}$$

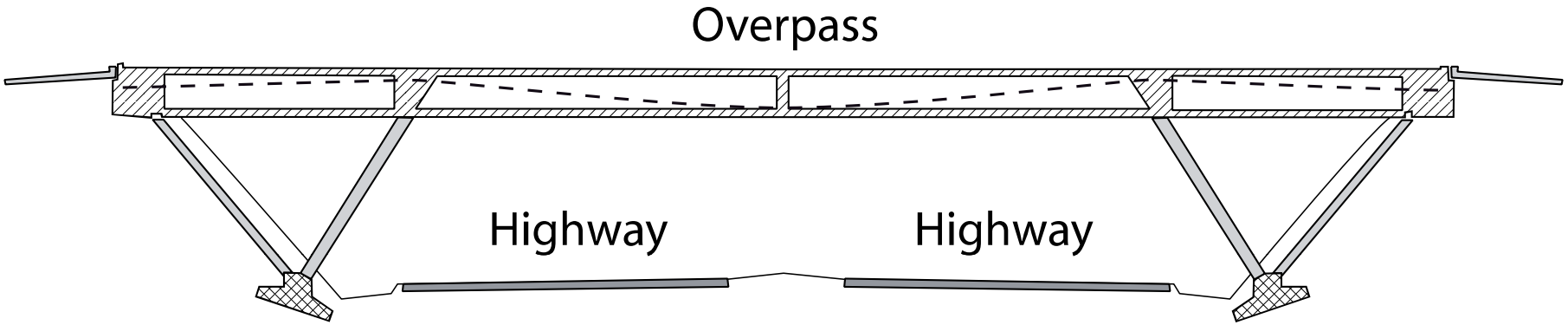
The Index of Robustness

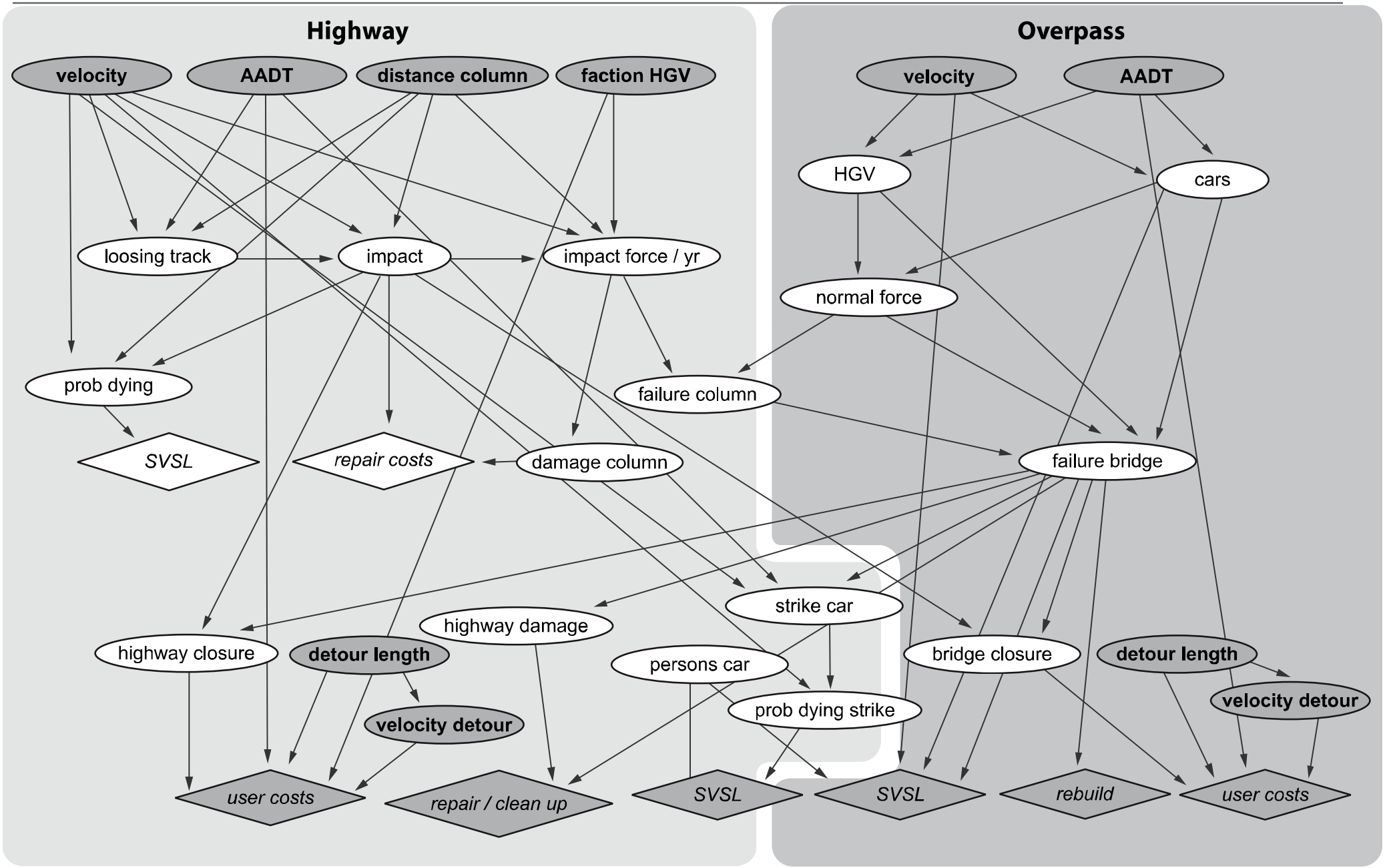
$$I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk}$$

