Fuzzy Process Safety Analysis for Process Industries

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Motivation

1. to disccuss issue of uncertainty in traditional the Process Safety Analysis (PSA)

2. to propose the general method to handle a PSA taking into account the uncertainty

3. to demonstrate the application of fuzzy logic in consequence analysis extreemly important for emergency management

Uncertainty

Uncertainty is a term used in different ways in a number of fields, including philosophy, statistics, economics, finance, insurance, psychology, sociology, engineering, and information science.

Uncertainty applies to predictions of future events or to the unknown. It is essentially the absence of information, information that may or not be obtainable.

In terms of PSA, uncertainty means the possibility of predicting wrong risk index with further essential effects to the emergency management

Uncertainties

- All engineering calculations are affected by uncertainties.

- The reasons are on one hand the stochastic nature of some of the phenomena involved (aleatory uncertainties) and on the other gaps in knowledge (epistemic uncertainties).

Dealing with uncertainties (three ways)

- Neglecting uncertainties may lead to faulty decision bases for dimensioning components and, hence, to components which are too weak.
- Safety factors (expert opinion) which may lead to an insufficient design, overdesign etc.
- By modelling which may essentially reduce the uncertainities

Uncertainty – sources and approaches

Type of uncertainty	Characteristic	Approaches	Methods
Objective	Physical variability	Probabilistic	Statistic Sensitivity
Subjective	Lack of knowledge	Possibility theory	**Fuzzy sets**

All types od uncertainties occur in PSA, especially subjective type

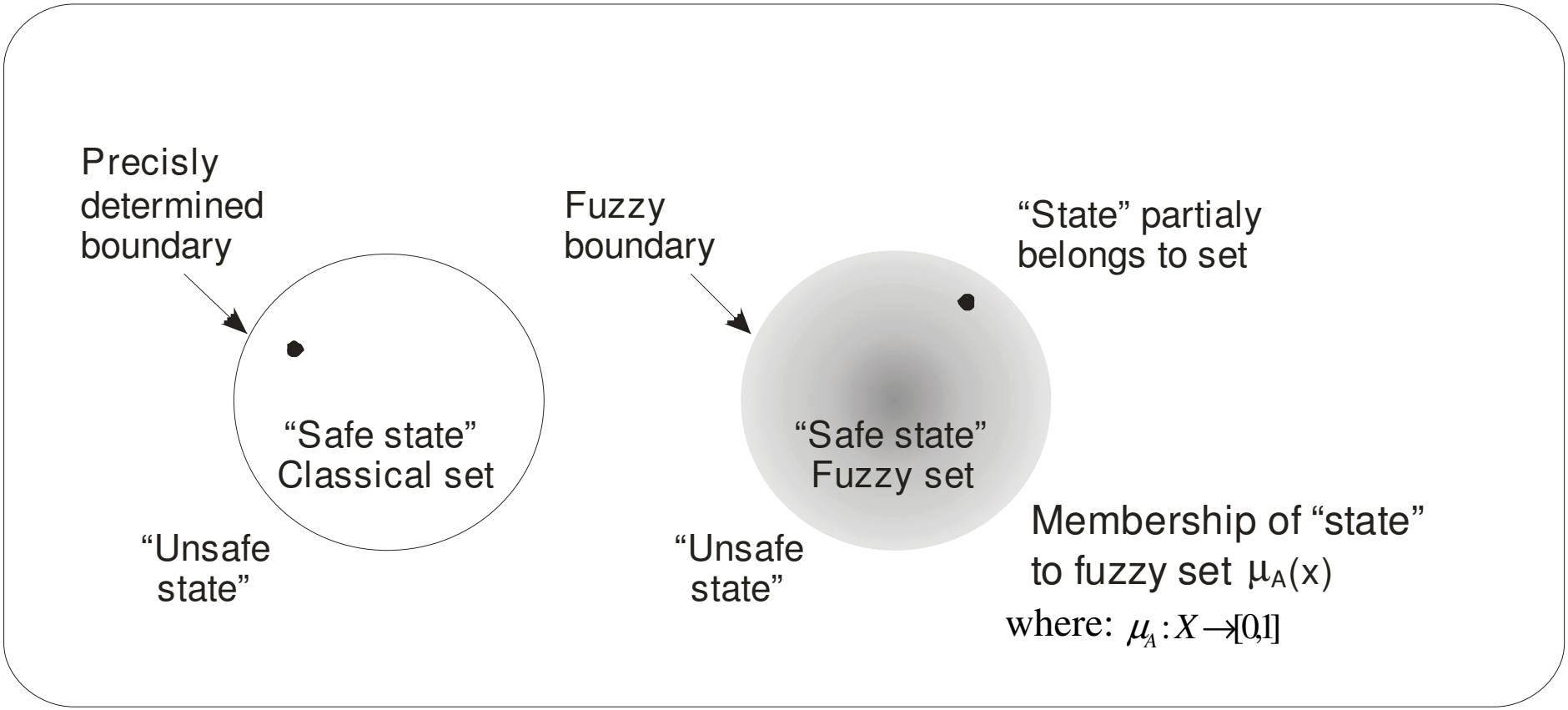
Fuzzy logic for process safety

- Ambiguity and vaguinees are treated by fuzzy logic

- PSA is a complex problem as characterized by the presence of diffrent types of uncertainty contained in the variables, models and assumptions

- Safety may be considered as a fuzzy concept because plant safety cannot be strictly classified as a safe or unsafe (because of the existence of inherent hazards); therefore safety level may belong simultaneously to safe state category and to unsafe state category with some memberships; this can only be realized by fuzzy sets.

