TRiceR, a cloud-based web application for supporting risk-based decisions associated with ice falling from wind turbine blades

Winterwind conference - 20 Apr 2021

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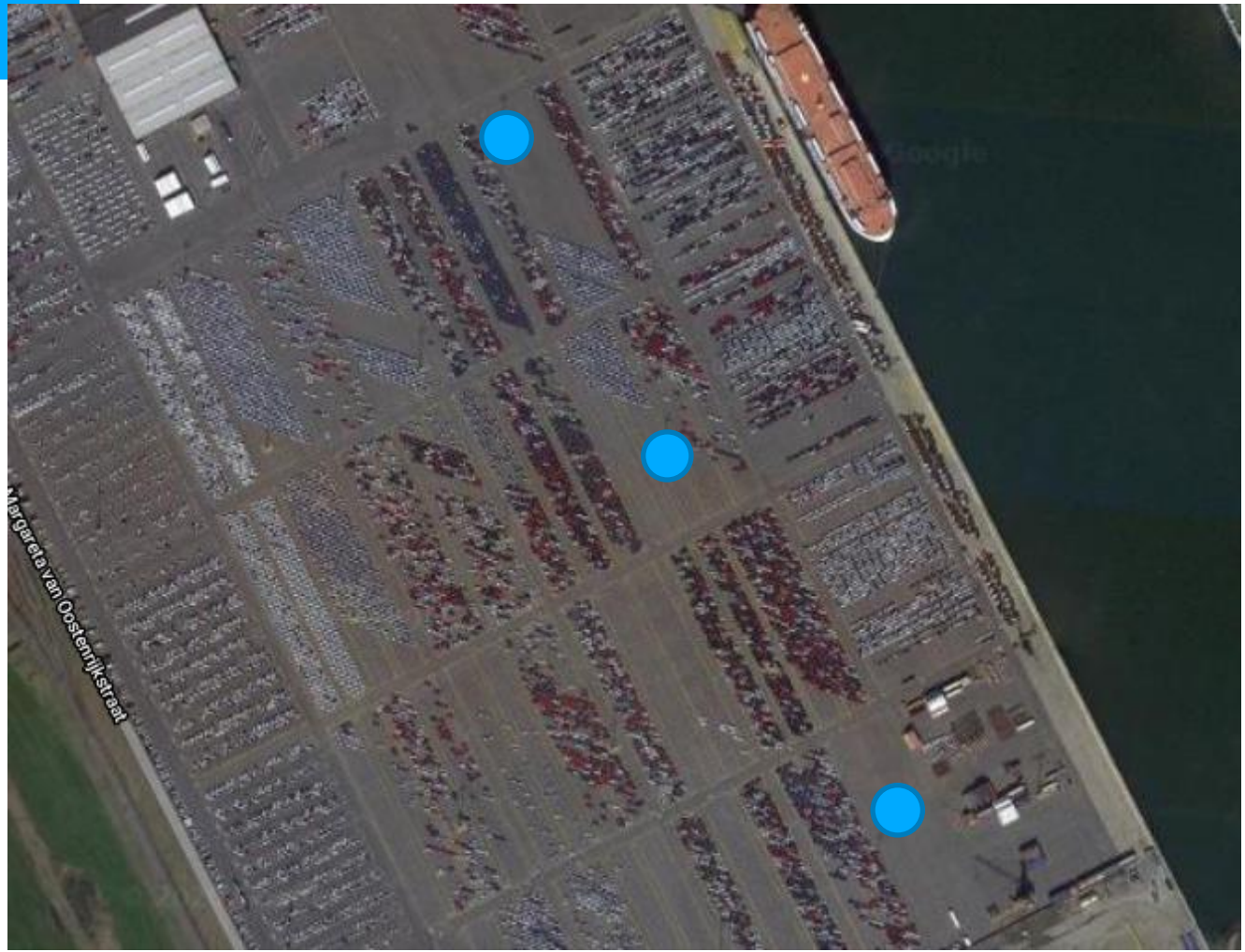
Case study



