CFD for risk analysis in urban environment - Tilburg city case study -

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Contents

- Introduction
- Risk calculations for transport in the Netherlands: RBM-II
- Jet release (RBM-II vs CFD, ammonia)
- Dense gas release (CFD vs Wind tunnel, CO_2)
- Conclusions


Introduction

- Why this study?
  - RBM-II is standard method for calculating risks of transport in the Netherlands (RBM = Risk Calculation Methodology)
  - RBM-II:
    - is uniform & fast
    - gives only a rough estimate and no detailed information
- Pilot-study to show added value of CFD for risk calculations

RBM-II

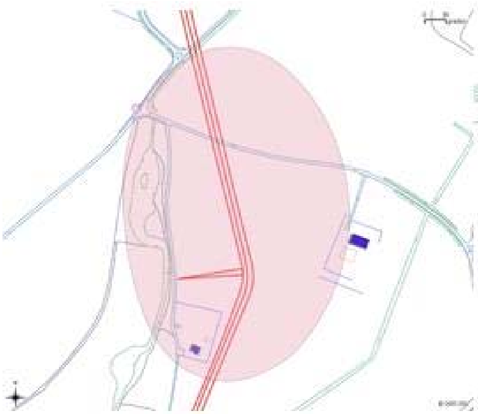
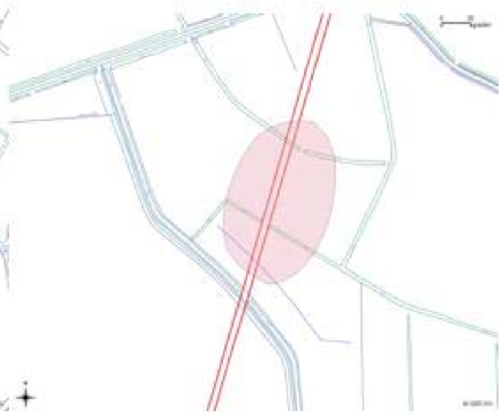
- Standard method for risk analysis for road, rail and water transport of hazardous materials
- Types of substances:
  - A flammable gas (propane)
  - B2 toxic gas (ammonia)
  - B3 very toxic gas (chlorine)
  - C3 very flammable liquid (pentane)
  - D3 toxic liquid (acrylonitrile)
  - D4 very toxic liquid (acrolein)
- Scenarios: large leak (g+l), small leak(g+l), BLEVE (g)
- Standard atmospheric conditions, probability based on meteorological data

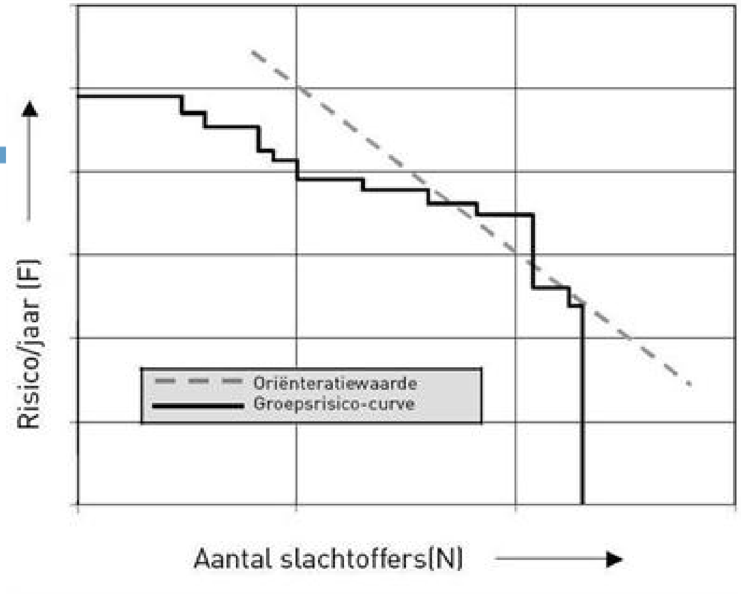

RBM-II (continued)

- 2 types of risks:
  - Individual risk (*plaatsgebonden risico*, PR)
  - Societal risk (*groepsrisico*, GR)

RBM-II (continued): Individual Risk

- Individual risk (*plaatsgebonden risico*, PR)
  - Probability for 1 unprotected person 24 hours present at a certain location to die as a consequence of the transport
  - Represented as iso-risk contours on a map
  - Fatality Probability should be below 10^{-6} per year (threshold)
- Societal risk (*groepsrisico*, GR)