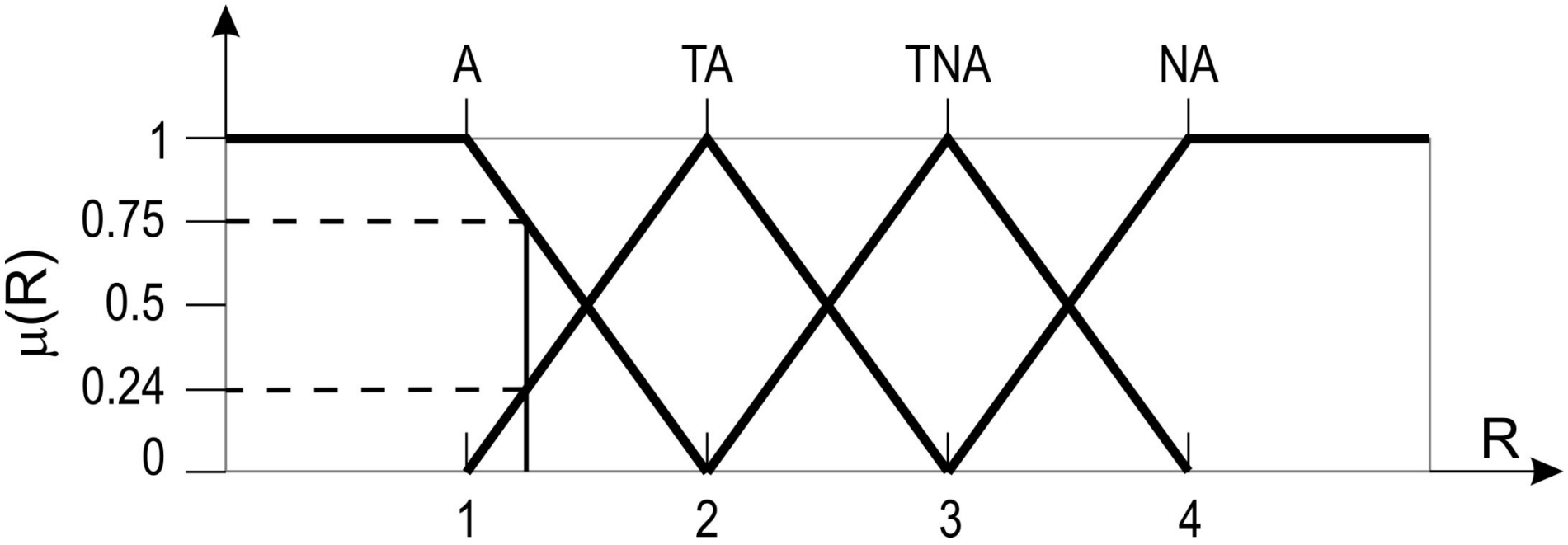
Fuzzy set



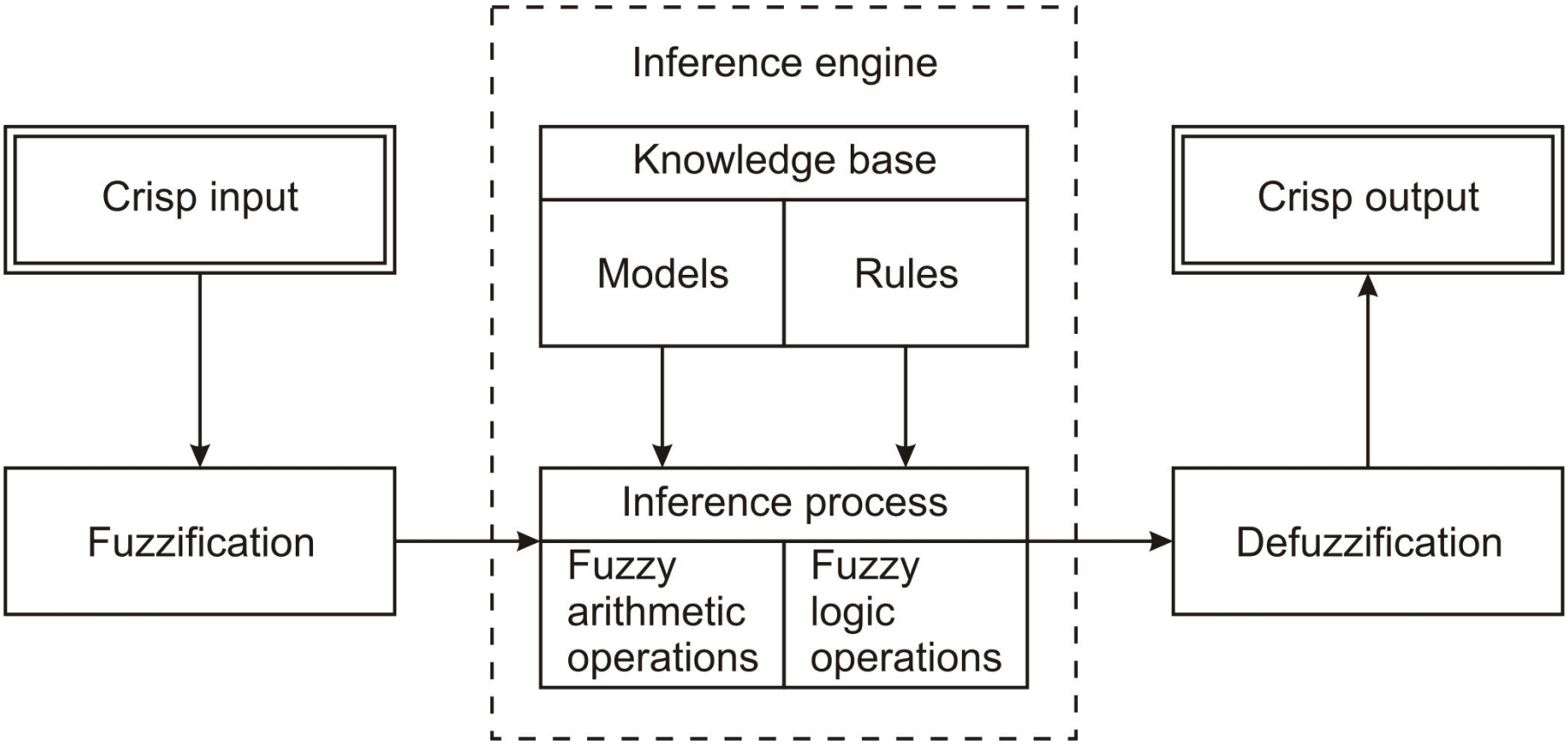
$$A = \{(x, \mu_A(x)); x \in X\}$$

