The introduction of the Weighted Risk Analysis

Dr. S.I. Suddle, M.Sc. (c.Eng.)

TU Delft

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stadsgewest Haaglanden

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Introduction

- Safety is a main item during the planning, realisation and management of large-scale projects
- Safety is a wide notion

- Desicion-making is complex ➔ human risks vs economical risks

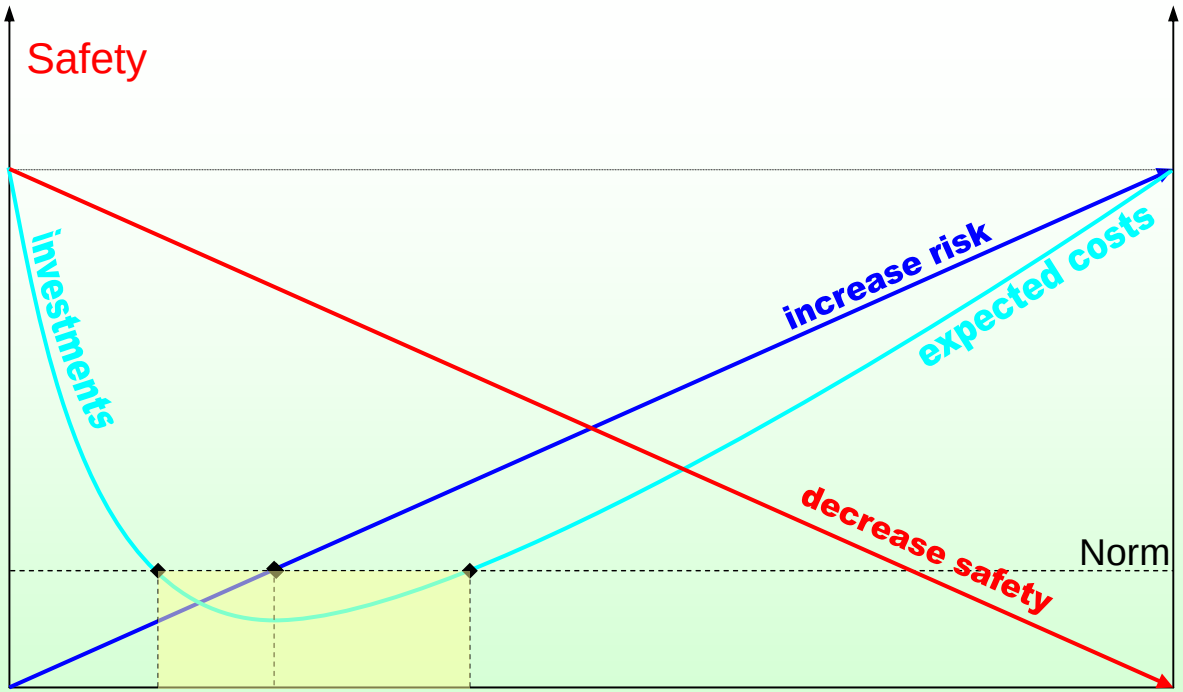
Subdivision of safety

<table>
<tr><td colspan="3">Safety</td></tr>
<tr><td>Social Safety</td><td colspan="2">Physical Safety</td></tr>
<tr><td rowspan="2">Crime incentive factors
Spatial factors
Institutional factors
Social factors</td><td colspan="2">Natural & Man-made hazards</td></tr>
<tr><td>Internal
Users
Passengers
Personnel</td><td>External
Third parties</td></tr>
</table>

Aspects of irrational behaviours

	Subjective Safe	**Subjective unsafe**
Objective safe	*Healthy unconcern*	*Paranoia*
Objective unsafe	*Naivety*	*Healthy anxiety*