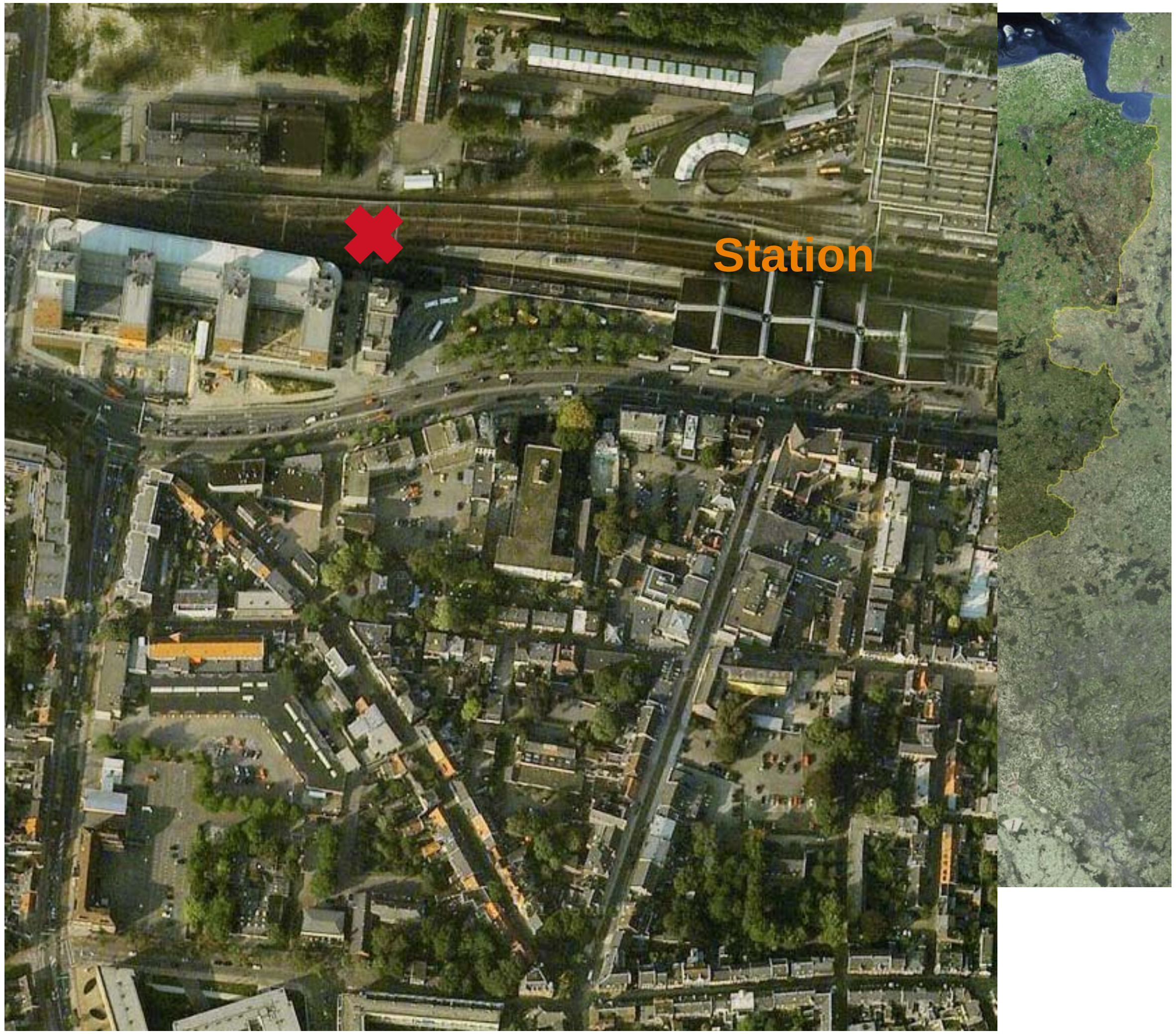


RBM-II (continued)

- Individual risk (*plaatsgebonden risico*,
- Societal risk (*groepsrisico*, GR)
  - Cumulative probability per year that at a certain number of people die as a consequence of the transport
  - Represented as an fN-curve: frequency of a number of casualties
  - Population density is important here
  - fN curve should be below guide value (10: 10^{-4}, 100: 10^{-6}, etc), more fatalities should have lower frequency