μ (x) is membership function describing degree of belonging for x in A

Fuzzy set



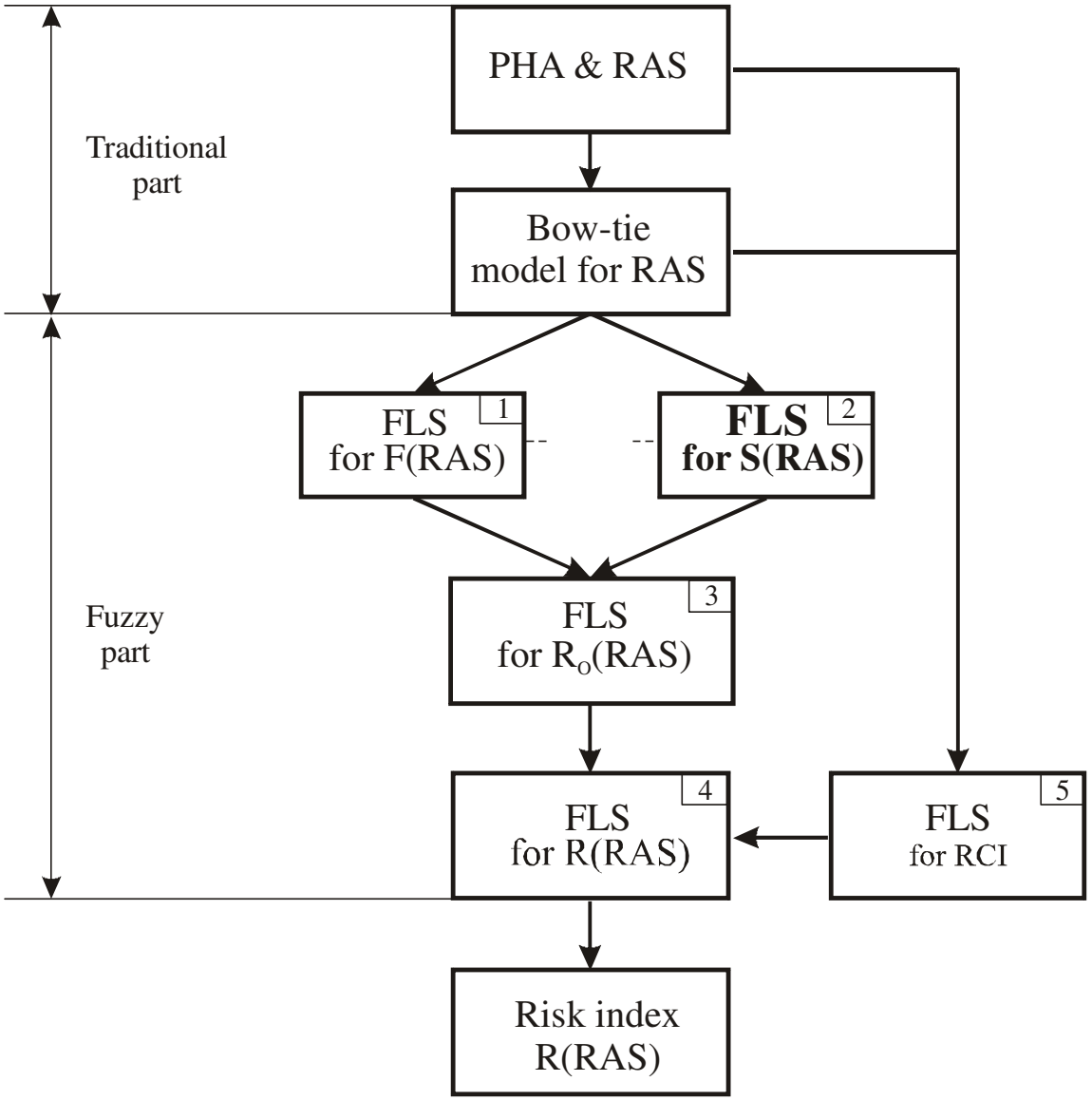
Fuzzy logic system (FLS)



