Modeling of human and organizational impacts for system risk analyses

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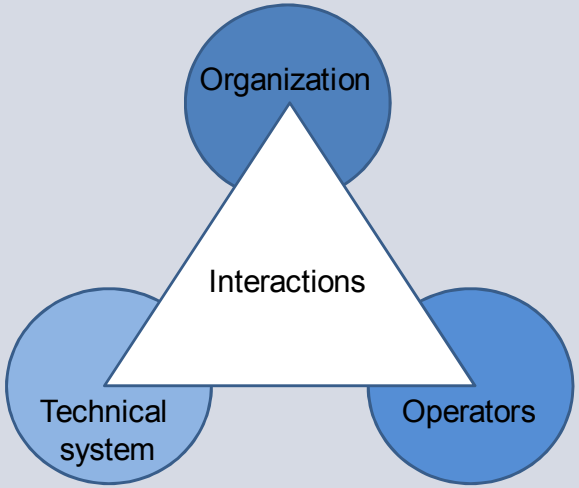
Problem statement

Object of study	**Socio-technical systems**
Objectives	**Risk analysis**
Characteristics	**Different kinds of actors**
	Different kinds of behaviors and interactions
Consequences	**Complex systems**
	Risk analyses have to be done by **stages**
Current situation	**Sector-based analyses**



Scientific contribution

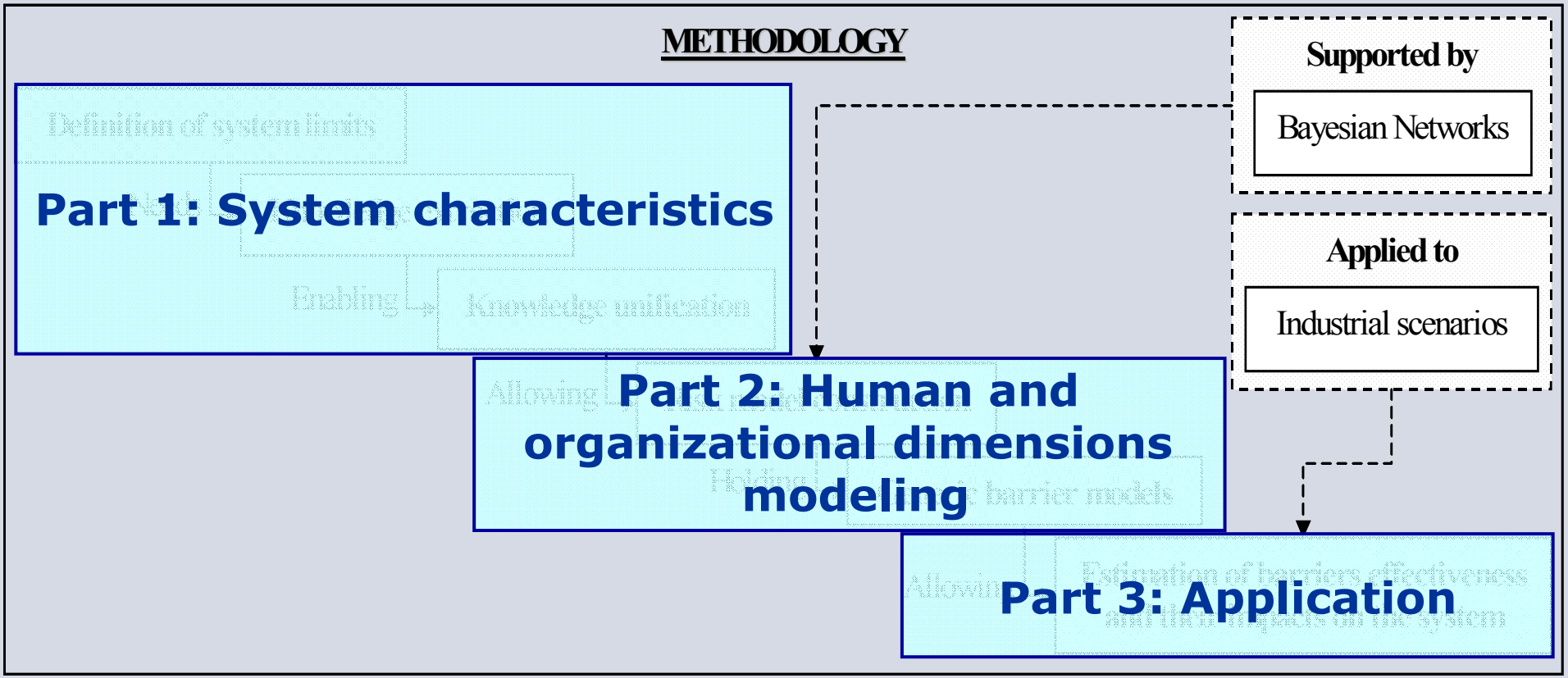
Methodology proposal for the **risk analysis modeling of complex socio-technical systems** …