Frank Vandewillebroek

Site security manager

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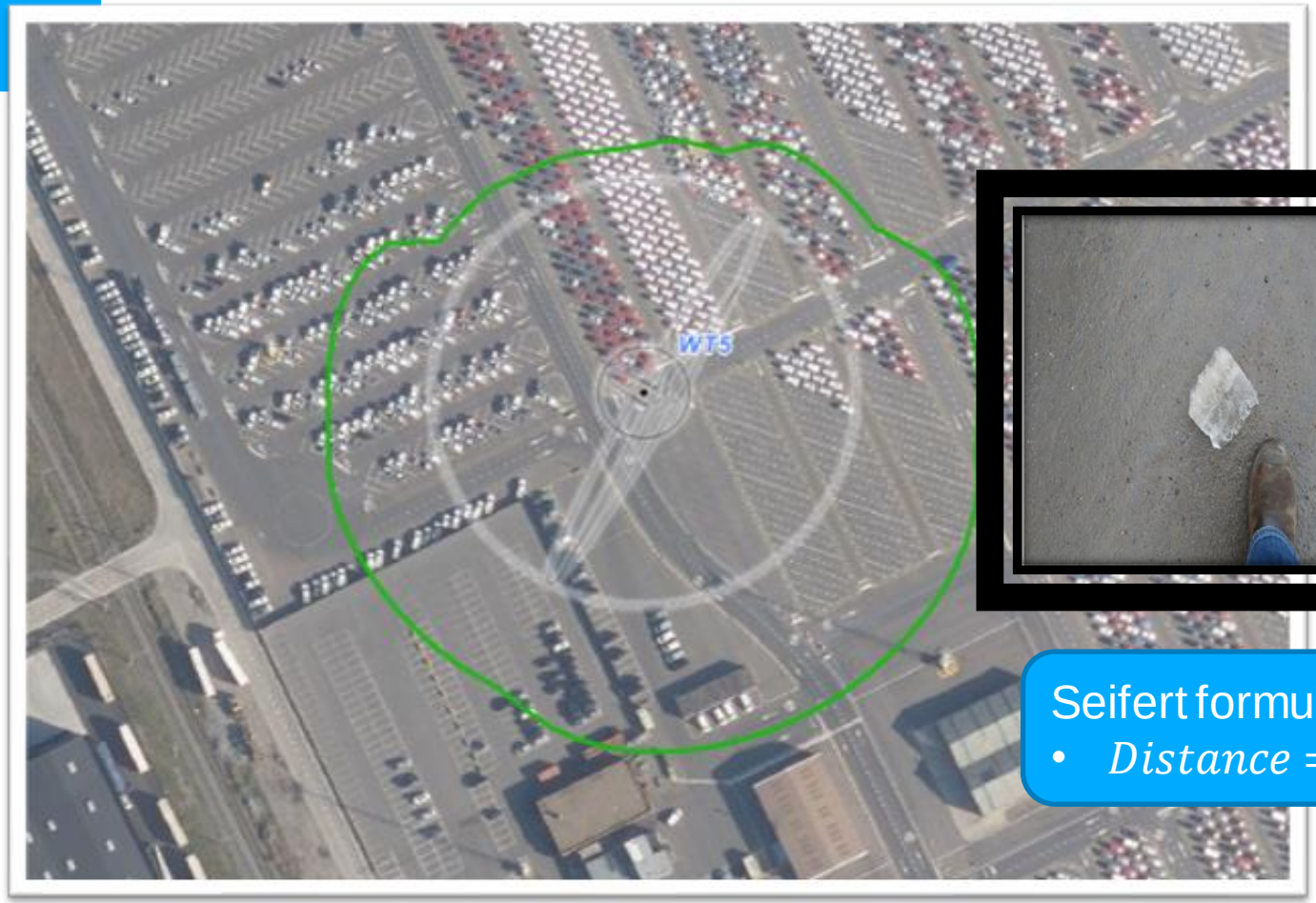
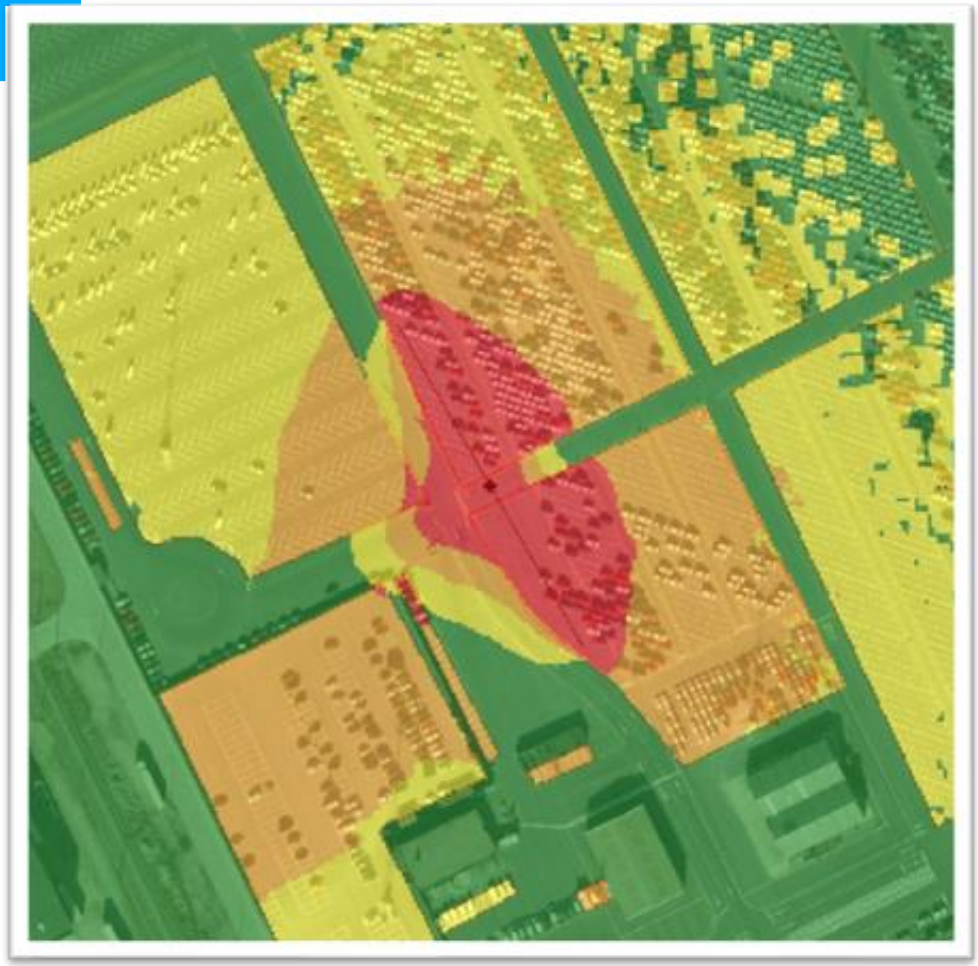