Assumptions for fPSA

- All linguistic variables (frequency, severity and risk) are represented by fuzzy logic sets (fuzzification) defined in their own universe of discourse
- A fuzzy logic system (FLS) is applied to all elements of the PSA
- Output fuzzy frequency (F) is calculated on the basis of „bow-tie model”
- Output fuzzy severity of consequences (S) is assessed using an expert opinien or applying fuzzy arithmetics to the consequence models (parameter method)
- Output fuzzy risk index (R) is assessed using FLS where knowledge of rules is provided by a risk matrix

Fuzzy PSA (fPSA)



Fuzzy Risk Correction Index (RCI)

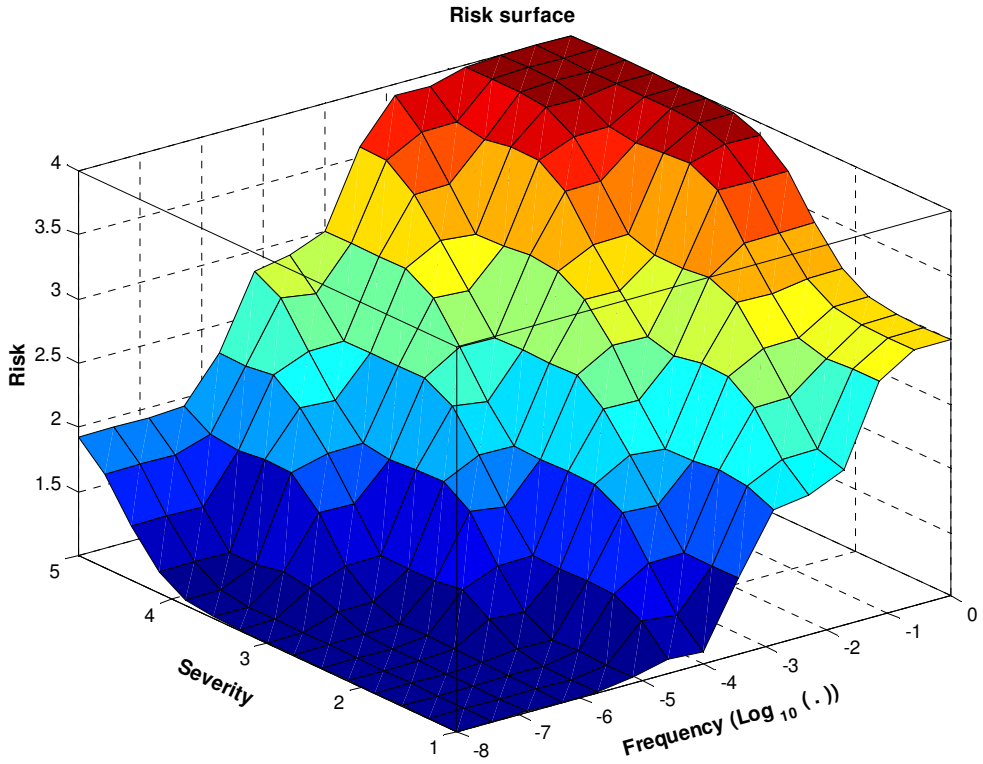
Quantitative factor to correct risk index due to uncertainities occuring in PSA hazard identification phase based on 2 parameters:

1. the experience of PSA team in the PSA analysis,

and

2. complexity of the plant.

