COORDINATION OF EUROPEAN RESEARCH ON INDUSTRIAL SAFETY
TOWARDS SMART AND SUSTAINABLE GROWTH

10 th SAF€RA Symposium "Safety in the age of digitalization and advanced materials"

RESMOD Project
RESilience enhancement MODel

Maria Francesca Milazzo
Department of Engineering
University of Messina, Italy
mfmilazzo@unime.it

22nd April 2024, Vienna (Austria)

Contents

- Background
- RESMOD project
- Organizational resilience modelling and results
  - *Seveso industry, process industry, and transportation sector*
  - *Transport and mining companies*
  - *Volunteer fire brigade units*
- Conclusions

Background: Complexity

- New **threats** impacting the industrial world increase the risk.
- Need for a **holistic strategy** for protection, prevention and response which, to be effective, must be based on aspects of **resilience**.
- Resilience is a **complex concept** that encompasses several dimensions.

Background: Resilience dimensions

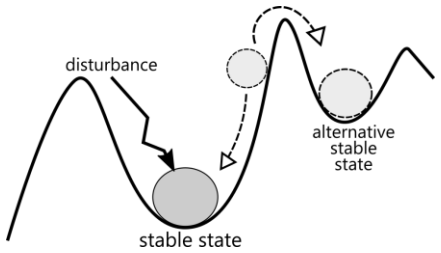
- The **technological dimension** => the characteristics and behavior of physical components and systems in the case of a change or incident.
- The **organizational dimension** => the organizations and institutions that manage the physical components of the systems.
- The **social dimension** => the population and community characteristics that render social groups either more vulnerable or more adaptable to hazards and disasters.
- The **economic dimension** => direct and indirect economic losses resulting from disasters.

Background: Resilient systems

THREATS

SET OF MEASURES

SYSTEM



RESilience enhancement MODel

Being resilient implies minimizing reductions in performance in the face of a successful attack and being able to work properly also in several levels of degraded mode, while healing measures and repair works can be undertaken.

NEEDS

Methods and means to allow the solution to recover, as quick as possible from such degraded modes, achieving minimum recovery time.

22nd April 2024, Vienna (Austria)

RESMOD project: Aims

SAF€RA's 2021 call:
«Industrial safety in the context of pandemics and exponential change»

Topic:

«Lessons learned from Covid-19 and capacity building for resilient response»

Project idea:

- a conceptual model for the organizational resilience evaluation for different industrial sectors covering both the manufacturing and the process sides and relying on the actual experience gained during the first and second waves of the pandemic emergency.
- organizational resilience assessment and resilience indicators setting-up to support business continuity and help dealing with unexpected events, absorbing the disruptive potential.

RESMOD project: Research teams and funding institutions

- University of Genoa, Polytechnic School, (DICCA) Department of Civil Chemical and Environmental Engineering

  Prof. Bruno Fabiano

- Consortium of VSB-Technical University of Ostrava, Faculty of Safety Engineering and Czech Occupational Safety Research Institute- VUBP (VSB)

  Prof. Ales Bernatik

- University of Belgrade-Faculty of Mechanical Engineering

  Prof. Vesna Spasojevic Brkic

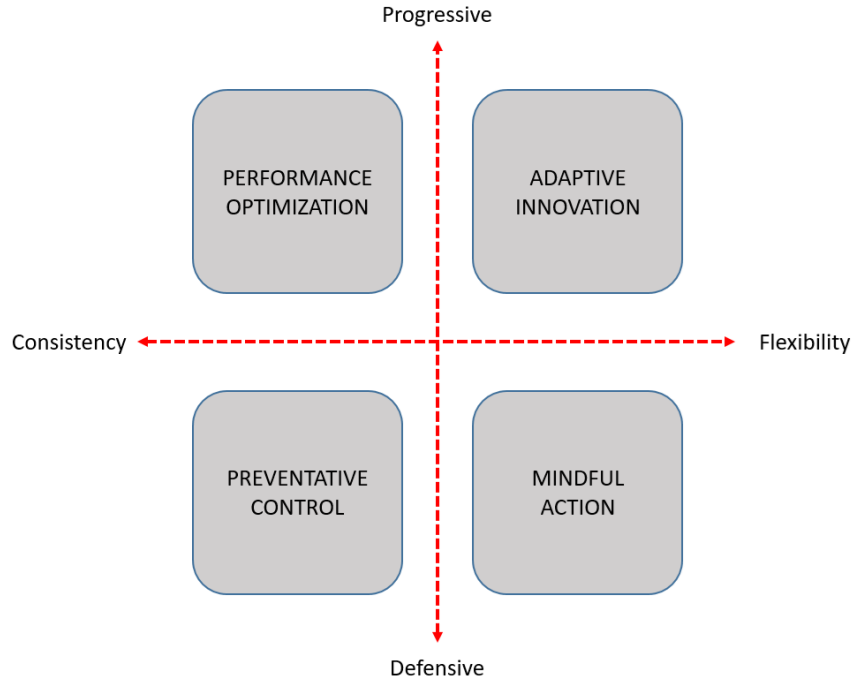
- University of Messina- Department of Engineering