Based on an **unified formalization and a system knowledge structuring** (functional, dysfunctional, behavioral and organizational knowledge) …

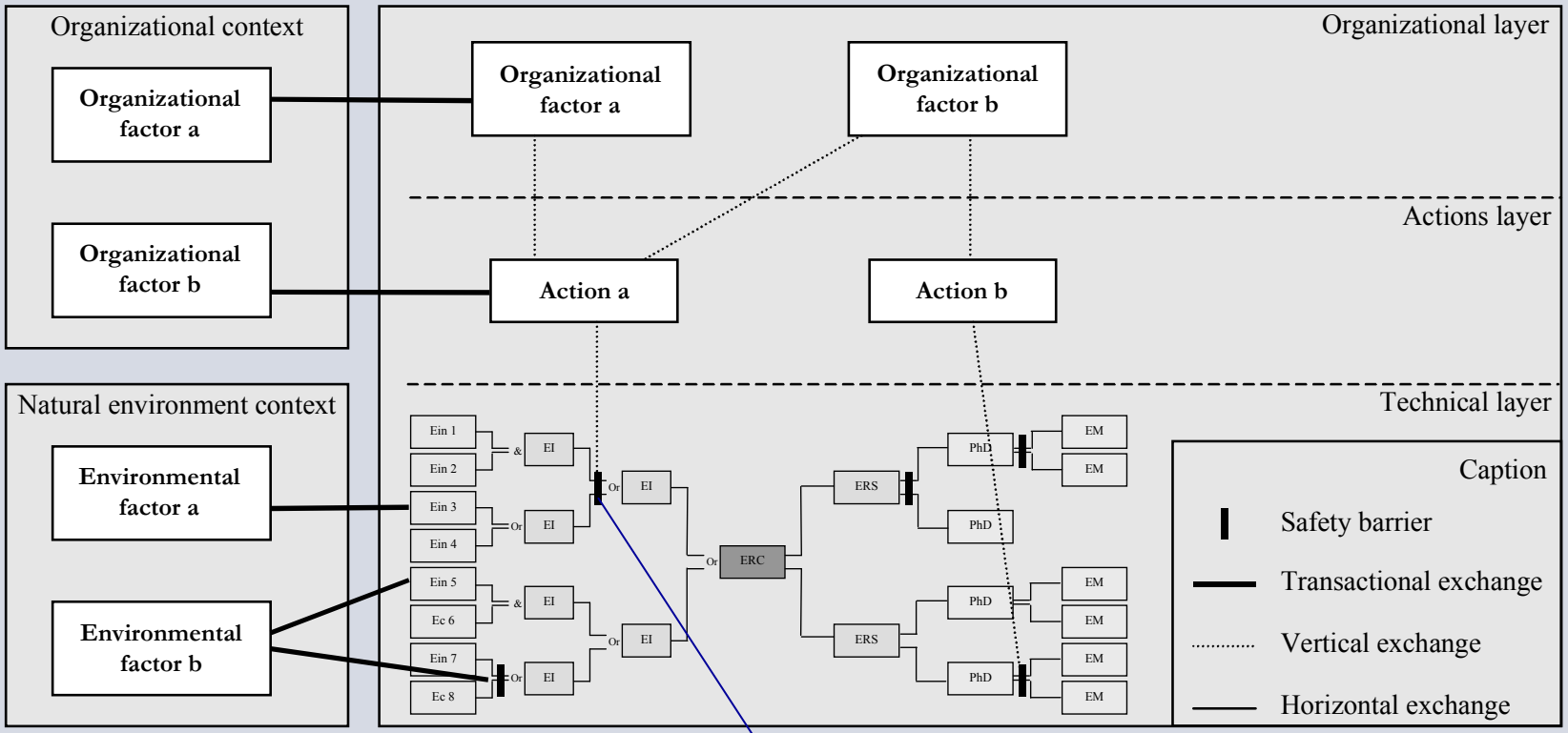
To use the model for:
1. **estimating** the occurrence probability of risky scenarios,
2. **evaluating** barriers impacts on system components and on its global performances,
3. **ordering** barriers according to their efficiency …