Fuzzy risk surface

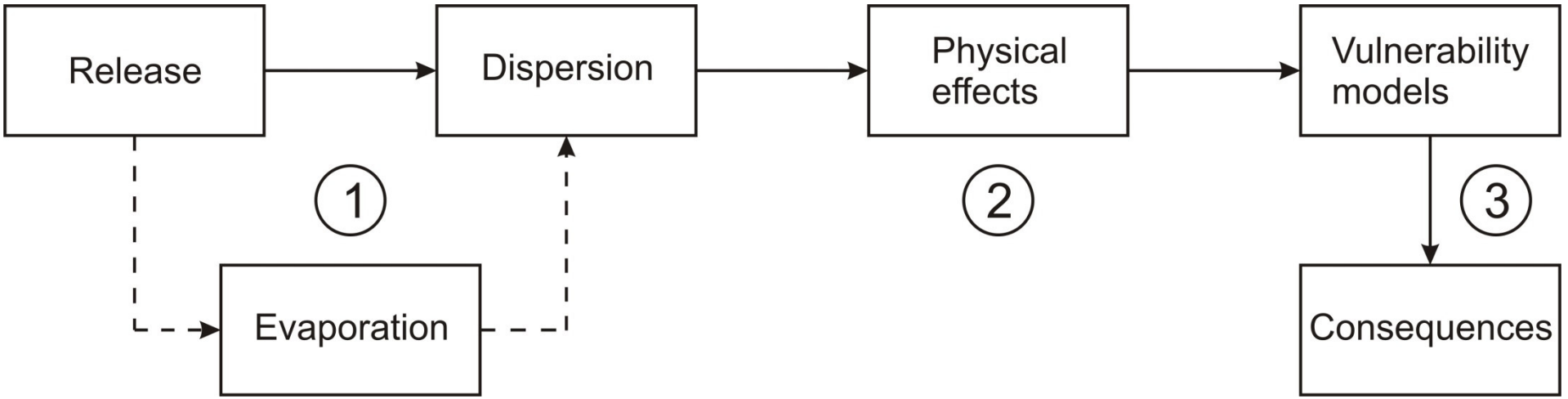


FUZZY RISK MATRIX

Consequence category / Frequency [1/year]	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5
$10^{0} – 10^{-1}$	TNA	TNA	NA	NA	NA
$10^{-1} – 10^{-2}$	*TA*	TNA	TNA	NA	NA
$10^{-2} – 10^{-3}$	TA	TA	TNA	TNA	NA
$10^{-3} – 10^{-4}$	A	TA	TA	TNA	TNA
$10^{-4} – 10^{-5}$	A	A	TA	TA	TNA
$10^{-5} – 10^{-6}$	A	A	A	TA	TA
$10^{-6} – 10^{-7}$	A	A	A	A	TA