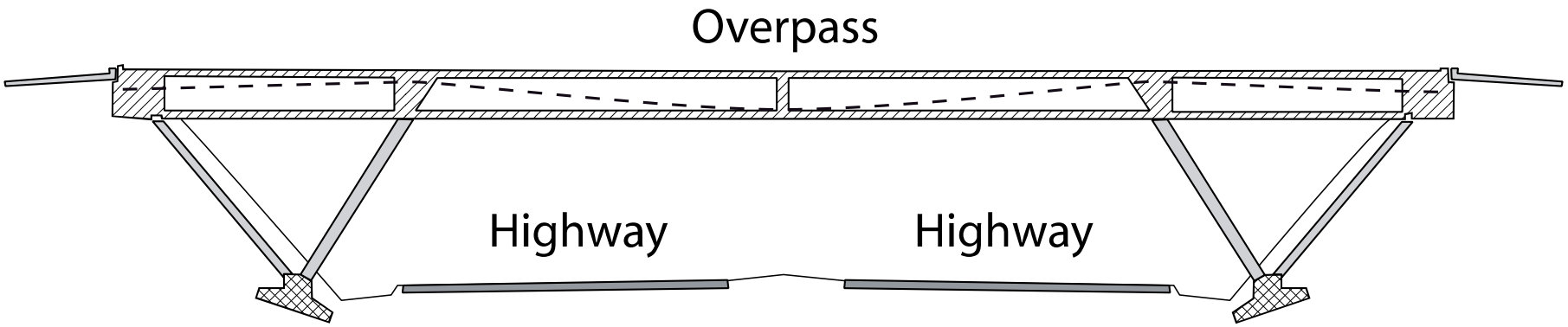
- Assumes values between zero and one
- Measures relative risk only
- Dependent upon the probability of damage occurrence
- Dependent upon consequences
- Is more than a characteristic of the structure

Risk Assessment

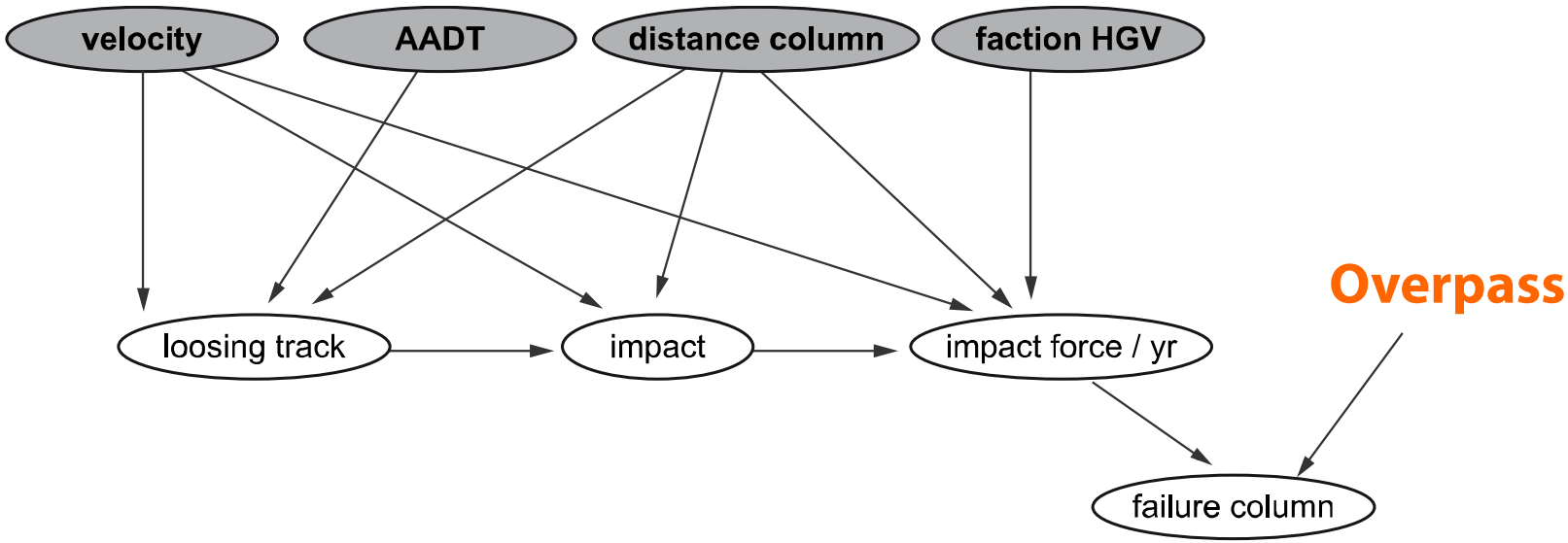
- This concept is applied to a V-column overpass consisting of:
  - pre-stressed box girder
  - columns
  - tension elements
- The risk due to vehicle impact is calculated by using influence diagrams