Jet release

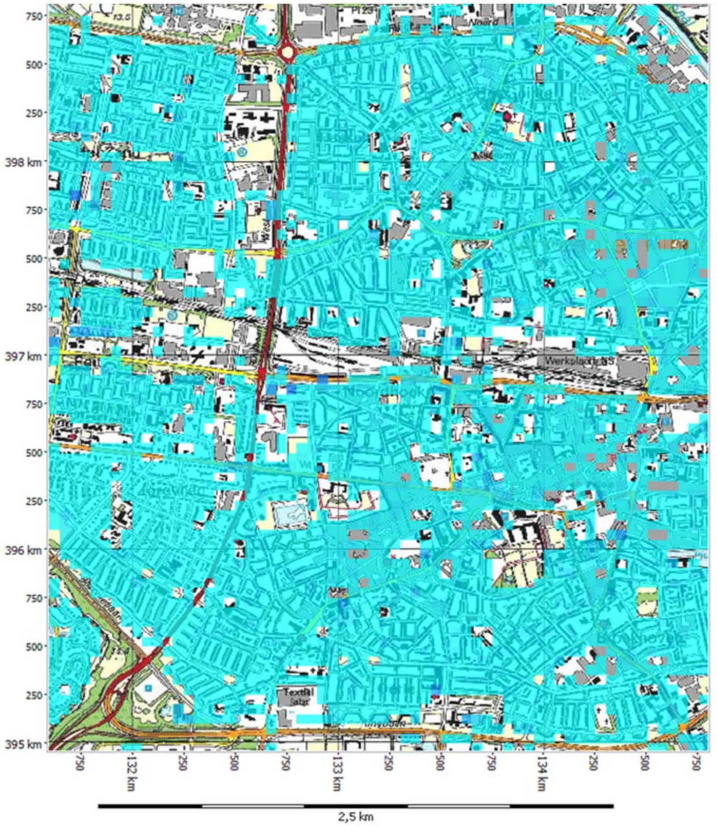
Tilburg: train station zone



Scenario definition in RBM-II

- Substance B2: ammonia
  - Transported as liquid
  - 2-phase release
- (semi-)continuous release
- D5 atmospheric stability class

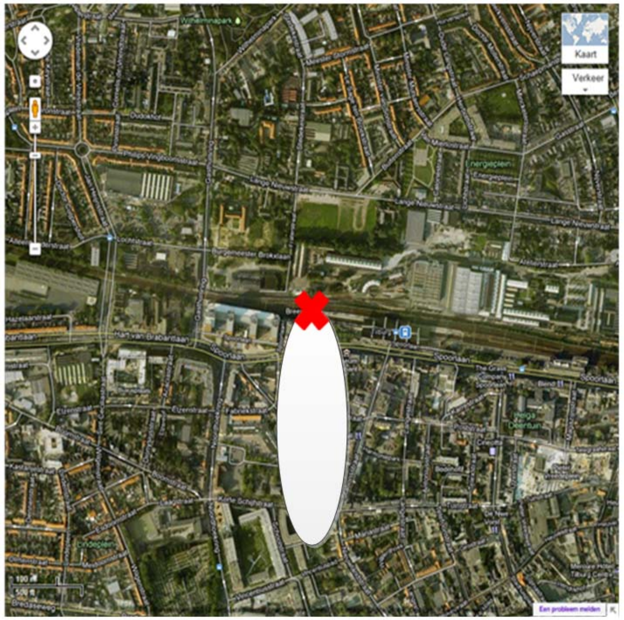
Storage		
Volume	89	m^3
Mass	50 000	kg
Pressure	616 257	N/m^2
Temperature	282	K
Release		
Diameter	0.075	m
Duration	667	s
Mass flow	75.01	kg/s
Rain out fraction	0.6859	-
Source strength	23.56	kg/s
Vapour mass fraction	0.4364	-



Results RBM-II

- All scenarios have standard cloud dimensions
- Lethality is based on concentration and duration of exposure
- For the current scenario:

	RBM-II		
Lethality (%)	Length (m)	Width (m)	Off-set (m)
1	453	99	0
10	340	75	0
25	281	62	0
50	211	45	0
75	174	37	0
90	135	28	0
99	75	16	0