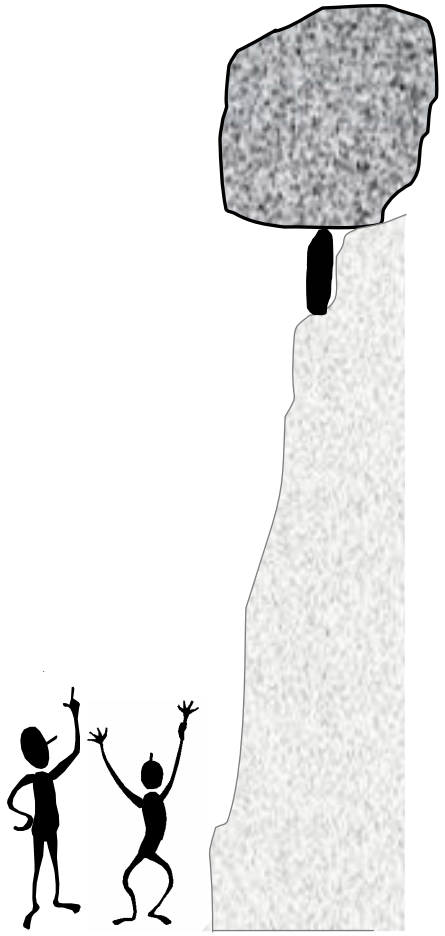
Safety versus Risk



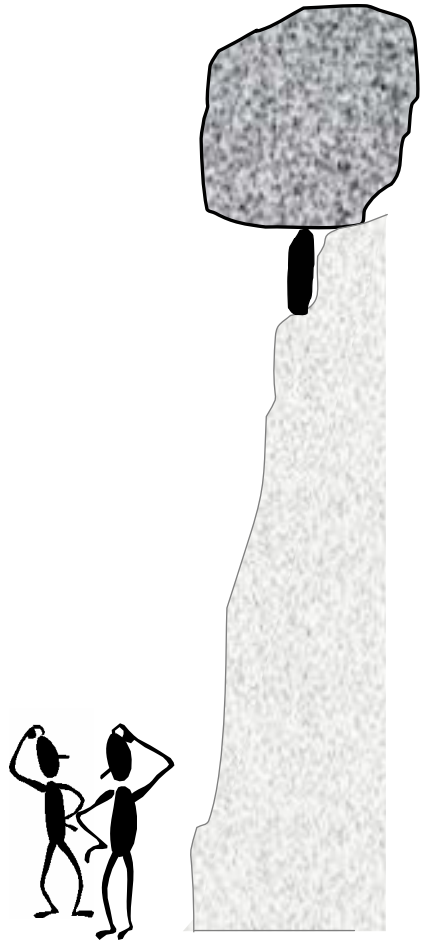
Undesirable Situation

Desirable Situation

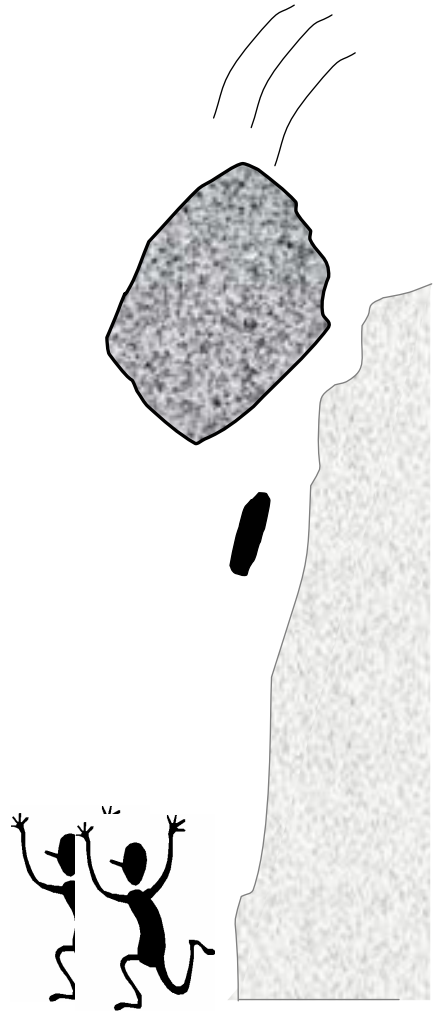
RISK PERCEPTION



RISK ASSESSMENT



RISK MANAGEMENT



Definition Risk

RISK= PROBABLITY x (NEG) CONSEQUENCES

But.. Psychology [Prof. Vlek]:

RISK= LACK OF PERCIEVED CONTROLLABILITY

Formal definitions of risk or riskiness

1. Probability of undesired consequence.
2. Seriousness of (maximum) possible undesired consequence.
3. Multi-attribute weighted sum of components of possible undesired consequence.
4. Probability x seriousness of undesired consequence (”expected loss”).
5. Probability-weighted sum of all possible undesired consequences (”average expected loss”).
6. Fitted function through graph of points relating probability to extent of undesired consequences.
7. Semivariance of possible undesired consequences about their average.
8. Variance of all possible undesired consequences about mean consequences.
9. Weighted sum of expected value and variance of all possible consequences.
10. Weighted combination of various parameters of the probability distribution of all possible consequences (encompasses 8 en 9).
11. Weight of possible undesired consequences (”loss”) relative to comparable possible desired consequences (”gain”).

Basic dimensions underlying perceived riskiness

1. Potential degree of harm or fatality.
2. Physical extent of damage (area effected).
3. Social extent of damage (number of people involved).
4. Time distribution of damage (immediate and/or delayed effects).
5. Probability of undesired consequence.
6. Controllability (by self or trusted expert) of undesired consequences.
7. Experience with, familiarity, imaginability of consequences.
8. Voluntariness of exposure (freedom of choice).
9. Clarity, importance of expected benefits.
10. Social distribution of risks and benefits.
11. Harmful intentionality.

Comparison Mathematical and Psychological definitions of Risk

Risk [fatalities or money/year]

$$R = P_f \cdot C_f \Rightarrow R = \sum_{i=1} P_f \cdot C_f$$

All possible scenarios

$$R = \sum_{i=1} P(H_i) P(F \mid H_i) P(C \mid H_i \cap F)$$

$$R_w = \sum_{j=1} \alpha_j \sum_{i=1} P_f \cdot C_f$$

WEIGHTED RISK [year^{-1}]

$$R_w = \sum_{j=1} \alpha_j \sum_{i=1} R_{ij}$$

$$R_w = \alpha_1 \sum_{i=1} R_{human,i} + \alpha_2 \sum_{j=1} R_{enonomic,j} + \alpha_3 \sum_{k=1} R_{environment,k} + \alpha_4 \sum_{l=1} R_{quality,l} + \ldots$$

Weighted Risk [year^{-1}]

$$R_w = \alpha_1 \sum_{i=1} R_{human,i} + \alpha_2 \sum_{j=1} R_{enonomic,j} + \alpha_3 \sum_{k=1} R_{environmen\,t,k} + \alpha_4 \sum_{l=1} R_{quality,l} + \ldots$$

α_1 = (monetary) value per casualty or injury [-]
α_2 = (monetary) value per environmental risk [-]
α_3 = (monetary) value per economical risk [-] (mostly $\alpha_3 = 1$)
α_4 = (monetary) value per quality risk [-], and so on

$$\alpha_1 \sum_{i=1} R_{human,i} = \sum_{k=1} \alpha_{1k} \sum_{n=1} R_{human,nk}$$