CLASSICAL RISK MATRIX

Consequence analysis

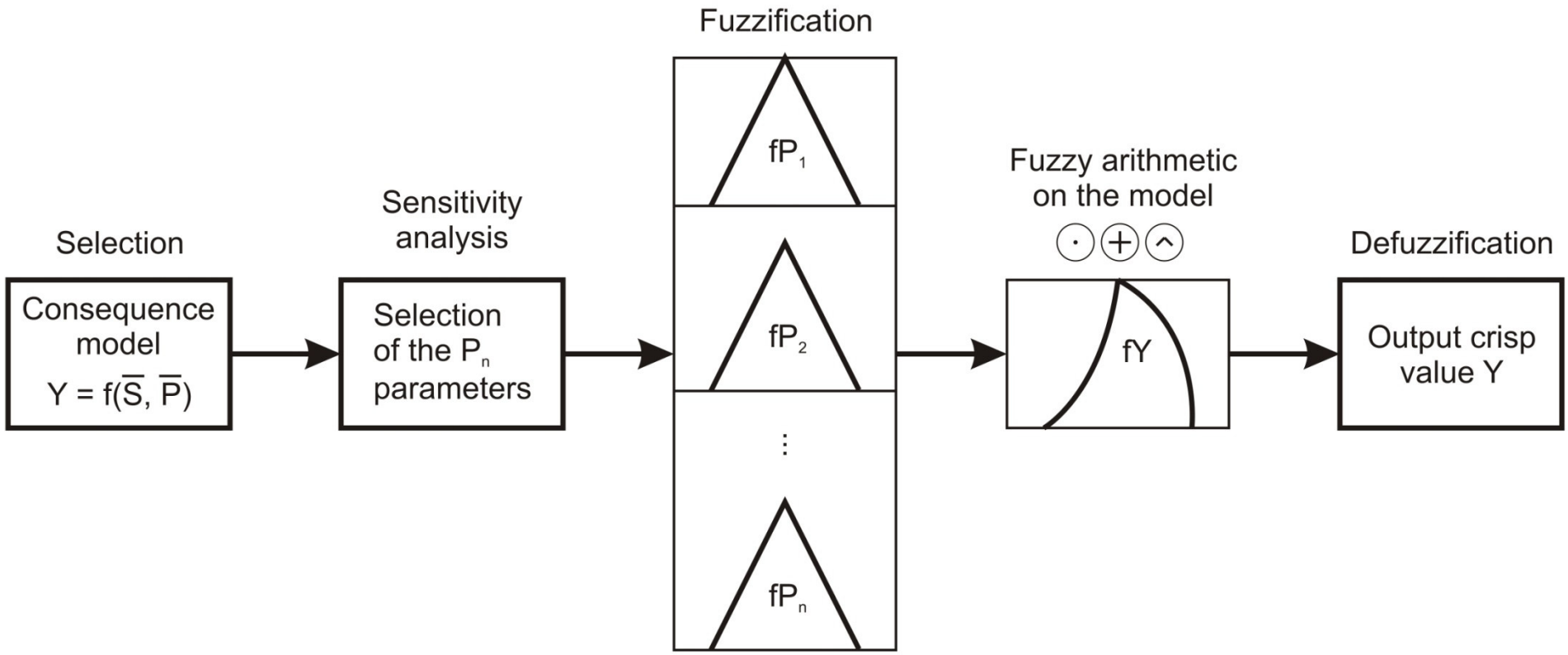


FLS for consequence analysis

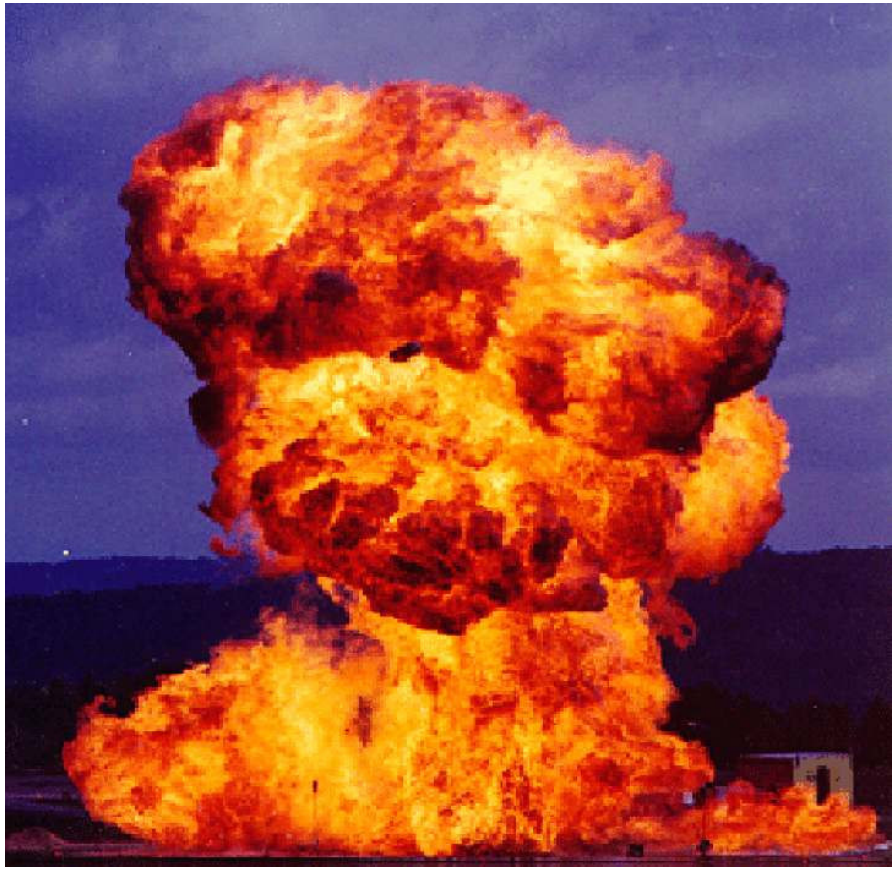
It can be performed by two methods:

1. simplified method based on the categorization of the severity of consequences into separate categories; further process applies assigning of fuzzy set for that category of release (fuzzification) and this is input data for risk matrix assessment,
2. parameter method used for particular consequence model, e.g. BLEVE model, fuzzification and further application of fuzzy algebric.