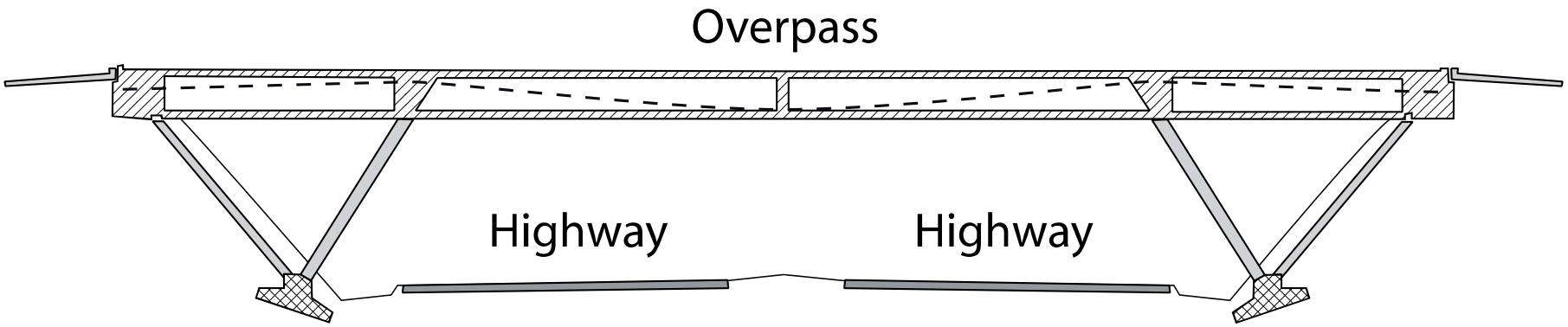


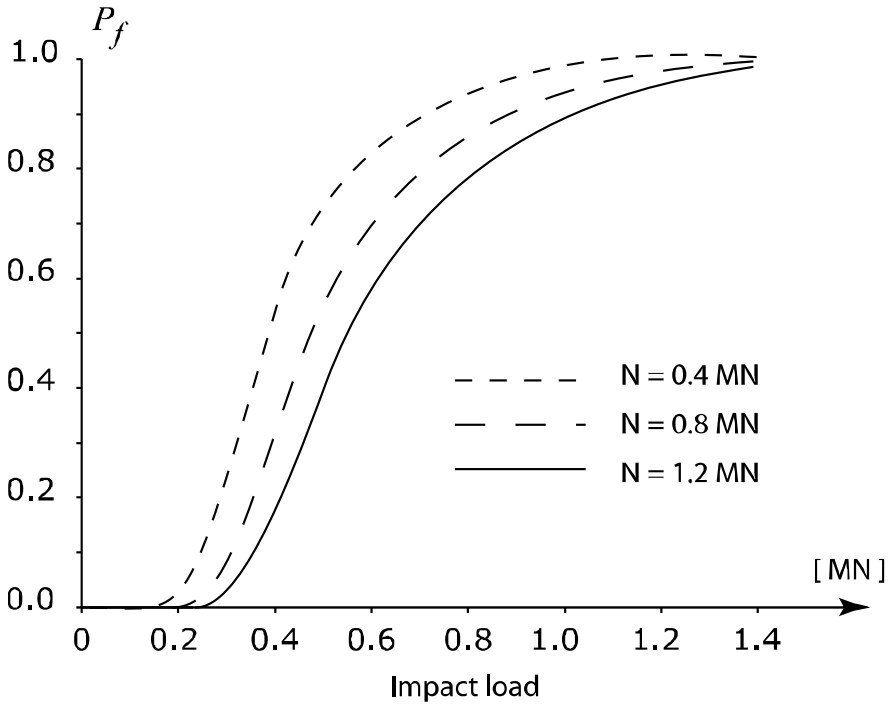

Highway
Overpass
velocity
AADT
distance column
faction HGV
loosing track
impact
impact force / yr
prob dying
SVSL
repair costs
damage column
highway closure
detour length
velocity detour
user costs
repair / clean up
highway damage
persons car
strike car
prob dying strike
SVSL
velocity
AADT
HGV
cars
normal force
failure column
failure bridge
bridge closure
detour length
velocity detour
SVSL
rebuild
user costs