Seifert formula

- $Distance = v_{wind} * height/15$



TRICER

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Risk-based approach

- Definition of set of possible scenarios
- Calculate risk as product of
  - Probability
  - Exposure
  - Damage
- Compare value with risk acceptance framework

TRiceR

account: tractebel

ON
Show results

SOCIETAL
Societal/Individual

+ New

- Demo
  - Demo
    - TR0
      - Conf1: fixed yaw 0°
        - Biking path
        - Fixed
        - Parking
        - Average
        - Walking path
      - Conf2 : fixed yaw 90° - DA
      - Conf2: fixed yaw 90°
      - Conf2 : fixed yaw 90° - DA 9/11/2020
      - Conf2 : fixed yaw 90° - DA 4/11/2020
    - TR1
      - Conf1: fixed yaw 0°
        - Parking
        - Biking path
        - Second parking
        - Average
        - Walking path
- Project 1

v 2.1.3

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TRiceR – Different use cases, different time horizons

Development

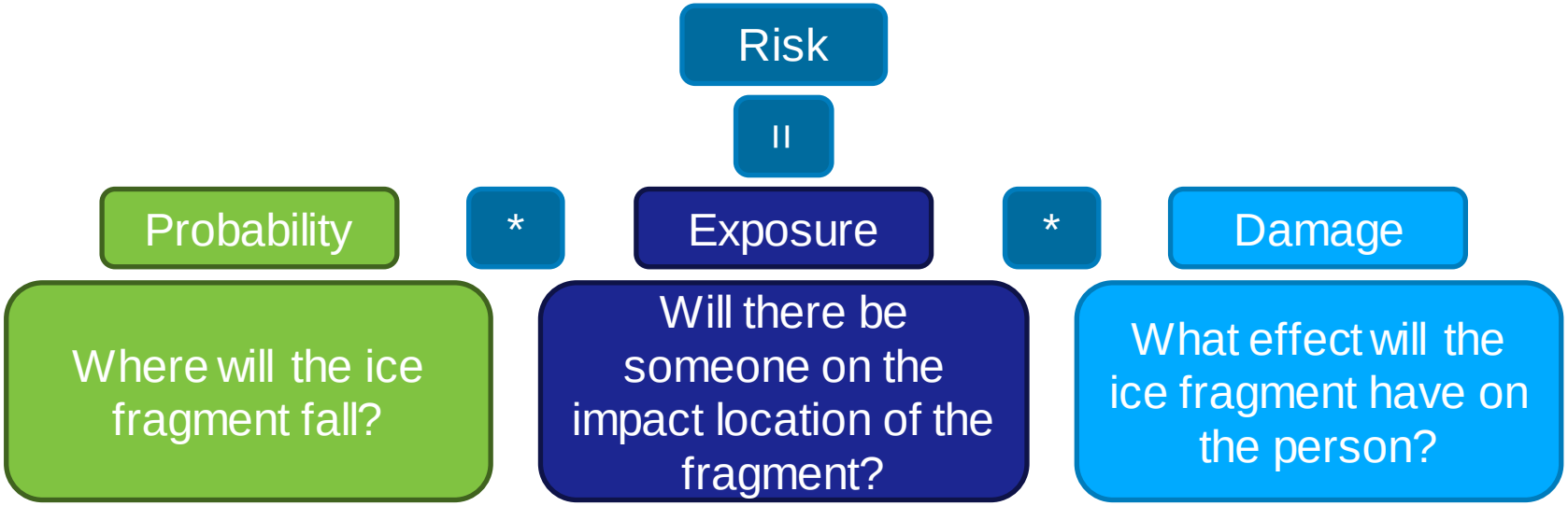
- Long term
- Ice fall risk over life time of wind turbine
- Average meteorological conditions over time span
- Part of the development track
- ‘One shot’ if no changing conditions
- Support for defining long term mitigation measures