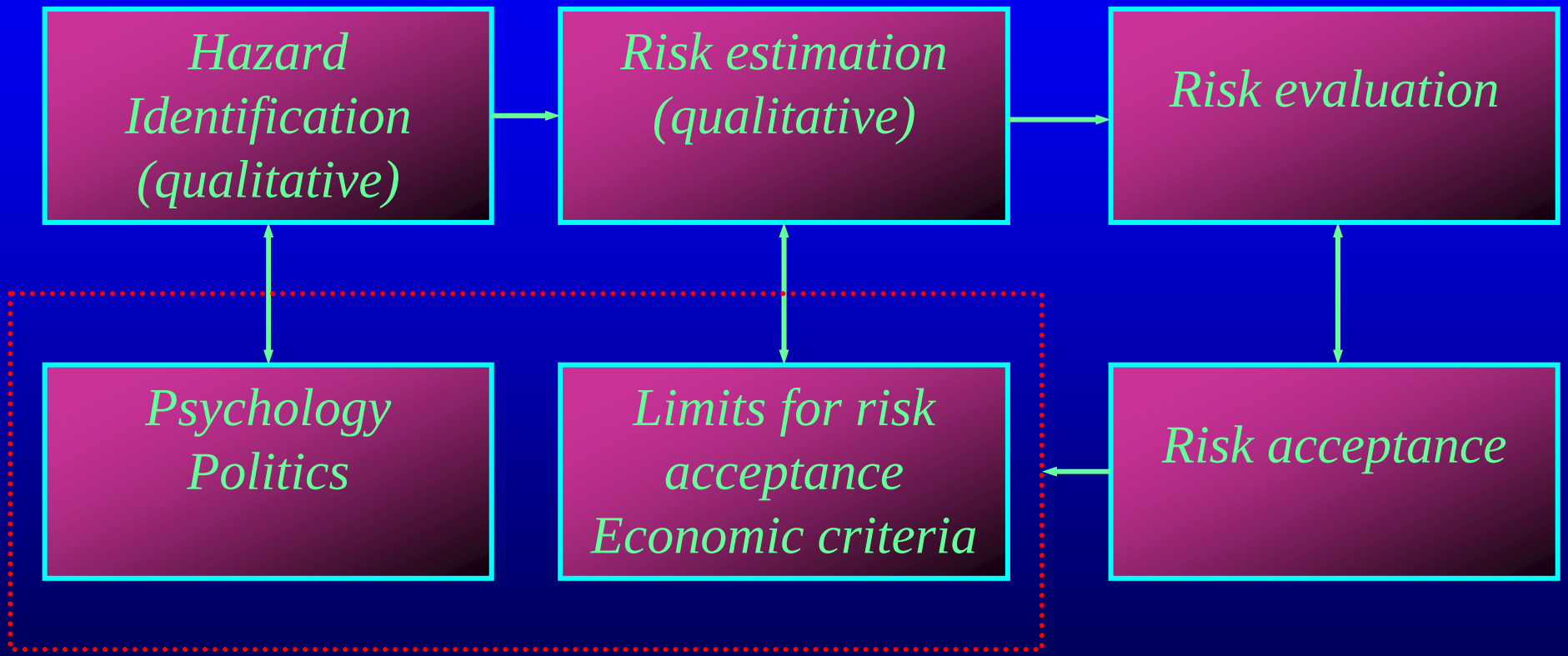
α_{1k} = monetary value per considered basic dimensions of underlying perceived riskiness [-]

Monetary value per casualty

Theoretical Evaluations	Value for α [€ per person]
Human capital calculations	300,000
Willingness to pay (hypothetical)	1,600,000
Road Safety (UK, 1987)	500,000
Cost of medical procedures for comparison (real)	2,000 - 300,000