Overpass
Highway
Highway

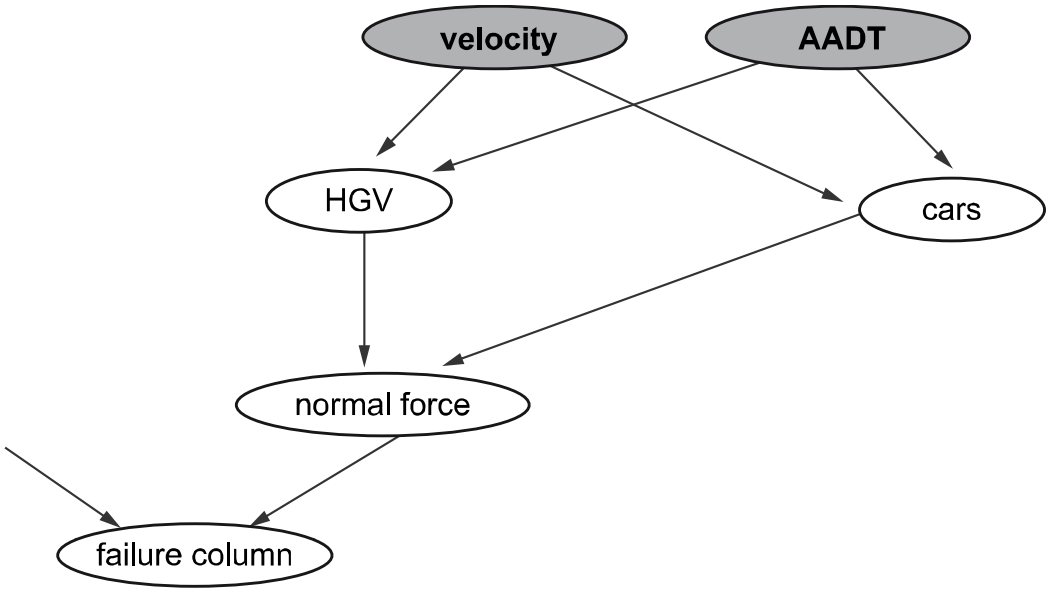
Highway

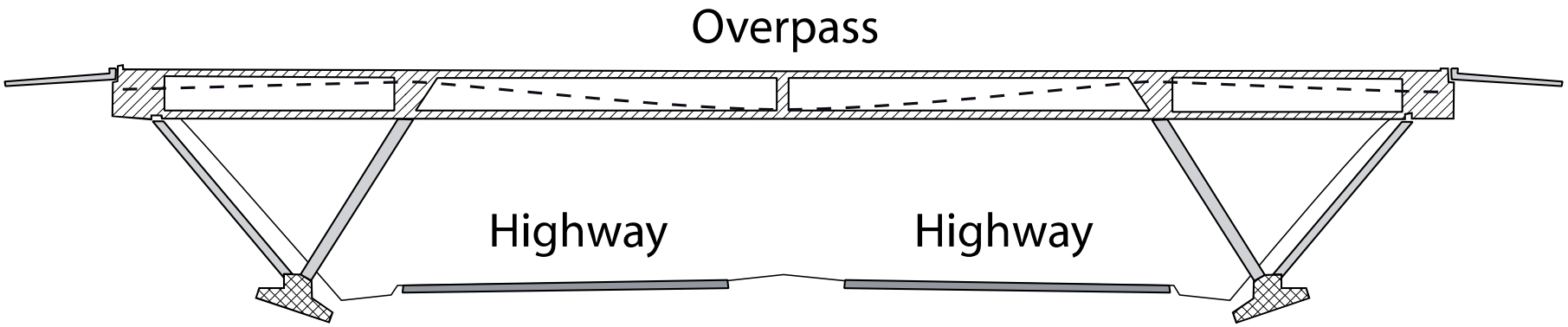

velocity
AADT
distance column
faction HGV
loosing track
impact
impact force / yr
Overpass
failure column


Overpass
Highway
Highway


P_f
1.0
0.8
0.6
0.4
0.2
0.0
N = 0.4 MN
N = 0.8 MN
N = 1.2 MN
[MN]
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Impact load