Operation

- Short term
- Ice fall risk for next day, next week
- Measured or forecasted conditions
- Assessment for each ice fall event
- Mitigation measures based on actual conditions.

Within the engine…

TRiceR – Risk-based approach



- Is risk level acceptable?
- What can we do about it?

TRiceR – Risk-based approach

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Risk analysis

Probability (P)

1 – Ice accretion model on a turbine

2 – Ice release model from a turbine

3 – Meteo model

3 – Stochastic ice fall model

Damage (D)

5 – Damage model of ice fragments

Exposure (E)

6 – Description and use of the environment

7 – Exposure model

8 - Risk level determination f(P,D,E)

Risk assessment

9 – Risk acceptance framework

Risk assessment

Acceptable

Attention

Unacceptable

Risk mitigation

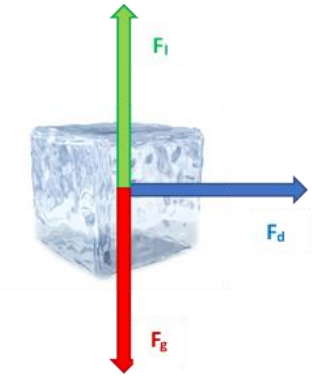
10 – Risk mitigation measures

11 – Effect of measures on model components & parameters

Reassessment

Acceptable

Probability – Fall movement



- 3 forces acting on ice fragment
  - Gravity F_g (& air resistance)
  - Lift F_l
  - Drag F_d

- $m.\frac{d^2s}{dt^2} = F_g + F_d + F_l$

Wind shear

Horizontal

$$m.\frac{d^2x}{dt^2} = F_d = k_h.(\boldsymbol{v_{wind}(t)} - \frac{dx}{dt})^2$$

Vertical

$$m.\frac{d^2z}{dt^2} = F_g + \boldsymbol{F_l} = Fg = m.g - k_v.(\frac{dz}{dt})^2$$

Average over 0

Solving these equations yields position of fragment at all times

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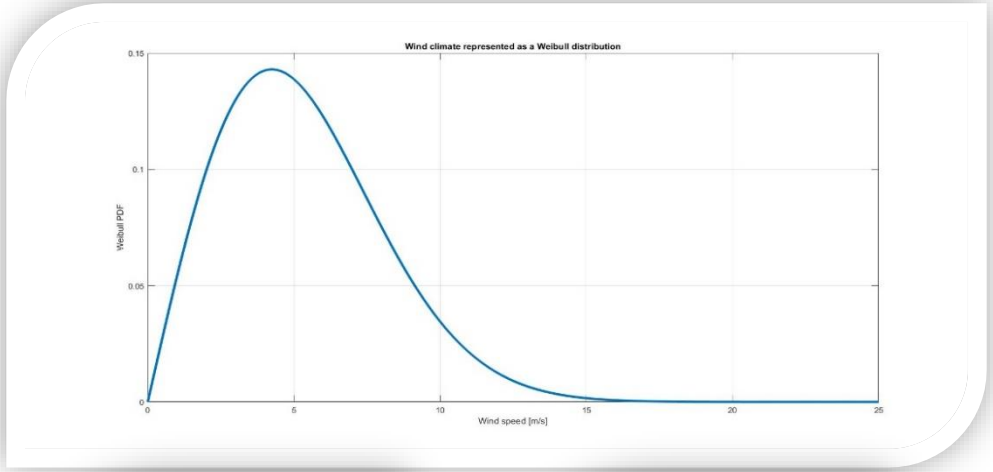
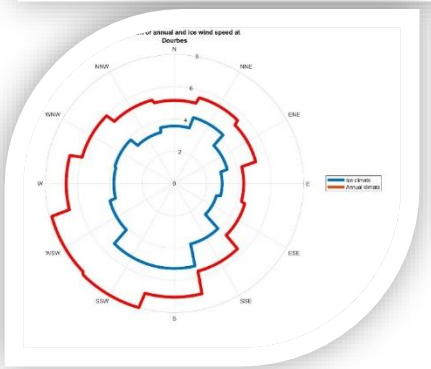
Probability – Model parameters