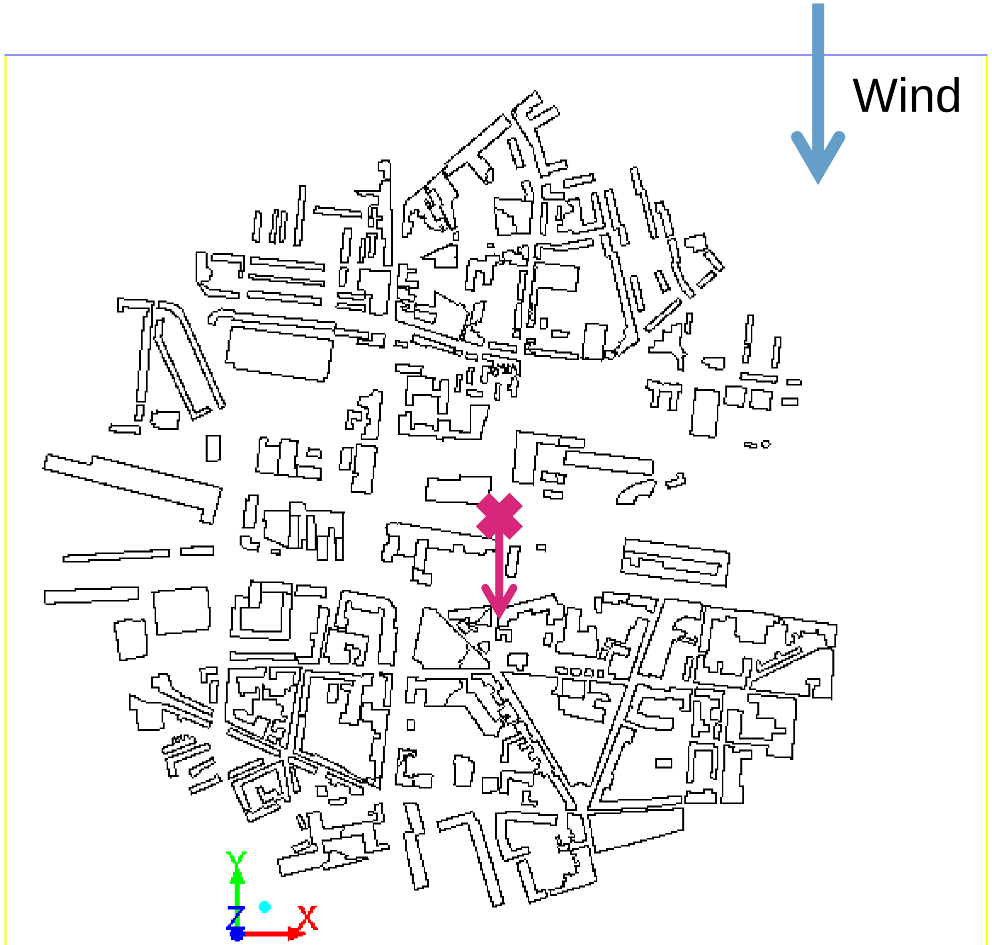


Scenario definition in CFD

- Continuous release
- 2-phase release: mass flow rate & vapour mass fraction identical to RBM-II:
  - 23.56 kg/s
  - 0.4364 [-]
- Diameter: 45 cm for a square source
- Droplet size: 75 µm

- D5 atmospheric boundary layer

Tilburg: CFD-domain



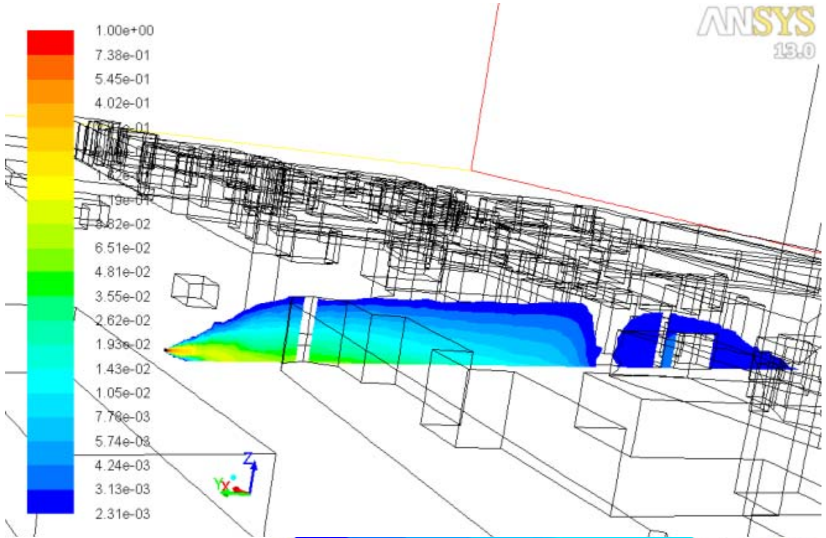
1000mx1000m
X300m
Full scale

9.1 10^6 cells

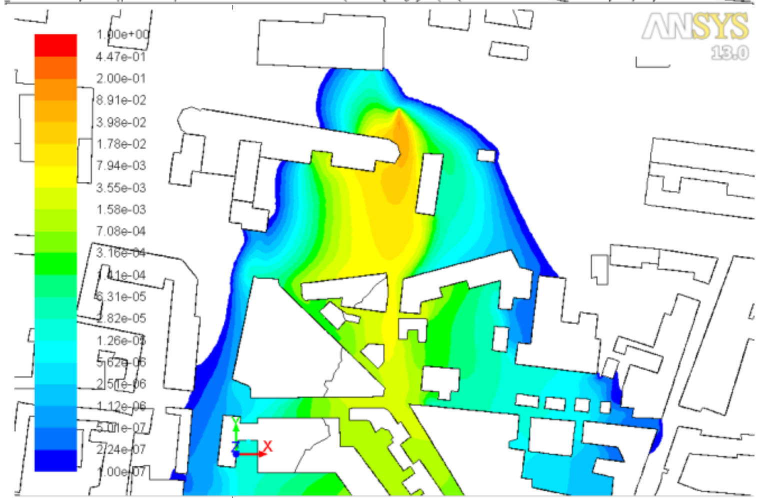
Tet-mesh with prism inflation layer (5 cells)