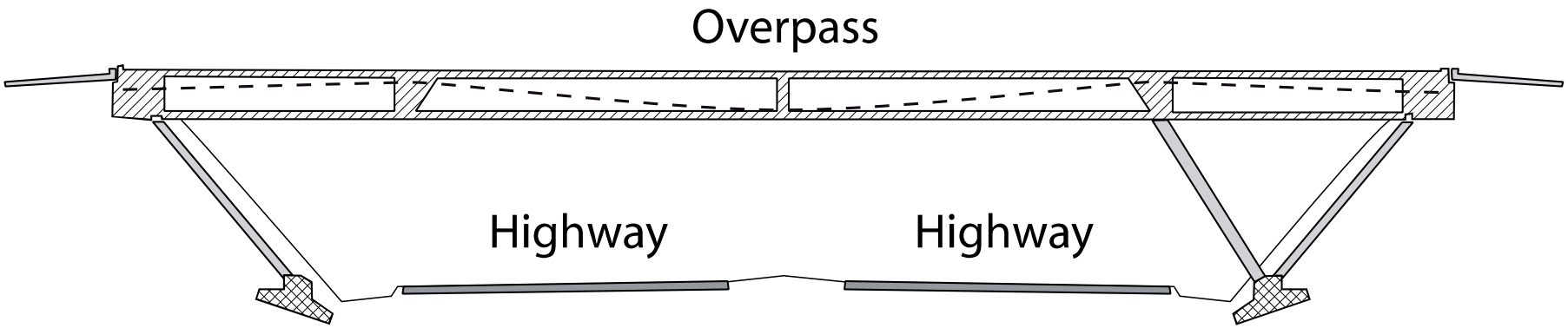
Overpass


velocity
AADT
HGV
cars
normal force
failure column



Direct Consequences

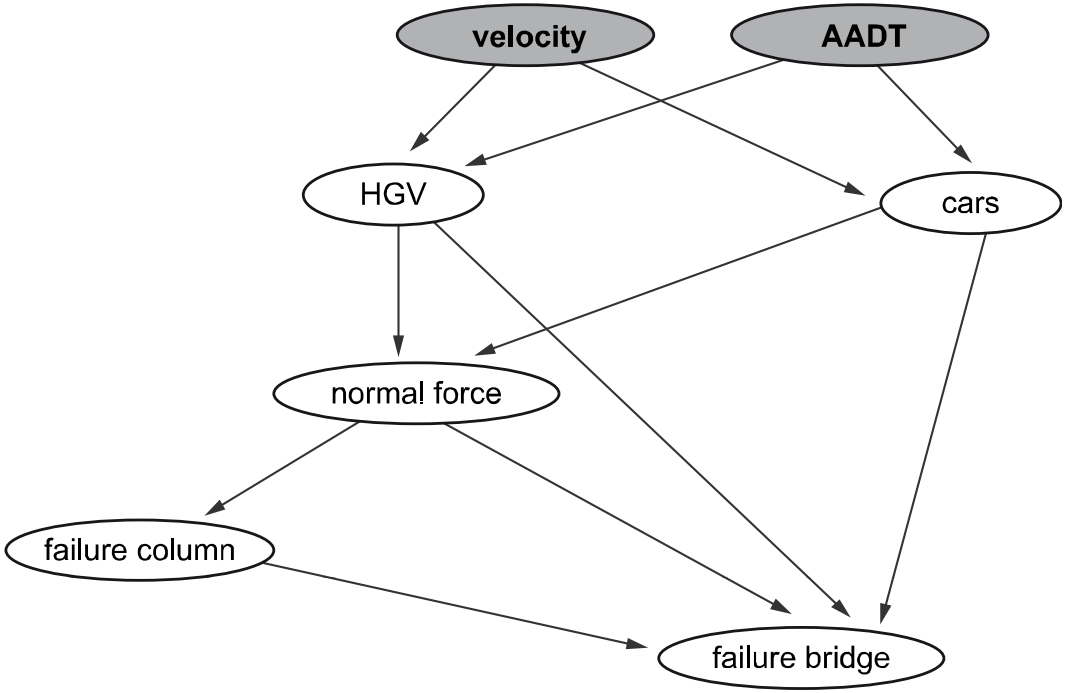
- fatalities / LQI
- repair costs
- property damage
- clean up costs

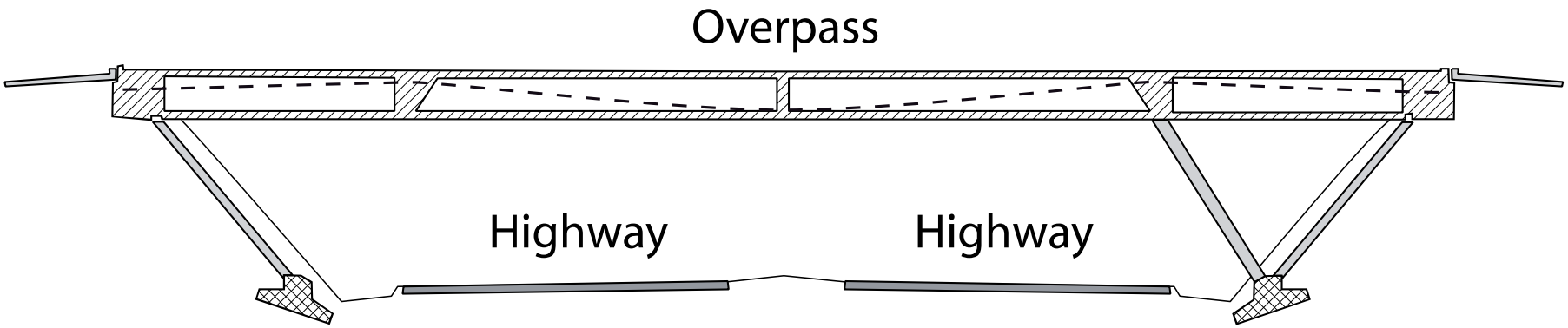


Indirect Consequences

- fatalities / LQI
- clean up costs
- rebuild costs
- property damage
- user costs