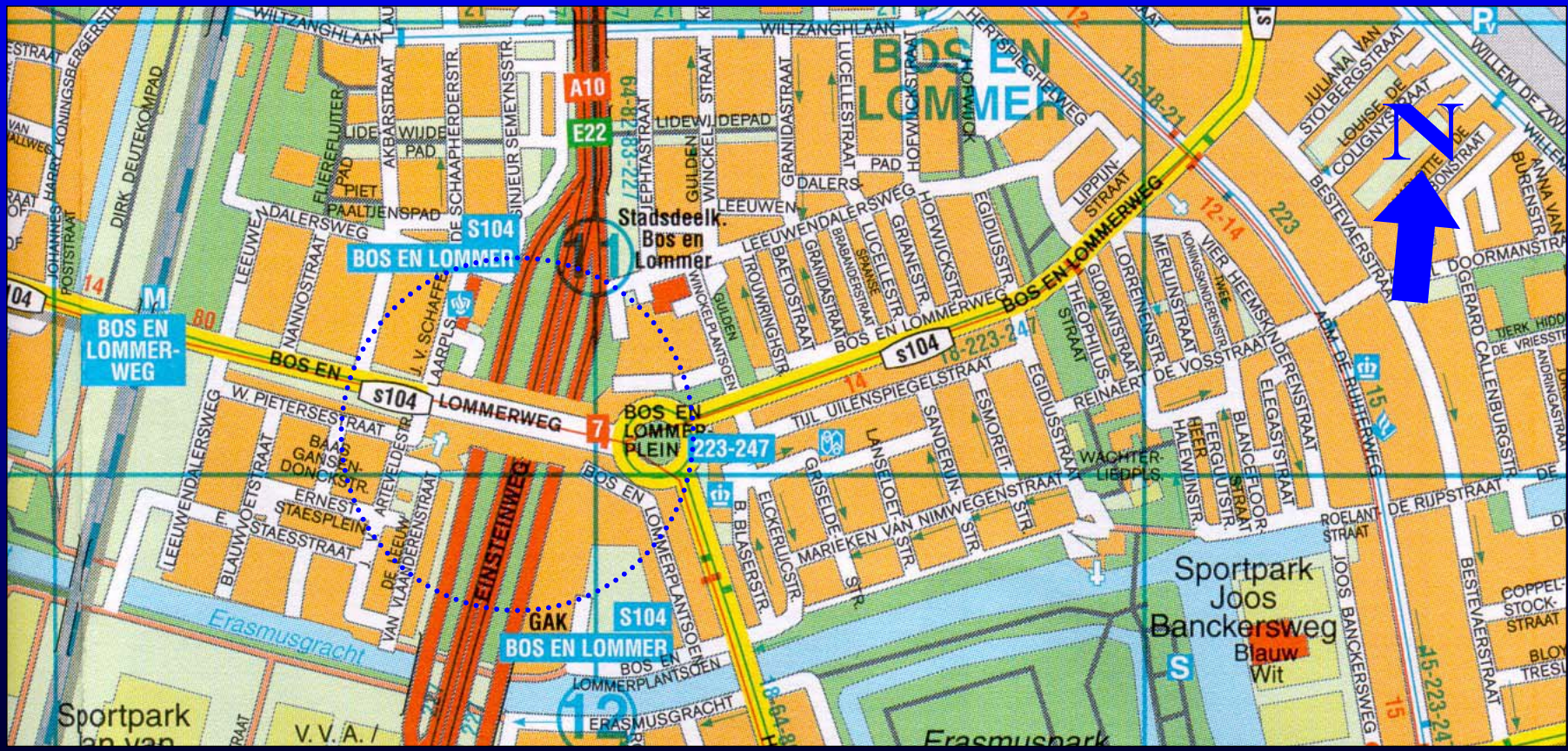
Voluntariness of an activity	Individual Risk [year^{-1}]	Costs per life saved
1. Voluntary risk	10^{-3}	€ 1,500,000
2. High degree of self-determination, direct individual benefit (car driving)	10^{-4}	€ 6.000.000
3. Low degree of self-determination, individual benefit (working conditions)	$5 \cdot 10^{-5}$	€ 15.000.000
4. Involuntary, imposed risk exposition, no direct benefit (local resistance of dangerous installation)	10^{-5}	€ 20.000.000