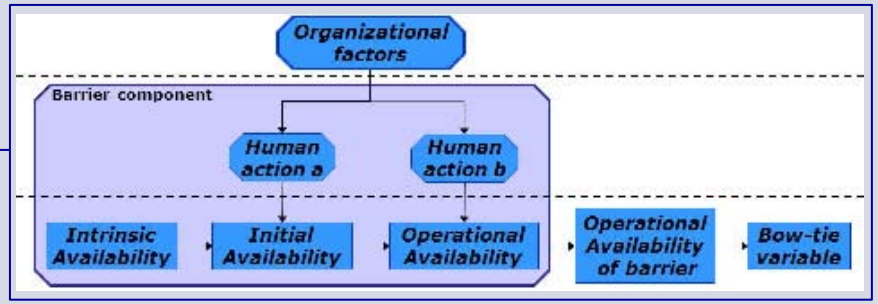
By taking **Bayesian networks** as modeling tool.

Outline


METHODOLOGY
Supported by
Bayesian Networks
Applied to
Industrial scenarios
Part 1: System characteristics
Part 2: Human and organizational dimensions modeling
Part 3: Application

Conceptual frame

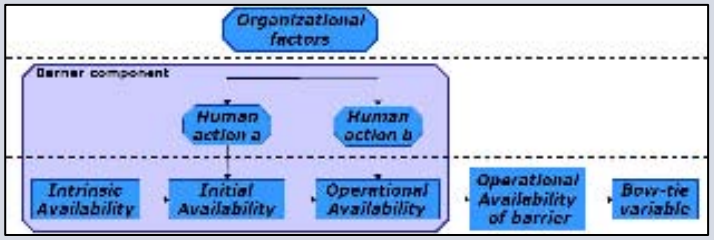




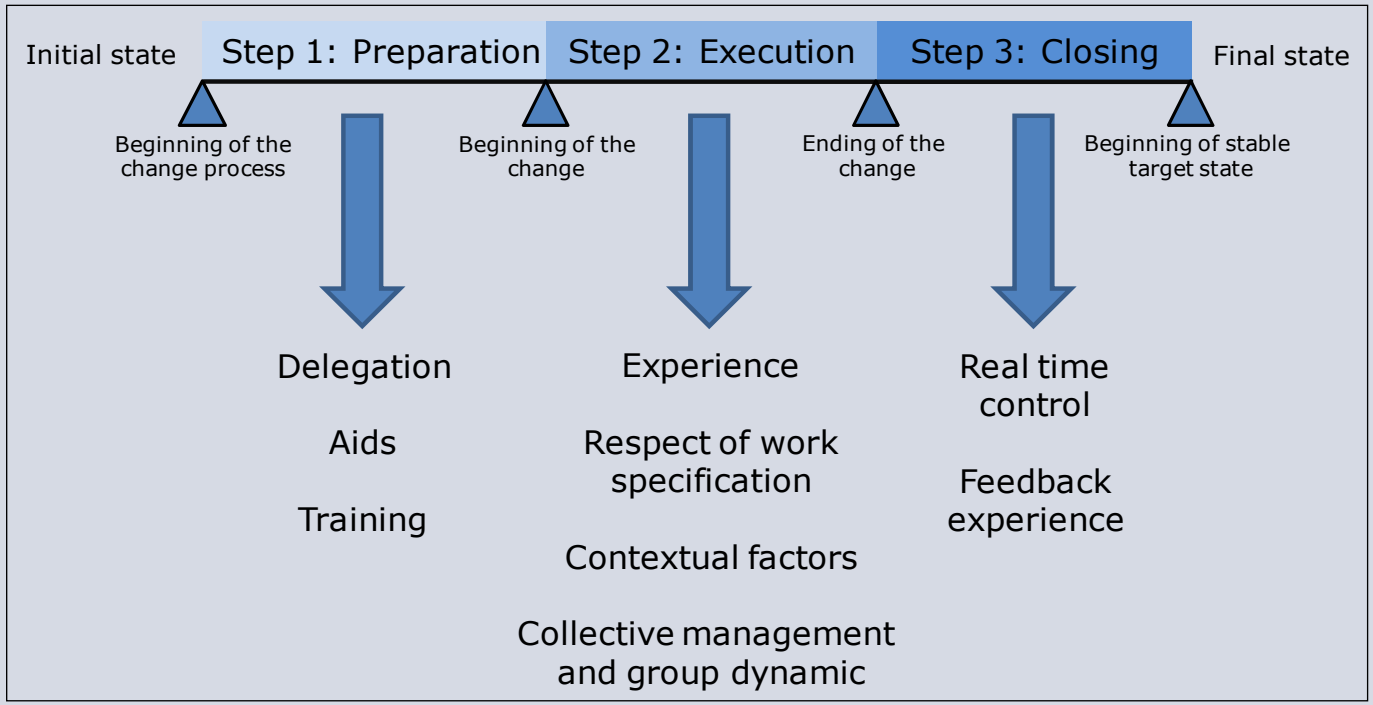
Human dimension

Object of study Human actions that have **influences on safety barriers**

Objectives Estimation of their **effectiveness**

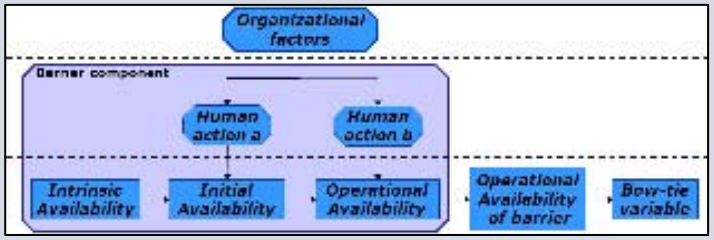


Characteristics



Organizational dimension

Object of study — Organizational factors that **impact human actions**



Objectives — **Identifying the organization's 'health'**

Characteristics

- **Pathogenic organizational factors**
- Aggregation of convergent signs (markers, signs and symptoms) that allow the characterization of a **negative influence on the system safety**
- Issued from **case and accident report analyses**

Representation

- Shortcomings in the organization culture of safety
- Failure in daily safety management
- Weakness of control bodies
- Poor handling of organizational complexity
- Difficulty in implementing feedback experience
- Production pressures
- No re-examining of the design hypotheses

Model objectives

Main objective

Estimating **human action effectiveness** considering its organizational context, enabling thereafter an estimation of safety barriers availability

Detailed objectives

1. Impacts of the **organization on the collective**
2. Impacts of the **collective on action effectiveness**
3. Impacts of the **organization on this effectiveness**
4. Diagnosis of critical situations
   Identification of most influent variables
5. Information concerning an action can be obtained