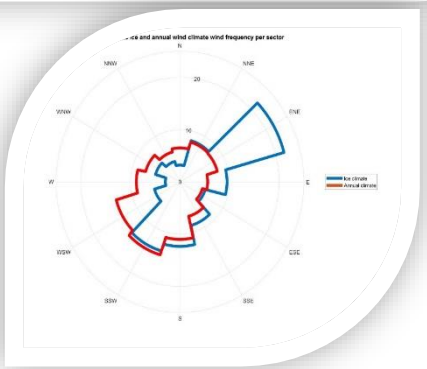
Wind speed & direction

- Long-term wind data
- < 5°C

- Take into account <u>all</u> wind speeds & frequency of directions!



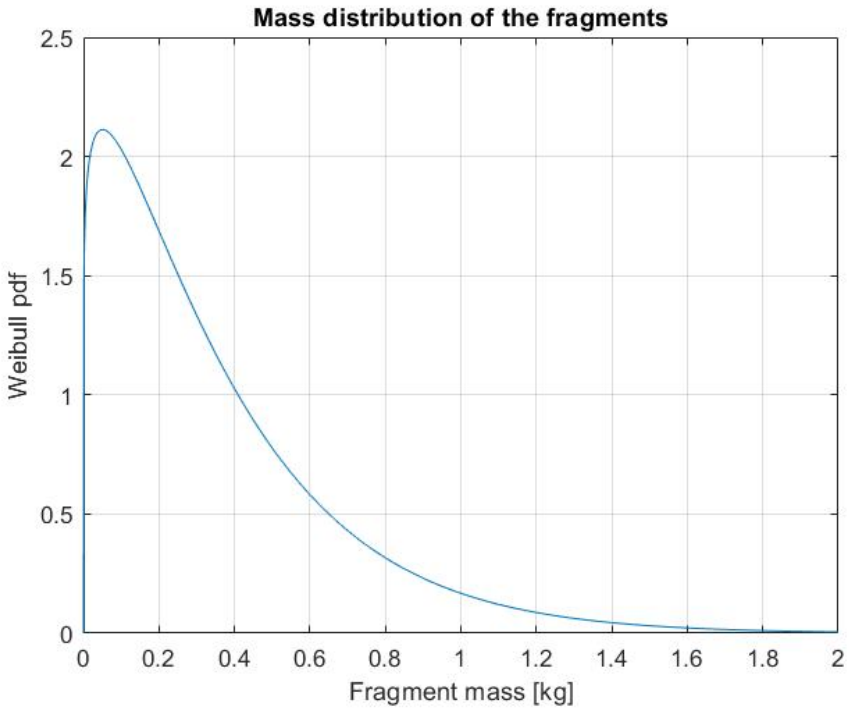




Probability – Model parameters

Fragment mass

- From literature
  - Weibull distribution
  - Average mass 360 g
  - 95% of fragment < 1 kg



Probability – Model parameters

Fragment ice type

- Depending on temperature and (relative) wind speed

Type of ice	Density kg/m³	Adhesion and cohesion	General appearance	
			Colour	Shape
Glaze	900	strong	transparent	evenly distributed/icicles
Wet snow	300 to 600	weak (forming) strong (frozen)	white	evenly distributed/eccentric
Hard rime	600 to 900	strong	opaque	eccentric, pointing windward
Soft rime	200 to 600	low to medium	white	eccentric, pointing windward