Overpass





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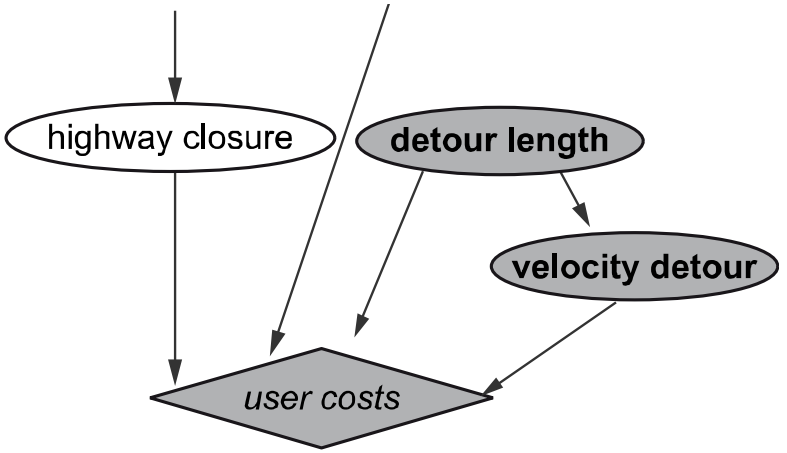
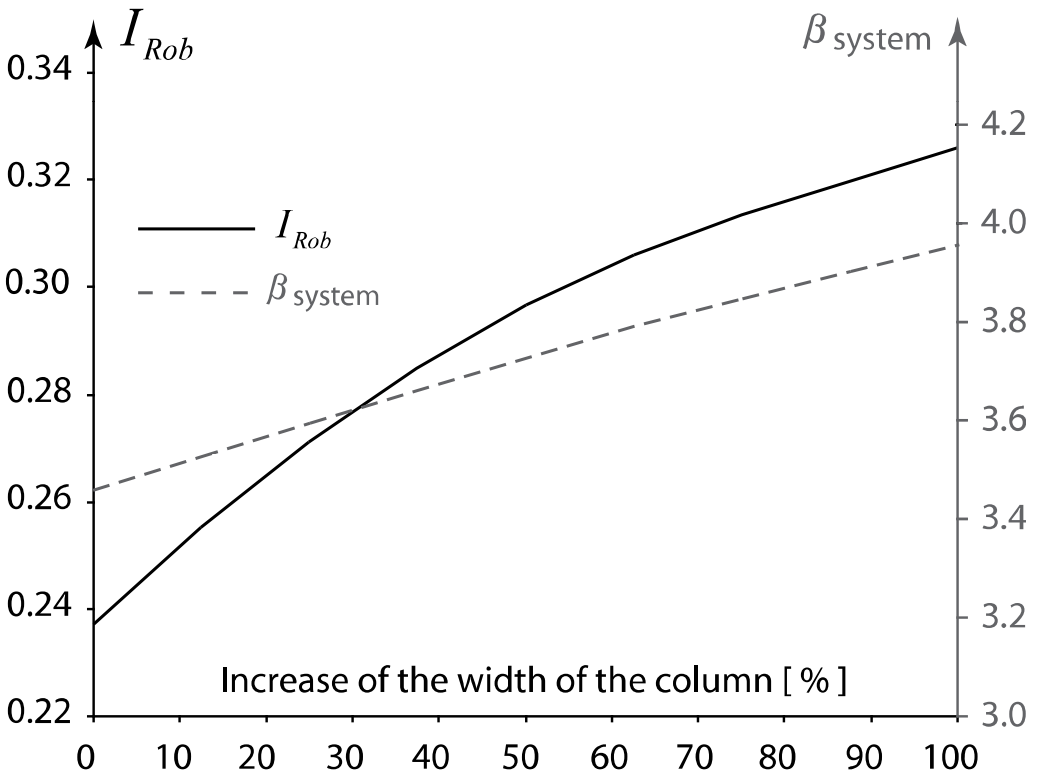


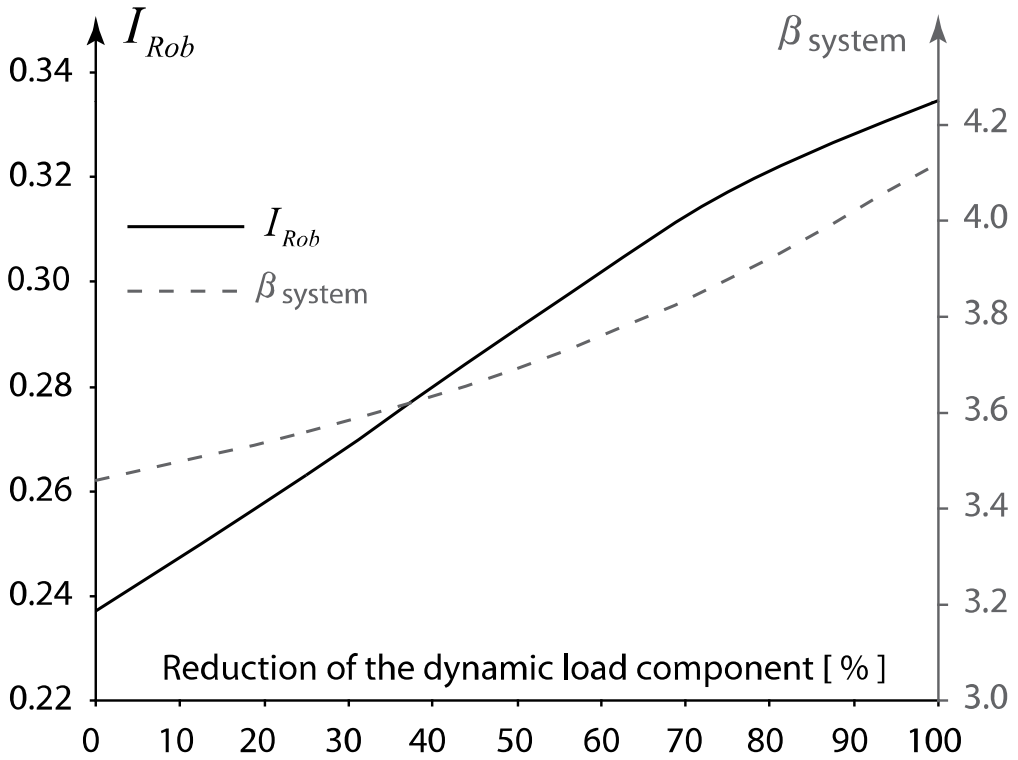
Measures to increase the robustness – Structural performance