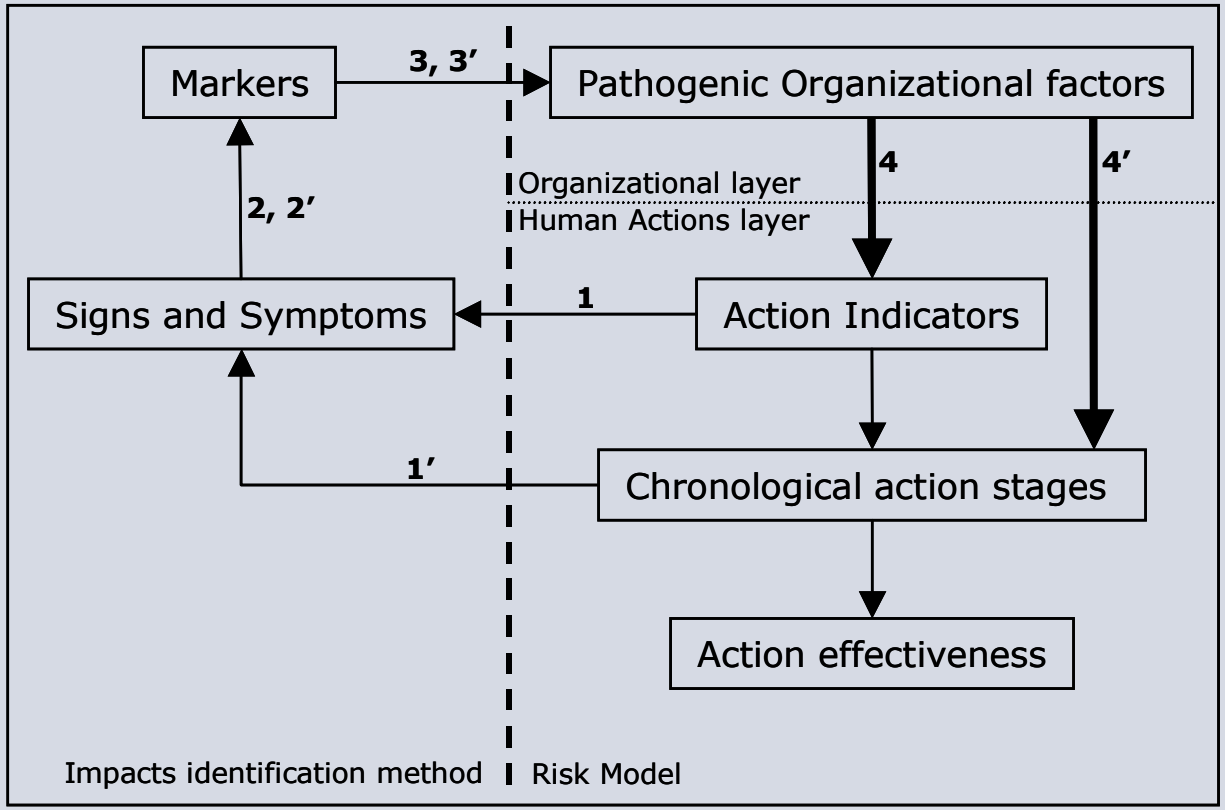
Yet implemented

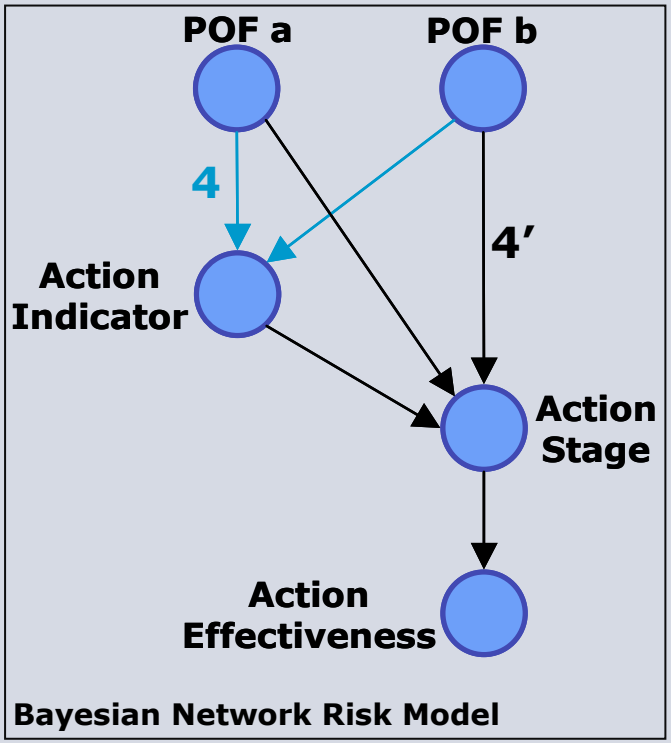
Feedback experience or experts judgments