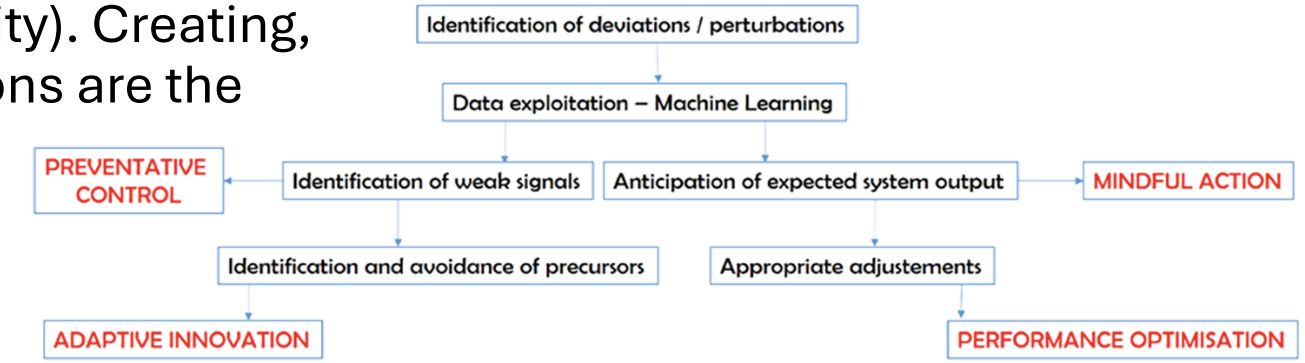
  Prof Maria Francesca Milazzo

RESMOD project: Methodology

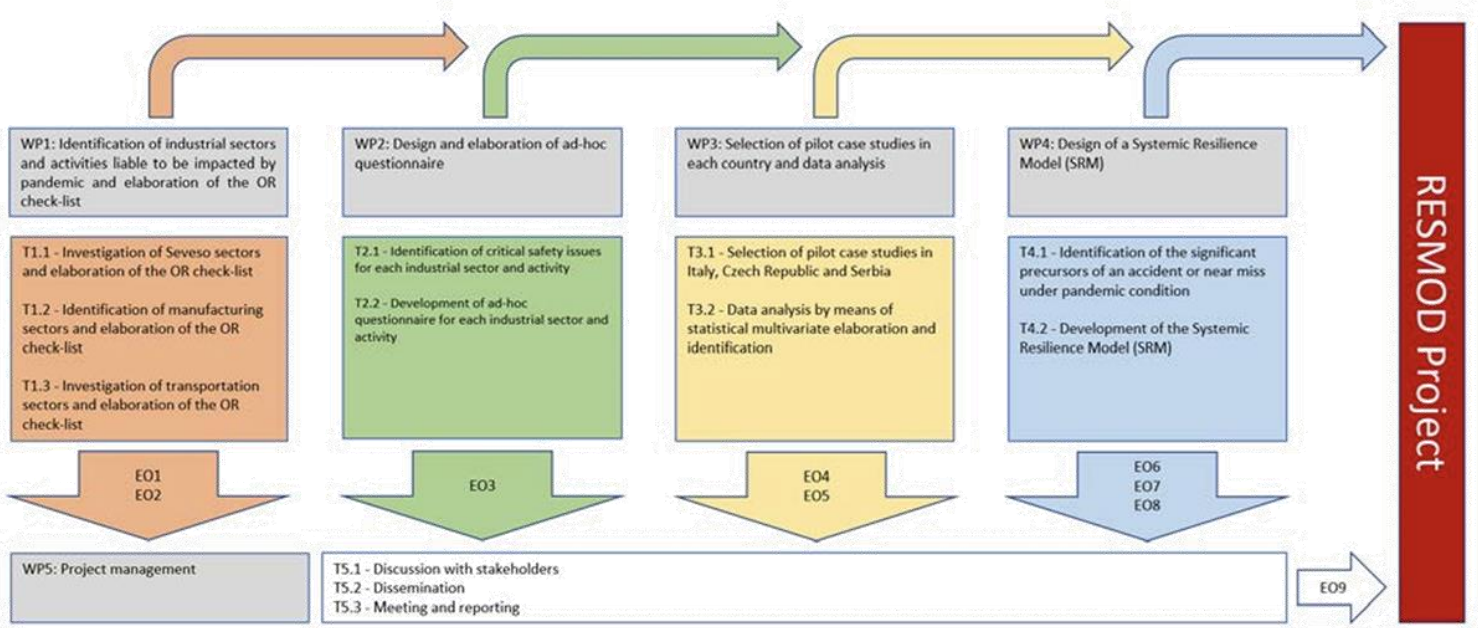
Main constitutive elements

1. Preventative control (defensive consistency). It is achieved by means of risk management.
2. Mindful action (defensive flexibility). It is the ability to ‘bounce forward’, to grow and prosper in the future.
3. Performance optimisation (progressive consistency). It relies on continuously improving, refining and extending existing competencies, enhancing ways of working and exploiting current technologies.
4. Adaptive innovation (progressive flexibility). Creating, inventing and exploring unknown solutions are the pillars of this property.





RESMOD project: Methodology



- Identification of industrial sectors and activities liable to be impacted by pandemic and elaboration of Organizational Resilience check-list;
- Design and elaboration of ad-hoc questionnaire;
- Selection of pilot case studies in each country and data analysis;
- Design of a Systemic Resilience Model (SRM) for identifying the significant precursors of an accident, or near miss under pandemic condition and it is developed with a data driven approach.

RESMOD project: Case-studies

Università di Genova

Università degli Studi di Messina

Seveso industry, process industry, and transportation sector

University of Belgrade

Transport and mining companies

VSB Technical University of Ostrava

VÚBP

Volunteer fire brigade units, representatives of the Central Fire School in White Poličany and of Fire Brigade

RESilience enhancement MODel

22nd April 2024, Vienna (Austria)

Organizational resilience modeling: Data collection

- Questions
- Answer on a 5-point Likert scale

Leadership and worker
1. The organization ensures that workers at all levels are encouraged to report hazardous situations, so that preventive measures can be put in place and corrective actions taken