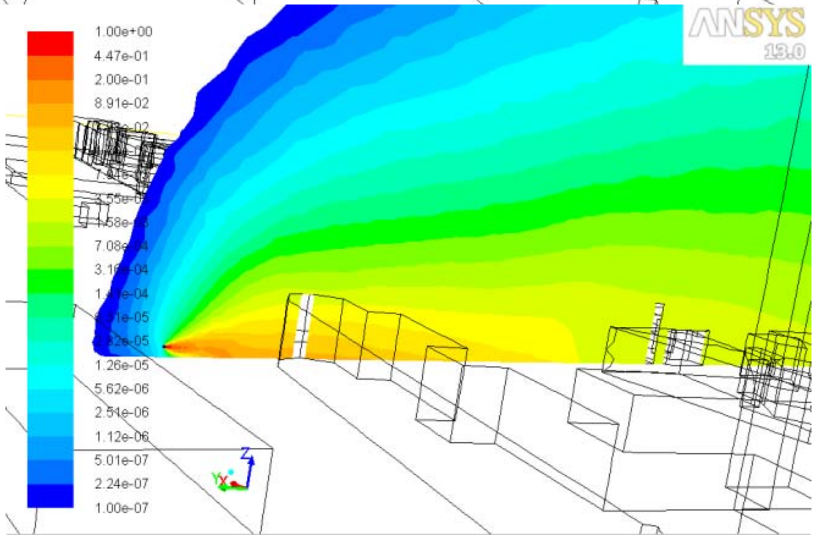
TNO innovation for life

Results CFD



1% lethality

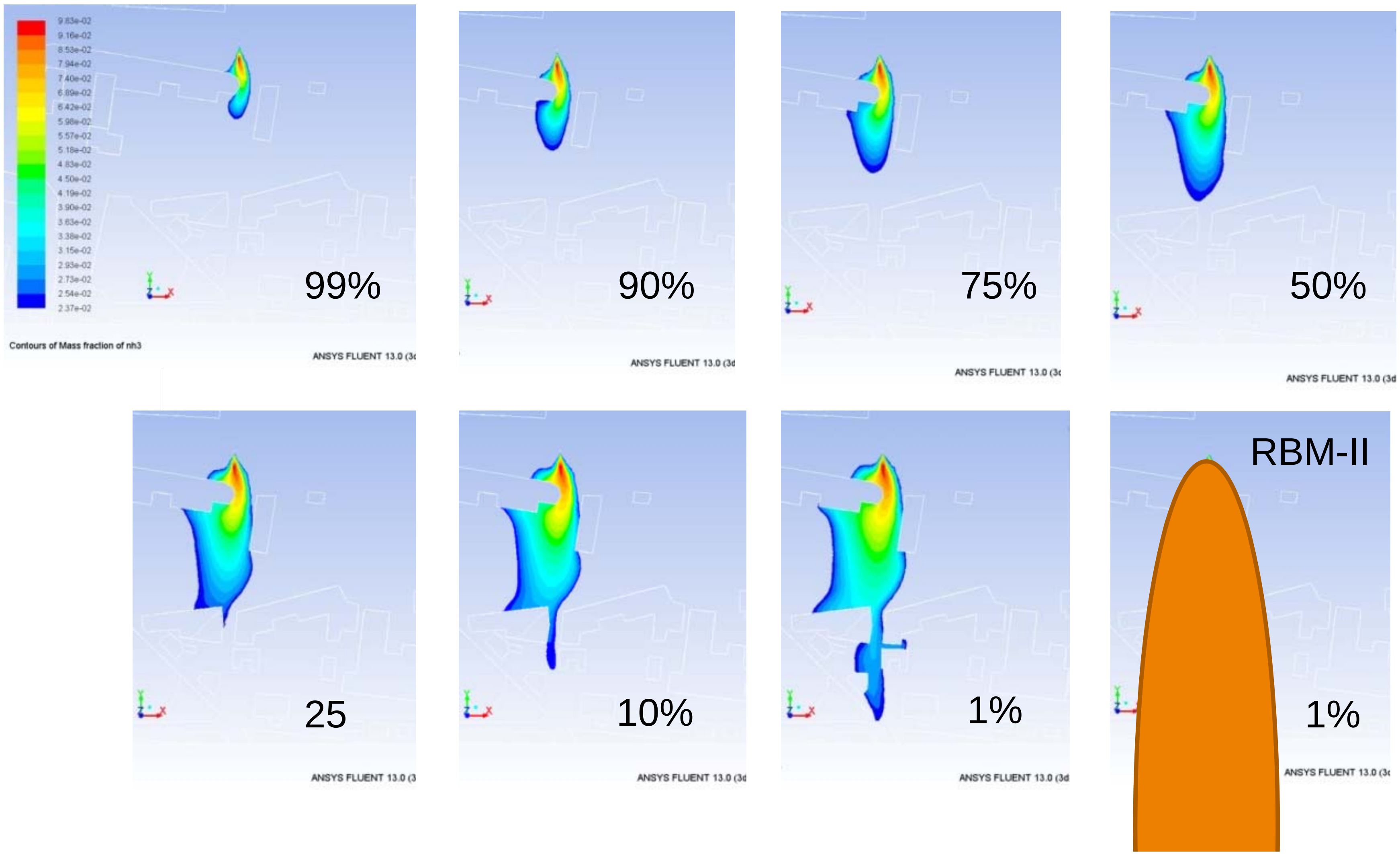




$1\ 10^{-7}$ mass fraction

Close to source: influence of building is clearly visible

Results CFD – lethality contours at 1m height

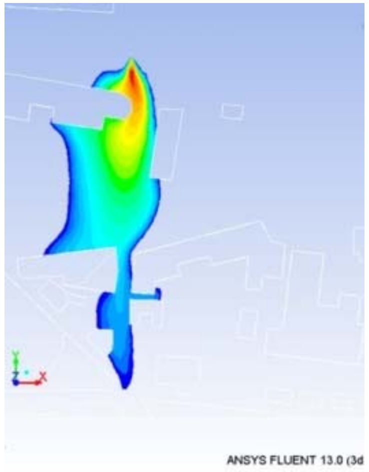



TNO innovation for life

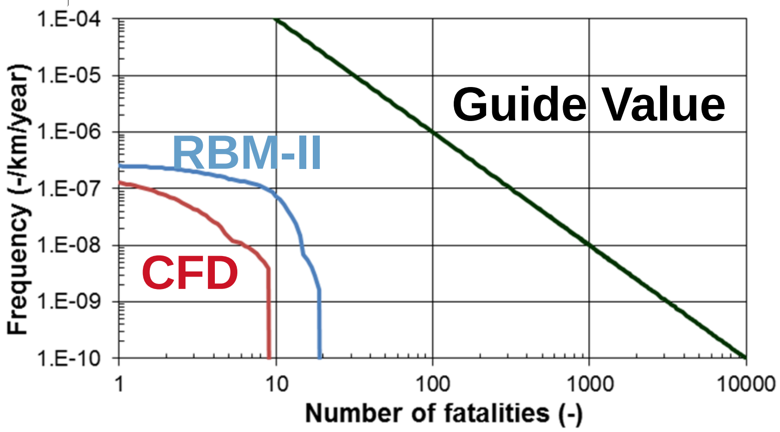
Comparison RBM-II and CFD: cloud dimensions

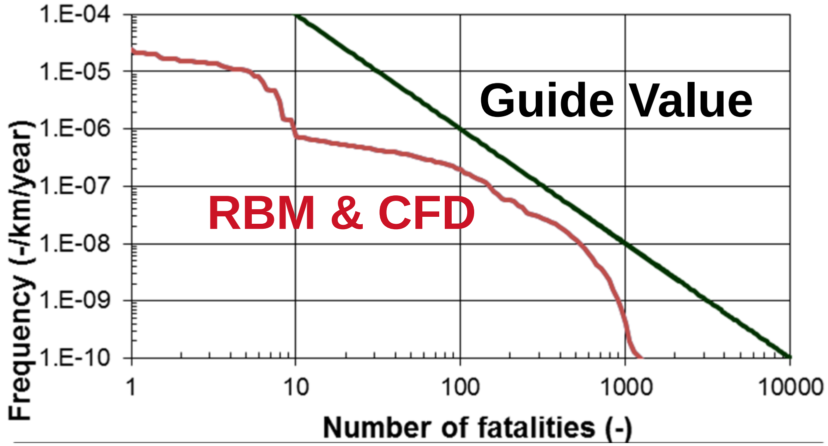
	RBM-II			CFD		
Lethality (%)	*Length (m)*	*Width (m)*	*Off-set (m)*	*Length (m)*	*Width (m)*	*Off-set (m)*
1	453	99	0	204	73	2
10	340	75	0	165	62	2
25	281	62	0	139	55	2
50	211	45	0	111	47	2
75	174	37	0	92	38	2
90	135	28	0	78	29	2
99	75	16	0	58	21	2

- RBM-II: longer and wider cloud, no off-set
- CFD: shorter and narrower cloud, small off-set, effects of buildings clearly visible



Comparison RBM-II and CFD: fN-curves





- For a single scenario fN-curves are different: curve obtained from CFD results is below RBM-II curve: CFD results in lower risk
- After adding all other scenarios (RBM-II calculations) no difference is observed in fN-curves