Not yet implemented

Impacts of the organization and other actions

Impacts identification method





Generic configuration

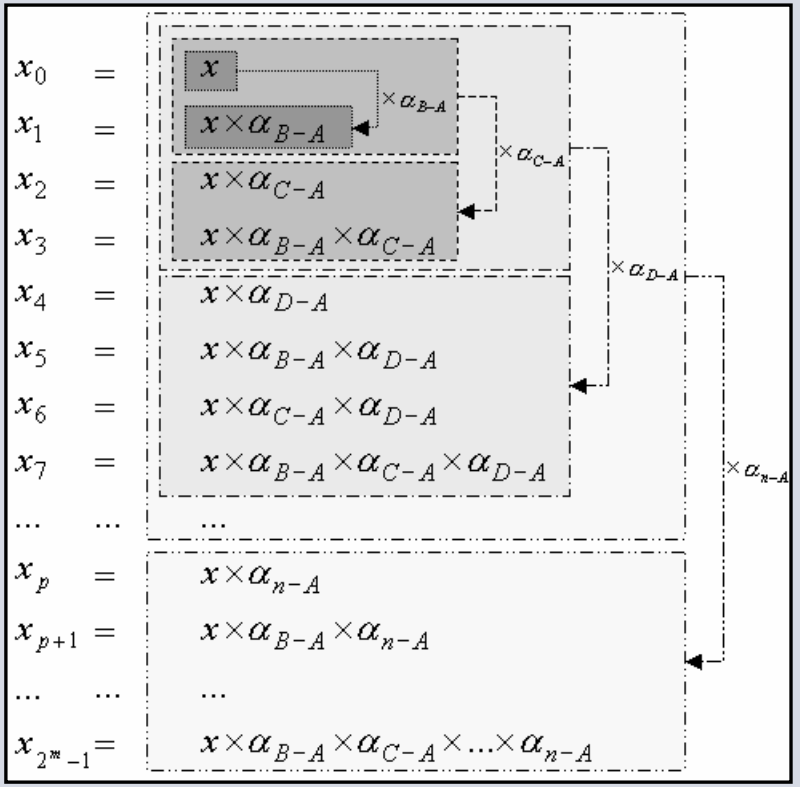
	Pathogenic Organizational Factors						
Indicators	SOCS	FDSM	WCB	PHOC	DIFE	PP	NRDH
De				X		X	
Ai	X		X		X	X	X
Tr		X	X	X	X	X	
Ex		X				X	
Rws	X	X	X	X		X	
Cf				X	X	X	X
Cmgd	X	X		X	X	X	
Rtc			X		X	X	X
Fe	X	X		X	X	X	
Human action stages							
Preparation (P)	X	X	X	X	X	X	X
Execution (E)	X	X		X	X	X	
Closing (C)		X	X	X	X	X	X

Observations
- All the POF **do not impact** all the action indicators and stages,
- All of these factors are **represented**,
- Different **meanings** could lead to a somewhat different configuration,
- **Simplifications** can be done for specific applications.

Quantification method

n	…	D	C	B	A	
					Non Degraded (ND)	Degraded (De)
ND	ND	ND	ND	ND	x_0	$1-x_0$
ND	ND	ND	ND	**De**	x_1	$1-x_1$
ND	ND	ND	**De**	ND	x_2	$1-x_2$
ND	ND	ND	**De**	**De**	x_3	$1-x_3$
ND	ND	**De**	ND	ND	x_4	$1-x_4$
ND	ND	**De**	ND	**De**	x_5	$1-x_5$
ND	ND	**De**	**De**	ND	x_6	$1-x_6$
ND	ND	**De**	**De**	**De**	x_7	$1-x_7$
…	…	…	…	…	…	…
De	ND	ND	ND	ND	x_p	$1-x_p$
De	ND	ND	ND	**De**	x_{p+1}	$1-x_{p+1}$
…	…	…	…	…	…	…
De	**De**	**De**	**De**	**De**	x_{2^n-1}	$1-x_{2^n-1}$