Risk analysis



minimise $$C_{tot} = C_0(y) + \sum_{j=1}^{n} \frac{R_{wj}}{(1+r)^j}$$

Case study Bos and Lommer



Case study Bos and Lommer

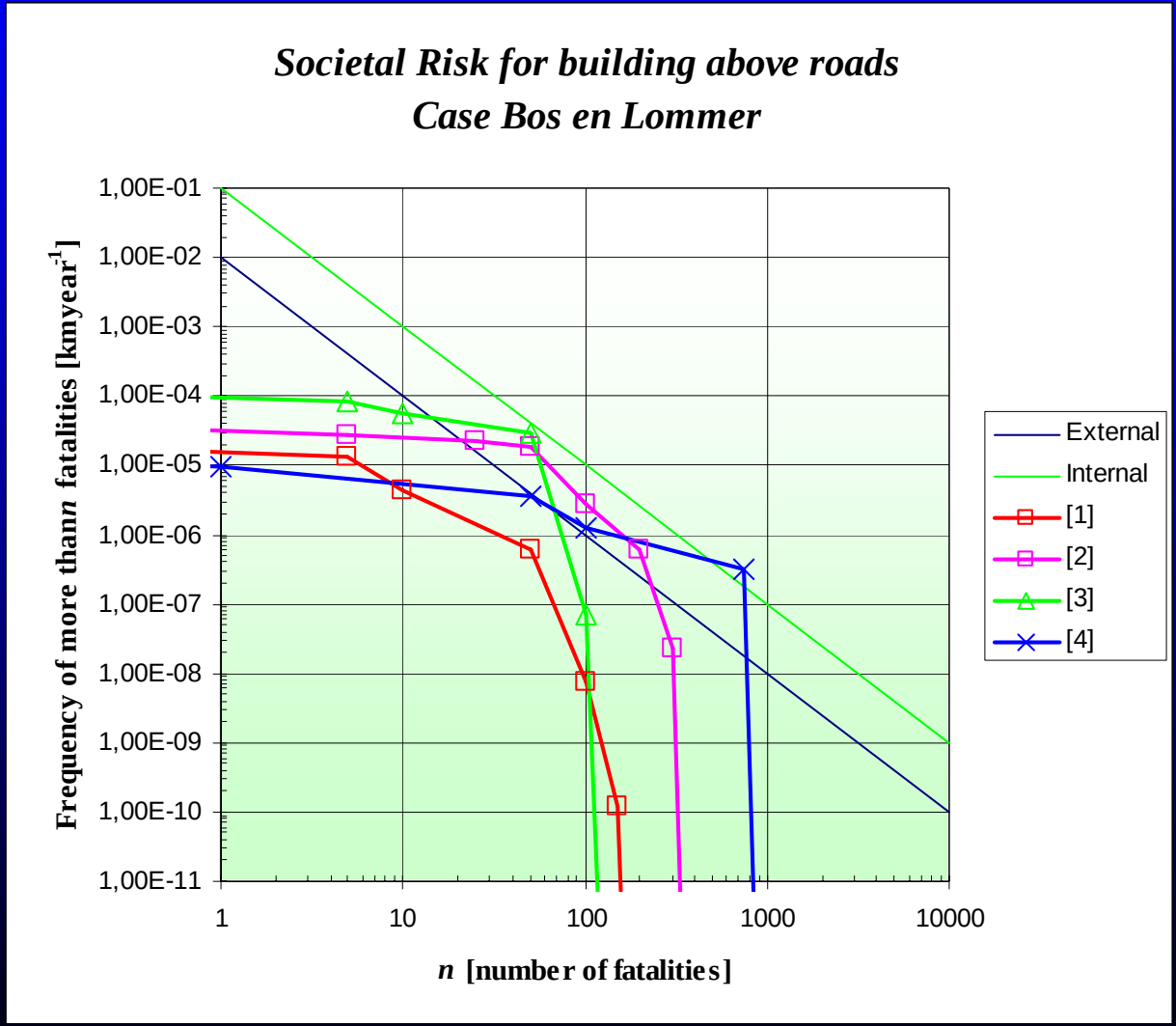
Case study Bos and Lommer

Input parameters for case Bos en Lommer

Characteristics of the road	
Type of road	3 x 2 lane motorway
Number of vehicles passed per day	159,000
Ratio of traffic type on the road	91% cars 8% truck traffic 1% busses
Transport of hazardous materials per year	36,501 LF trucks 3,664 GF trucks
Ratio transport of hazardous materials per year	0.122807 not hazardous traffic 0.729123 LF 0.14807 GF
Covering length	79.5 m
Frequency of an accident	$8.30 \cdot 10^{-8}$
Maximum people in the covered infrastructure	100
Characteristics of the building above the road	
Function of the building	Offices
Floor space of the buildings	20,000 m^2
Length of the building	79.5 m
Width of the building	85 m
Height of the building	20 m
Maximum people in the building	800
Characteristics of the vicinity	
Population density	50 persons/ha