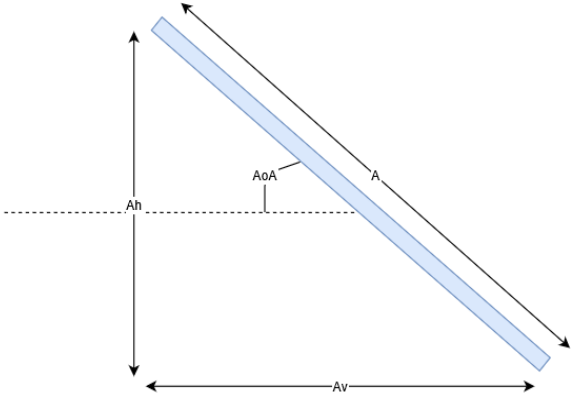
Ice fall model – Model parameters

Fragment shape and dimensions

- Thin plates
- Dimensions ‘normally’ distributed with high std.

Fragment angle of attack (AoA)

- Important for drag and air resistance.
- Random between 0° & 90°

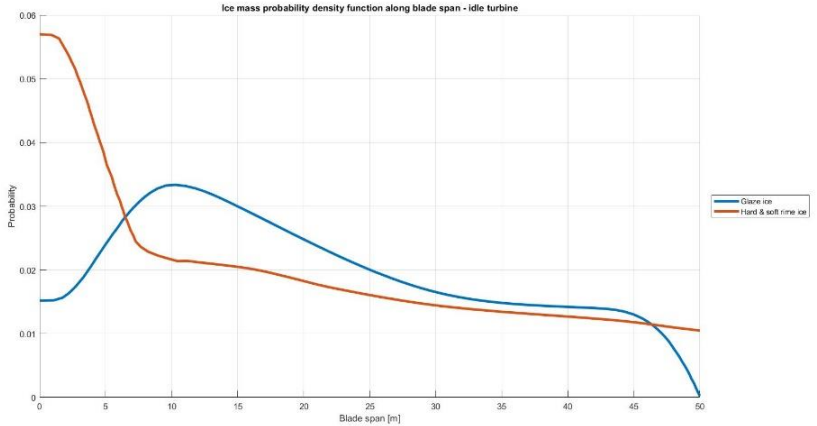


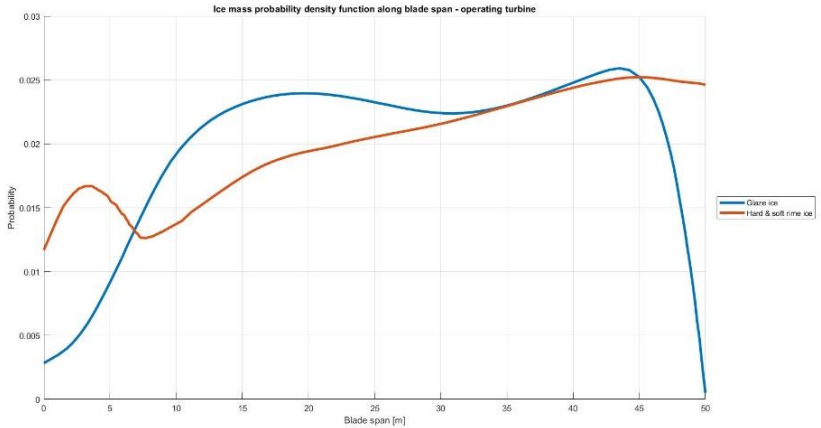