With

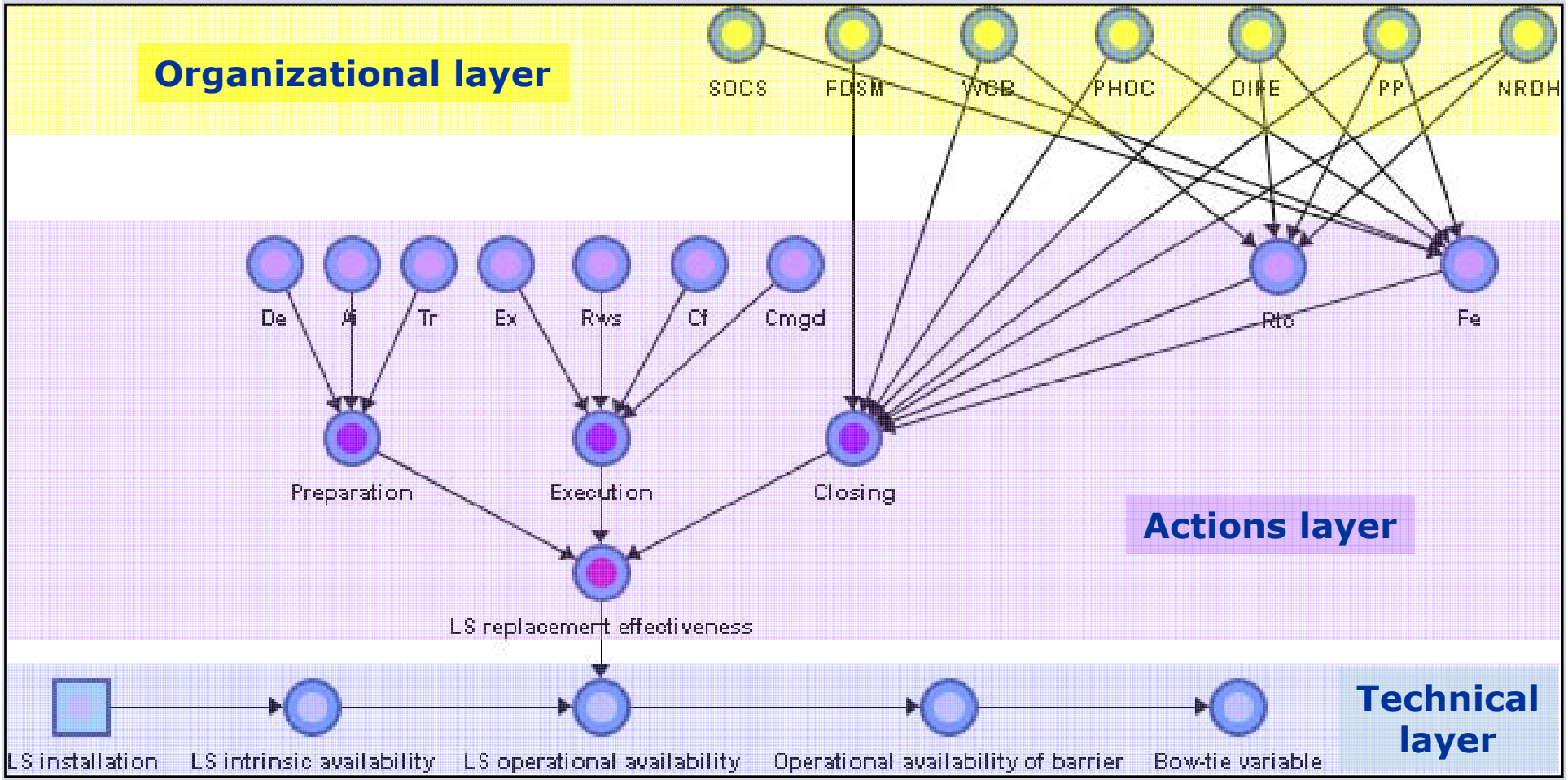


$$f(\alpha_{B-A},\ldots,\alpha_{n-A}) = \prod_{i=B}^{n} \alpha_{i-A}$$

Studied system

Object of study	**Replacement action** of a level sensor	
Subsystem	Safety barrier 'avoid a tank overfilling' Made up of a level sensor, an automatic alarm and a manual valve	
Kind of process	Chemical process of a classified installation	
Characteristics	Number of employees	less than **100** people
	Production capacity	**200 millions pounds** per year
	Certifications	**ISO 9001**, **ISO 14001**, **OHSAS 18001**
Current situation	Recent restructurings Internal and external competition The subcontracting (workforce cutting, increase of the workload)	
Conclusions	Weaken the system, could eventually lead to risky situations	
	Two POF identified by organizational experts: - **Shortcomings in the organization culture of safety (SOCS)** - **Production pressures (PP)**	

Partial bayesian network model



Model quantification

Quantification of the initial situation

Human and organizational variables — '**Non degraded state**' = **99.99%**
Technical variables — '**LS intrinsic availability**' = **99%**

Quantification of conditional probability tables

Specific scale — '**No Impact**' (NI), '**Little Impact**' (LI), '**Impact**' (I), '**Important Impact**' (II), '**Total Impact**' (TI)