FLS for consequence analysis –parametr method

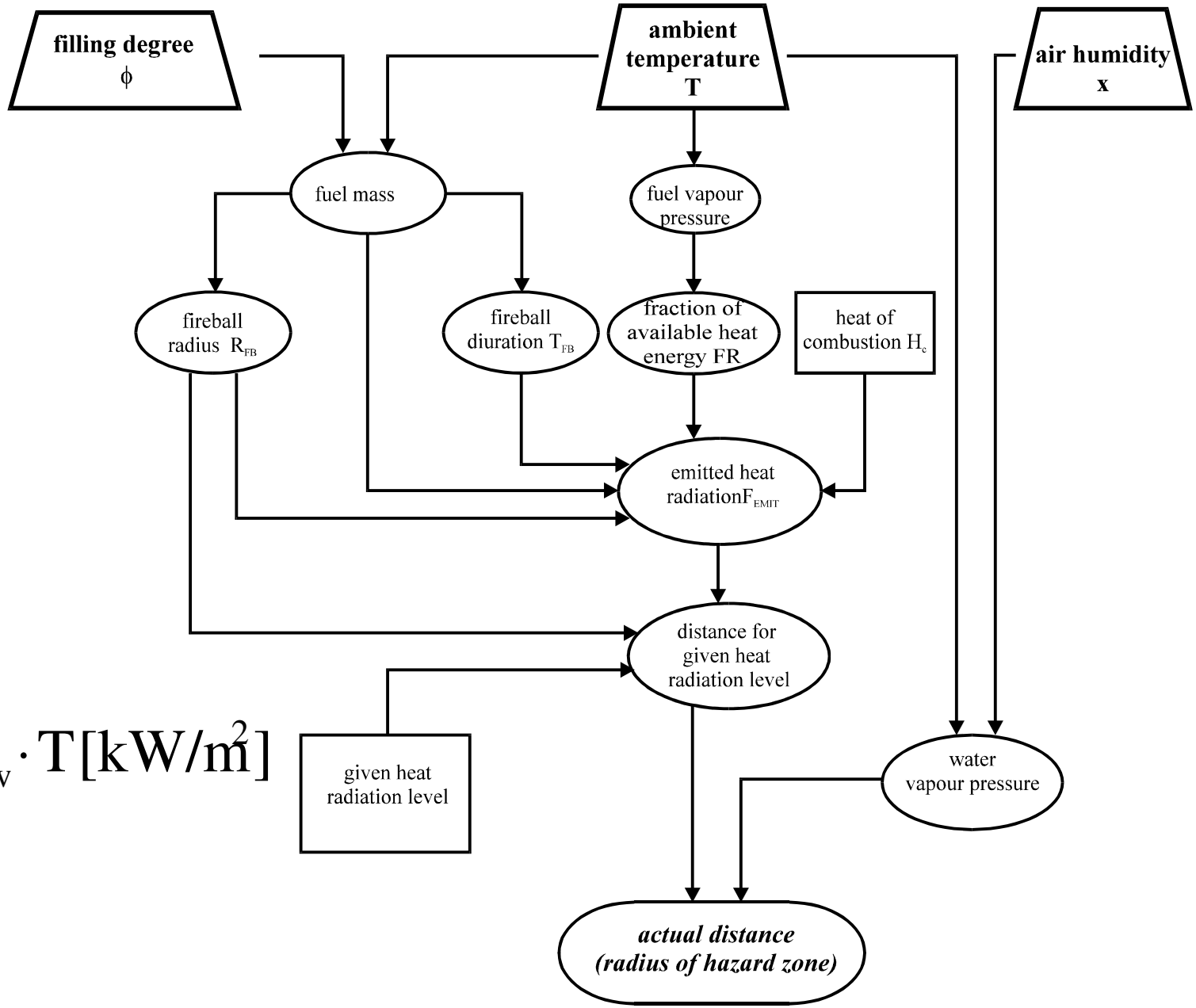


FLS for BLEVE –an example



Important output data: distance (radius) to hazardous radiation level

BLEVE calculation



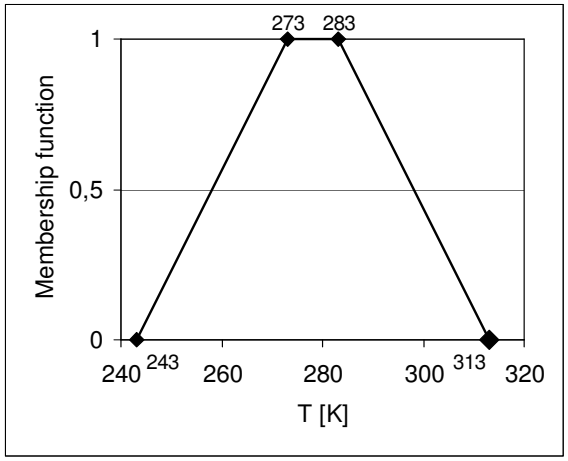
$$I = E_p \cdot F_{view} \cdot T [kW/m^2]$$

BLEVE - an example

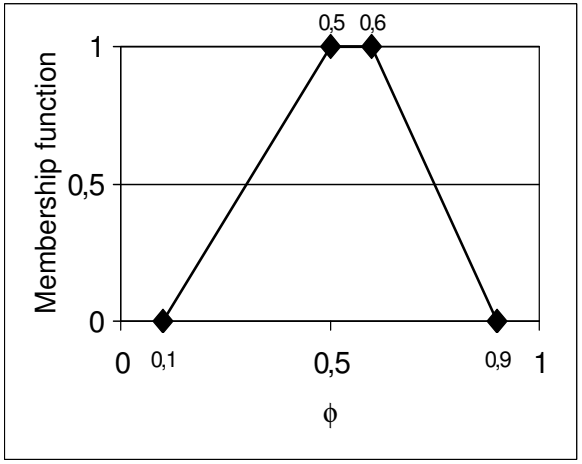
- 600 m3 tank with LPG with the help of PHAST program

-three threshold values for thermal radiation - 4, 12.5, 37.5 kW/m2

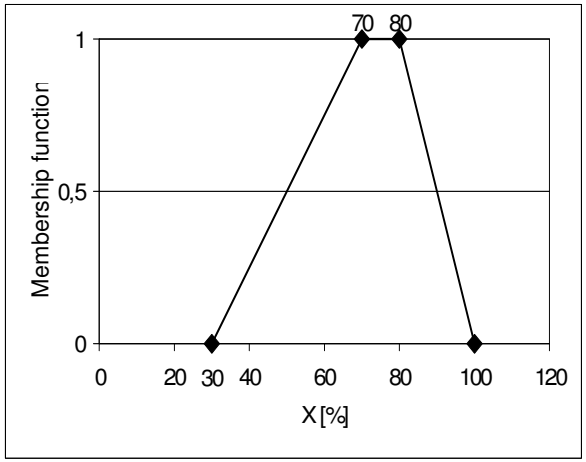
Fuzzification of sensitive parameters -fuzzy sets