Probability – Model parameters

Fragment starting position

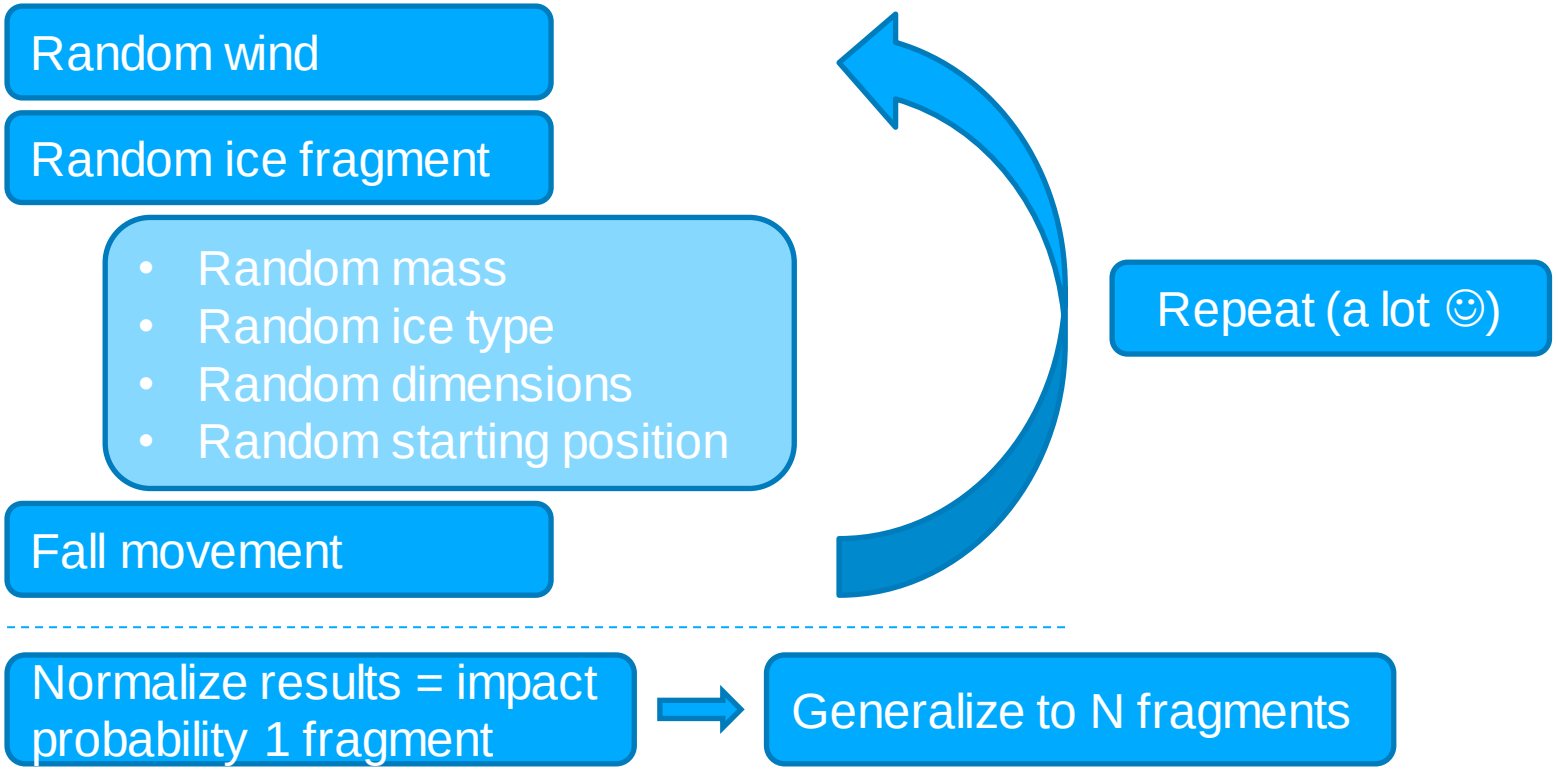
Total ice mass

- Turbine perpendicular to wind direction (if not positioned).
- Ice accretion on blades
- Depends on:
  - Environmental conditions
  - Ice type
  - Operation of turbine
  - Duration
- *Lamraoui* model