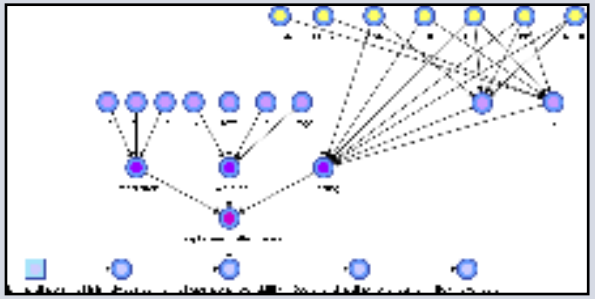
	Pathogenic Organizational Factors						
Indicators	SOCS	FDSM	WCB	PHOC	DIFE	PP	NRDH
De				I		II	
Ai	LI		I		II	I	II
Tr		LI	I	I	I	I	
Ex		II				II	
Rws	LI	II	NI	II		I	
Cf				LI	LI	II	I
Cmgd	I	II		II	I	II	
Rtc			II		I	II	I
Fe	II	II		II	TI	II	
Human action stages							
Preparation (P)	I	II	LI	I	I	II	I
Execution (E)	I	II		II	LI	II	
Closing (C)		I	I	I	II	II	LI

	Human action stages		
Indicators	P	E	C
De	II		
Ai	I		
Tr	I		
Ex		II	
Rws		I	
Cf		II	
Cmgd		TI	
Rtc			I
Fe			II
Human action effectiveness	II	TI	I

Results analysis – Simulation cases

Configuration 1 *A priori* results

LS replacement effectiveness	99.90%
LS operational availability	99.20%



In coherence with data used to build the model

Configuration 2 Presence of pathogenic organizational factors

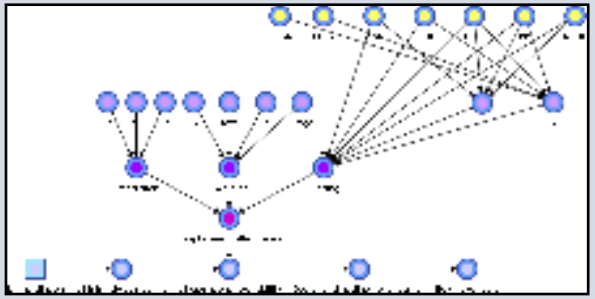
SOCS	PP	LS replacement effectiveness	LS operational availability
Present	Absent	45.79%	72.28%
Absent	Present	7.84%	53.40%
Present	Present	4.27%	51.62%

Production pressures have to be handled in priority.
Human action effectiveness is more impacted than the technical component availability.

Results analysis – Diagnosis case

Configuration 3 LS replacement action: 'ineffective'

Action stage	1	Execution	66.57%
	2	Preparation	32.55%
	3	Closing	26.37%
Action indicator	1	Cmgd	30.12%
	2	Fe	23.21%
	3	Ex	14.54%
	4	Rws	14.24%
	5	Cf	12.22%
	6	De	9.47%
	7	Ai	9.14%
	8	Rtc	8.51%
	9	Tr	8.34%
Pathogenic organizational factor	1	PP	9.38%
	2	FDSM	9.00%
	3	PHOC	8.54%
	4	SOCS	5.52%
	5	DIFE	5.52%
	6	NRDH	3.00%
	7	WCB	1.67%



Confirm the previous conclusion (concerning Production pressures)

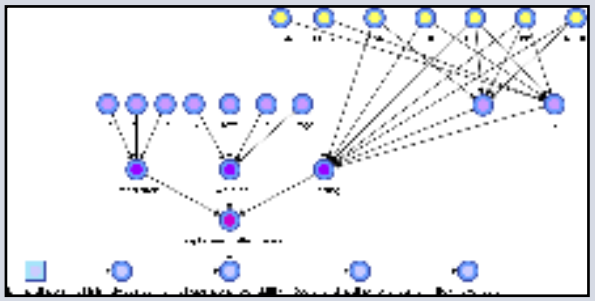
Identify the set of **most probable causes of this ineffectiveness**
Direct causes can be explained by other causes (**indirect ones**).

Collective treatment (not only parts of them)
In the considered example, in priority both: Execution, Cmgd and Production pressures

Conclusions and Perspectives

Handling of **human and organizational aspects for a probabilistic risk analysis of socio-technical systems** by:
1. defining representative generic variables for each dimension,
2. leading to a generic qualitative configuration,
3. quantified through 'aggravation factors',
4. modeled with bayesian networks.

Necessary consideration of the **whole causes for the treatment of a system weakness**



Reduce the **complexity** by using OOBN

Quantification classes for **influences in actions layer**

Quantification classes for **influences between organizational and actions layers**

Human and organizational bow-tie initiators or events

Consider **measure and model uncertainties**