Ambient temperature

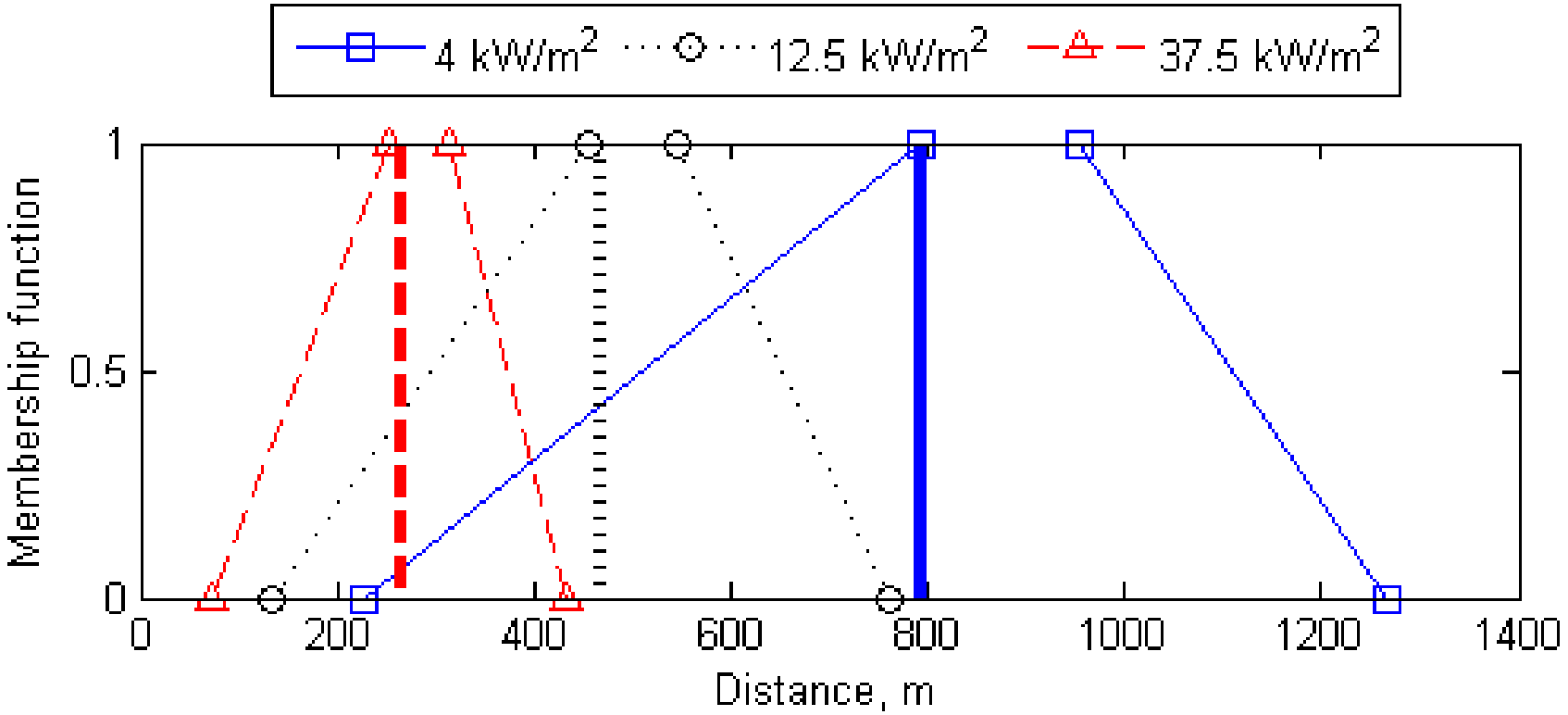


Filling degree



Air humidity

BLEVE results



Range of distance for different radiation levels

BLEVE results

Type of analysis	Range of distance to radiation level [m]		
	4 kW/m^2	12.5 kW/m^2	37.5 kW/m^2
Non – fuzzy	876	506	283
Fuzzy	793	467	264

Overprediction of hazardous zone distance by about 10 %

Conclusions

- Process Safety Analysis (PSA), representing numbers of uncertainties those may lead to important overlooks in the risk assessment of the process plants.

- One of the promising methods for reduction of the uncertainties in process safety assessment is fuzzy logic, which allows to apply imprecise and approximate data that are typically met in PSA to receive a quite precise output results.

- The fuzzy PSA model is presented which consist of traditional part typical for qualitative hazard identification and the fuzzy part used for the quantitative assessment of risk components. Fuzzy part is based on built- in the FLS in particular elements of RA.

- Preliminary tests indicate that fuzzy PSA can produce more precise results concerning both elements of risk (frequency and severity) as well as to include the effect of the quality of PSA on overall risk index.