Dense gas release

Dense Gas Release

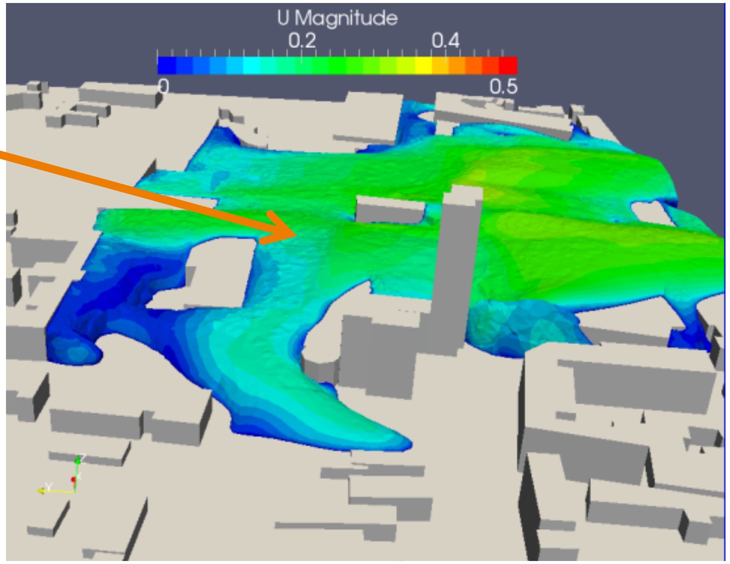
Wind tunnel model

Source Train station


Qualitative comparison CFD and wind tunnel

Source

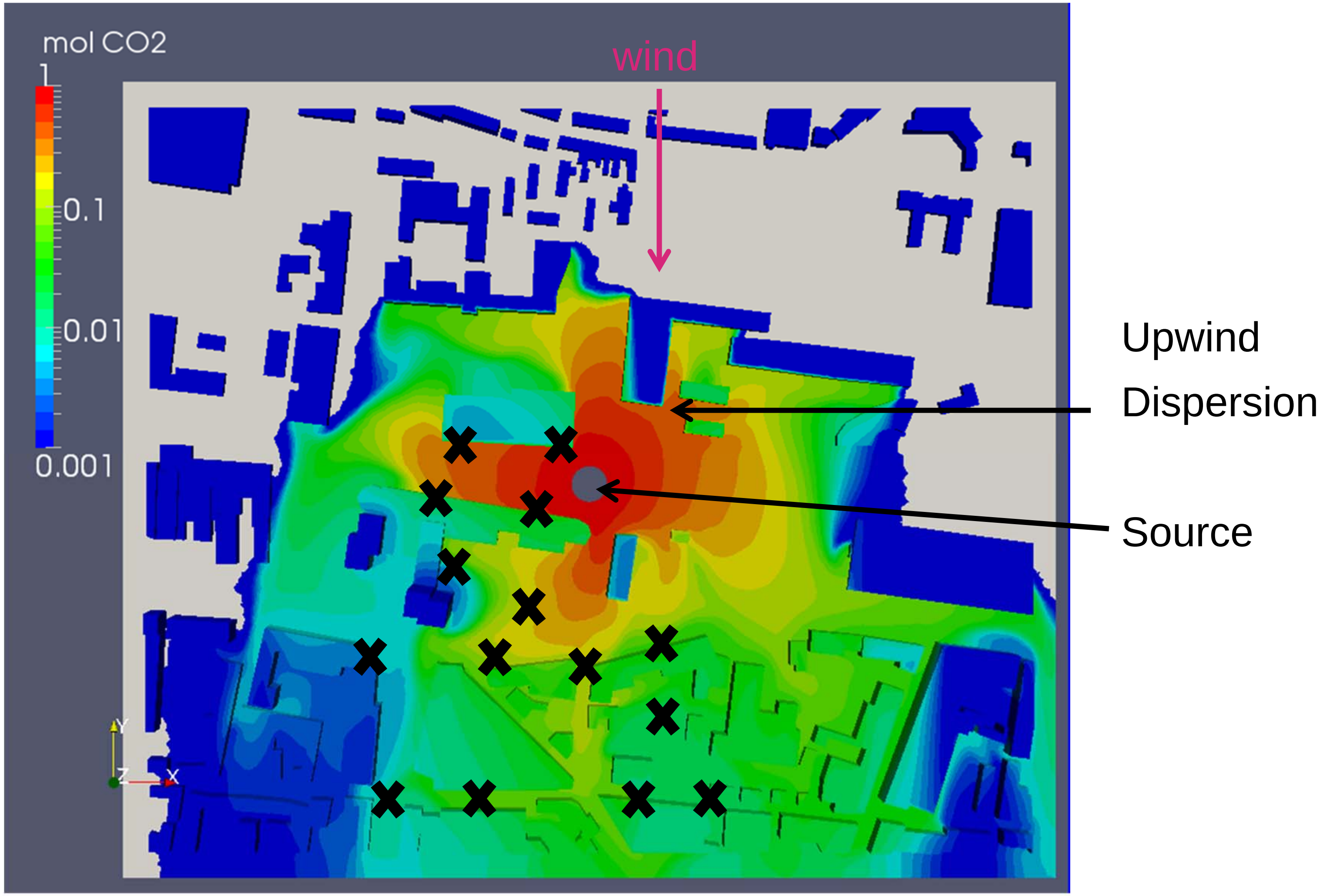
wind

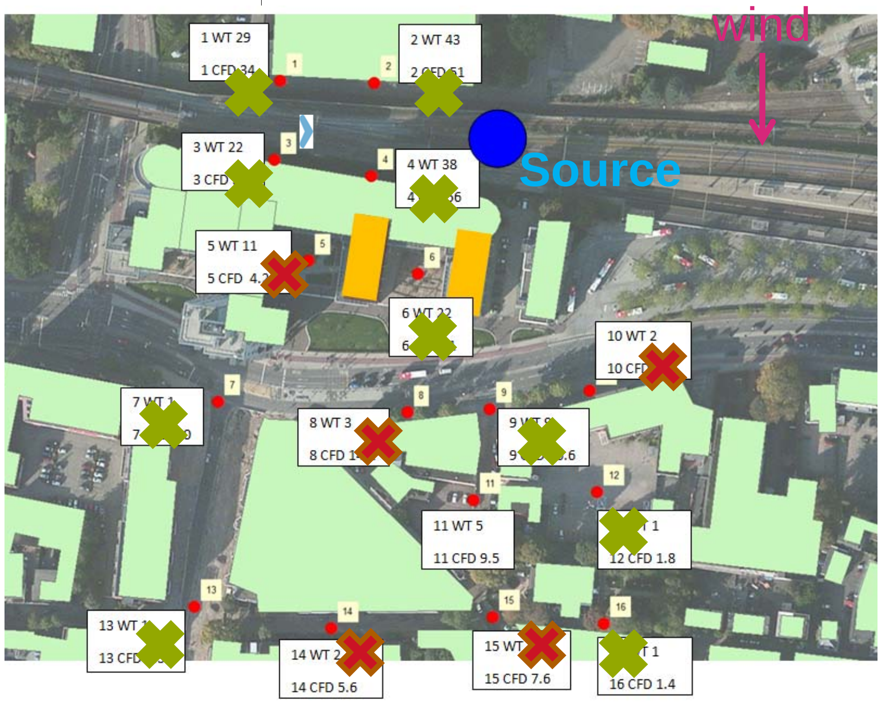
Global dispersion pattern is comparable:

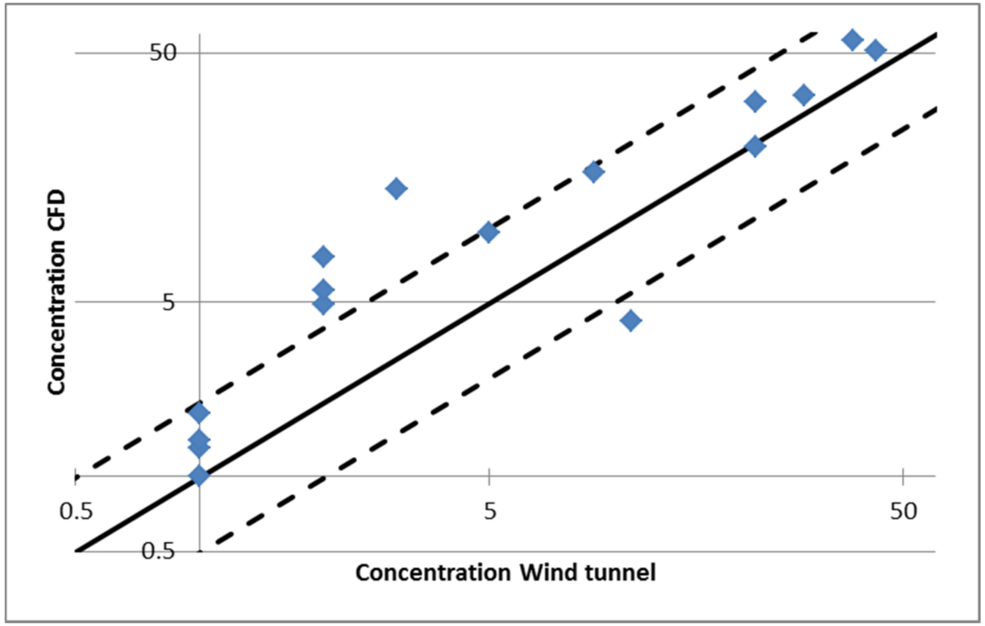
- Upwind dispersion due to dense gas behaviour
- Effect of buildings

Calculated CO_2 concentration



Quantitative comparison





11 measurements (out of 16) are within a factor of 2
Plume width and upwind dispersion are calculated correctly

- Measurement time in wind tunnel too short to obtain steady state (sensors 14 +15)
- Sensor locations have high gradients

Conclusions

- CFD and RBM-II give different effect distances for the jet release:
  - length from CFD is half of length from RBM-II
  - Width from CFD is 2/3 of width from RBM-II
- No difference in total societal risk – only 1 scenario studied

- Good agreement between CFD and wind tunnel is found for dense gas release in built environment

- When buildings or measures are expected to significantly influence dispersion CFD is best choice for calculating effect distances