Case study Bos and Lommer

Case study Bos and Lommer



Case study Bos and Lommer

Safety Measures	(Sub)total Costs C_{tot} if$_t$ α = € 0	$E(N_d)$	Total Costs if$_t$ α = € 1,000,000	Total Costs if$_t$ α = € 10,000,000
0. Starting situation	€ 300	$4.2 \cdot 10^{-3}$	€ 4,500	€ $420 \cdot 10^{3}$
1. Banning transport of LPG	€ 62,000,000	$2.9 \cdot 10^{-3}$	€ 62,002,900	€ $62 \cdot 10^{6}$
2. Rerouting transport of LPG (not through urban areas)	€ 55,300	$2.9 \cdot 10^{-3}$	€ 58,200	€ $345 \cdot 10^{3}$
3. Transport of LPG through pipelines	€ 62,500,300	$2.9 \cdot 10^{-3}$	€ 62,503,200	€ $63 \cdot 10^{6}$
4. Transport of LPG takes place during the night	€ 1,062,300	$2.9 \cdot 10^{-3}$ - $4.2 \cdot 10^{-3}$	€ 1,065,200	€ $1 \cdot 10^{6}$

Safety Measures	Investments C_o	Economical risk C_i	Total costs C_{tot}	$E(N_d)$
0. Starting situation	-	€ 300	€ 300	$4.2 \cdot 10^{-3}$
5. Fire protection layer for building above infrastructure	€ 720,000	< € 300	€ 33,750,000	$2.9 \cdot 10^{-3}$
6. Explosion resistant building above infrastructure	€ 11,000,000	< € 300	€ 11,000,300	$2.9 \cdot 10^{-3}$
7. Building above infrastructure with small *L*/*D*	€ 5,316,000	< € 300	€ 5,316,000	$2.9 \cdot 10^{-3}$
8. Fire protection layer for building above and in vicinity	€ 80,000,000	< € 300	€ 80,000,300	$2.5 \cdot 10^{-3}$

Case study Bos and Lommer

Elements of the Weighted Risk R_w for year 1	**Safety Measure**								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Starting situation	**LPG Ban**	**Reroute LPG**	**LPG through pipe line**	**LPG during night**	**Fire prot. building**	**Expl. Resist. building**	**Small *L/D***	**Fire prot. vicinity**
Investments C_0	0	-	$5.5 \cdot 10^3$	$6.3 \cdot 10^7$	$1 \cdot 10^6$	$7.2 \cdot 10^5$	$1.1 \cdot 10^7$	$5.3 \cdot 10^6$	$8.0 \cdot 10^7$
Economical risk C_i	300	$6.2 \cdot 10^7$	300	300	300	300	300	300	300
Human risk $E(N_d) \cdot \alpha$	$2.9 \cdot 10^3$	$4.2 \cdot 10^3$	$2.9 \cdot 10^3$	$2.9 \cdot 10^3$	$4.2 \cdot 10^3$	$2.9 \cdot 10^3$	$2.9 \cdot 10^3$	$2.9 \cdot 10^3$	$2.5 \cdot 10^3$
Quality risk $R_{quality} \cdot \alpha_{quality}$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-8 \cdot 10^4$	$-1 \cdot 10^5$	$-8 \cdot 10^4$
Environmental risk $R_{env} \cdot \alpha_{environmental}$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^4$
Benefits	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$	$-2 \cdot 10^6$
R_w [€·year^{-1}]	$-2 \cdot 10^6$	$6.0 \cdot 10^7$	$-2 \cdot 10^6$	$6.1 \cdot 10^6$	$-1.1 \cdot 10^6$	$-1.4 \cdot 10^6$	$8.9 \cdot 10^6$	$3.2 \cdot 10^6$	$7.8 \cdot 10^7$

Conclusions and discussion

- WRA ➔ enables to quantify all risk elements *with the monetary values*
- Monetary values are sometimes difficult to estimate
- monetary value of human must be higher than the traditional € 1,000,000.=
- WRA is a rational tool for decision-making

QUESTIONS
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