- Increase reliability of components – vulnerability of one member is reduced
- Expected value of the indirect consequences decreases faster than direct consequences



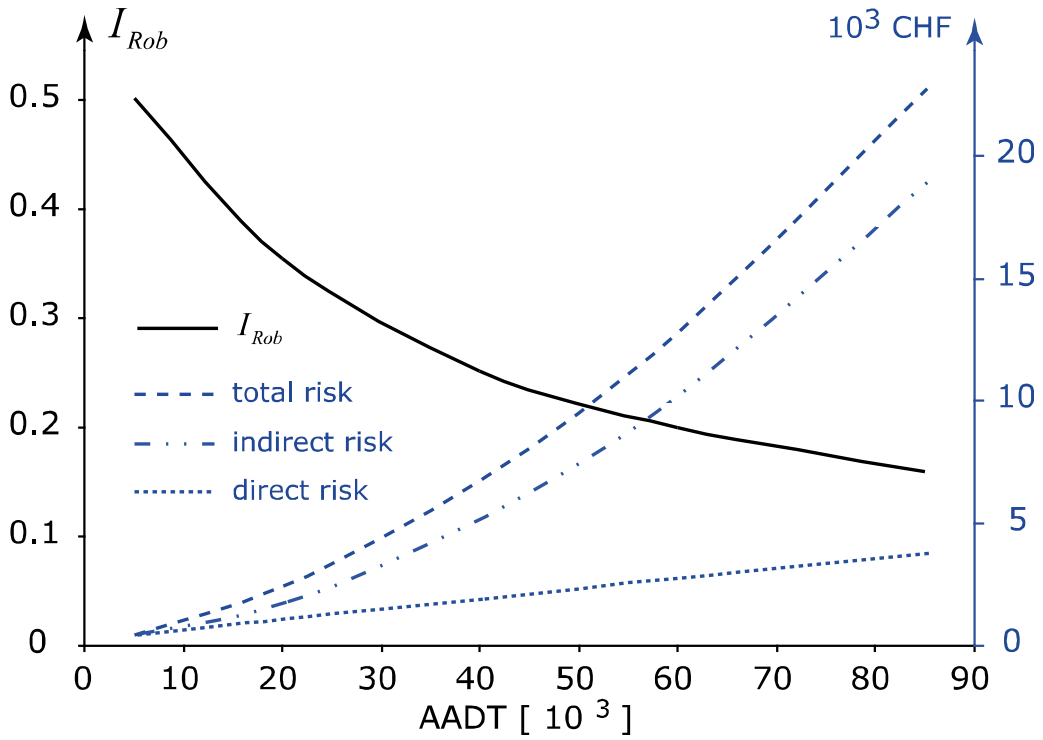
Measures to increase the robustness – Structural performance

- Increase reliability of components – increase of the damage tolerance.
- The index is converging to an upper limit.



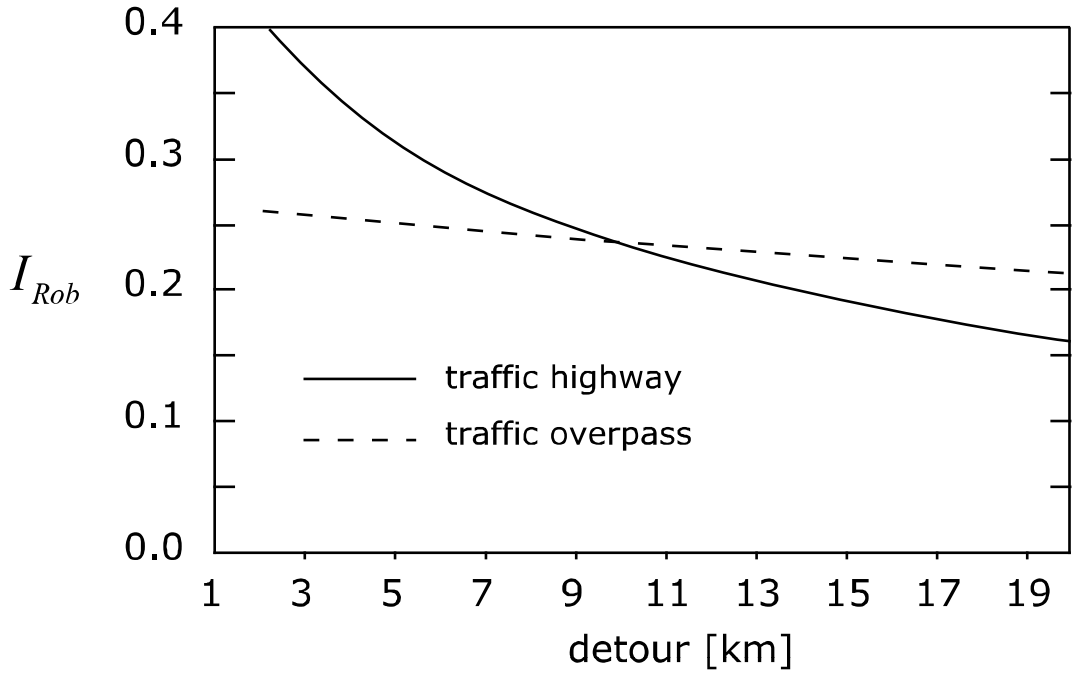
Measures to increase the robustness – System performance