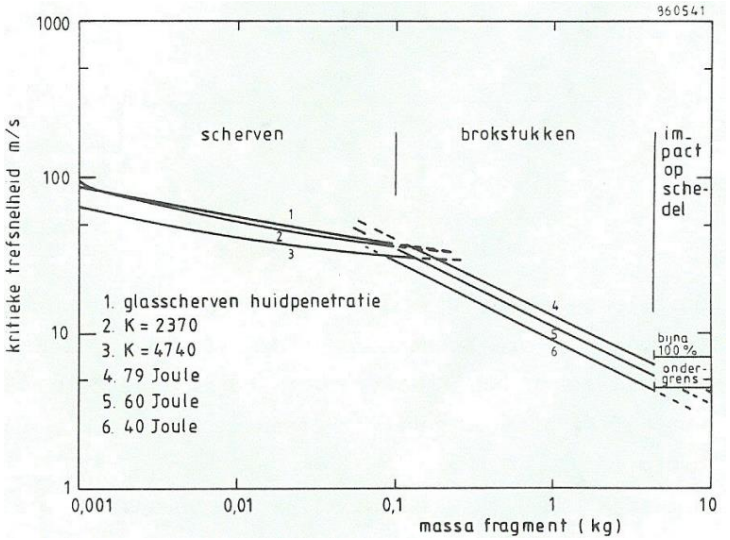
Probability – Monte Carlo process

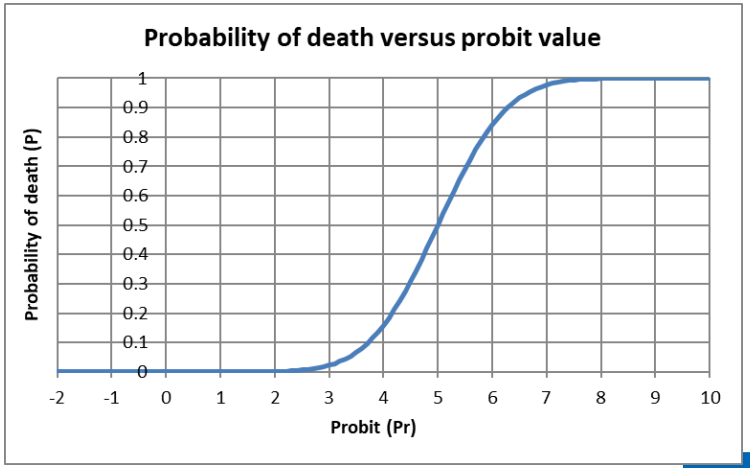


Damage – Damage model

- Damage = Lethality
- Not all fragments will be lethal.
- Weighted lethality rate through 3 probit functions.

Shard / shrapnel	fragments < 100g
Energy	100g < fragments < 4.5kg
Skull base fracture	4.5 kg < fragments

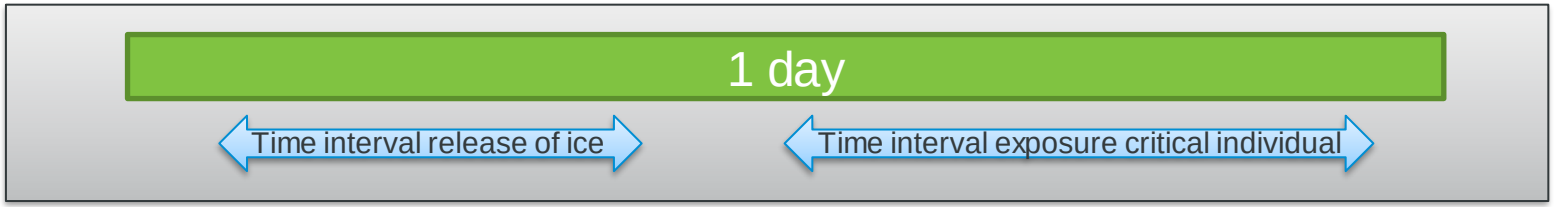




Exposure – Coincidence of ice release and presence of person

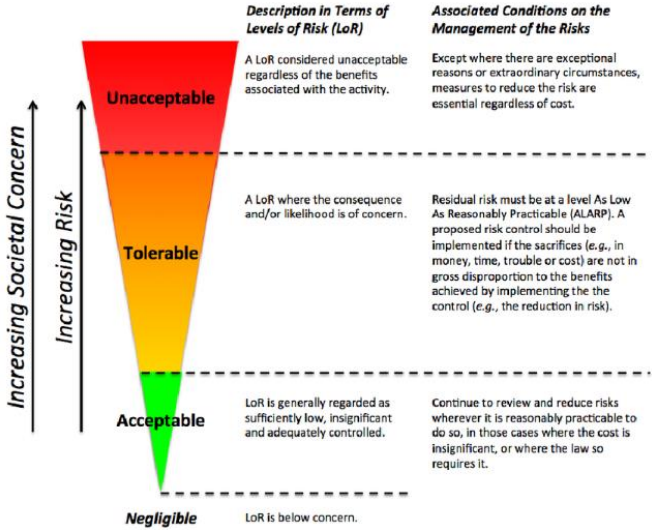
- To have a risk at a location, fragment must fall on it, fragment must be able to do damage and … somebody needs to be there.

- Ice fall day
- Ice fall release t_r
- Exposure time of individual t_p depends on use of location.



Risk acceptance framework – ALARP Principle

- With P, D & E risk level can be calculated.
- Compare to acceptance framework
  - Unacceptable region
  - Tolerable region
    - High attention
    - Low attention
  - Acceptable region
- In tolerable region: reduce risk As Low As Reasonable Practicable (ALARP)



Risk mitigation – How to reduce risk level

Turbine measures

- Rotor positioning, preventive shutdown, reactive shutdown, blade heating…

Environmental / Technical measures

- Construction of roof, protective nets, lights, static or dynamic signs, physical exclusion zones…

Organisational measures

- Communication, SMS warning system, manual removal, access time limitation, enforce PPE…

- Can be modelled in the analysis and the effects visualised!

!

- Difficulty: What parameters are affected?

Further info ?

Request a demo !

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