- Reduction of consequences
- Indirect risk increases disproportional to the average daily traffic



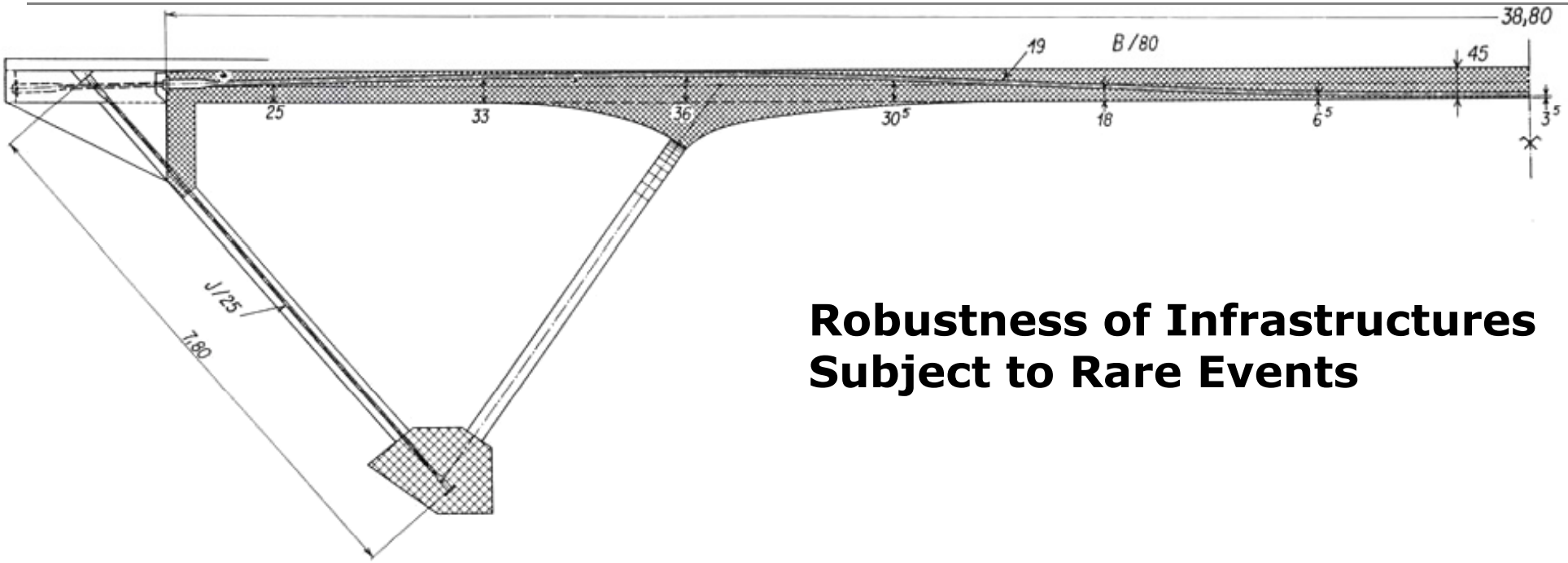
Measures to increase the robustness – System performance

- Increase the redundancy of the roadway network
- Affects mainly the risk due to user costs
- User costs have a large influence on the decision making in roadway networks



Conclusions

- The proposed index of robustness is applicable to complex and realistic systems.
- It accounts consistently for different robustness related aspects
- It is shown that influence diagrams have a large potential for the risk assessment of rare events
- The site and object specific character of rare events can be accounted for by implementing specific information in the network.
- Further work is necessary to set criteria's for acceptable values of the index of robustness.



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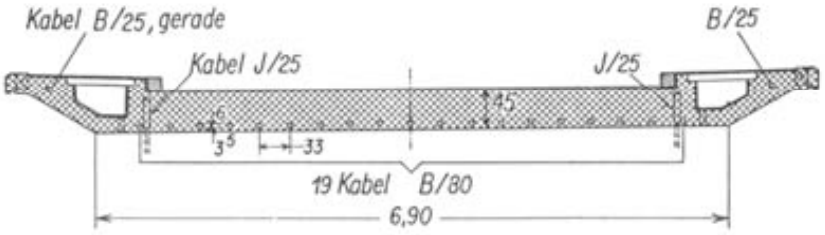

Thank you for your attention