2. Processes for the assessment of risk to the OH&S management system consider day-to-day operations and decisions (e.g. peaks in workflow), as well as external issues (e.g. economic change)
3. When the assessment of OH&S and other risks has identified the need for controls, the planning activity determines how these are implemented in operation (such as emergency planning with including financial aspects)
4. OH&S objectives affect the risks and opportunities and performance criteria identified by the organization as necessary to achieve the planned results of the OH&S management system

Support
1. The organization provides the resources needed for the establishment, implementation, maintenance and continual improvement of the OH&S management system*
2. The competence of workers is affected by the knowledge and skills needed to appropriately identify hazards and deal with OH&S risks associated with their work and workplaces
3. Temporary workers, contractors and subcontractors, visitors and any other parties are not able (trained) to identify threats and reduce the OH&S risks to which they are exposed on the work
4. The communication process(es) established by the organization provide the gathering, updating and dissemination of information and ensure that relevant information is provided, received and understandable to all relevant workers and interested parties
5. The complexity of the documented information is at the minimum possible level and includes documented information regarding planning to address legal requirements and other requirements on the evaluation of the effectiveness of these actions

Organizational resilience modelling: Data collection

Operation
1. The management timely provides the on-site personnel with adequate protective equipment and such execution of the procedure is adequately considered as the additional risk
2. The shutdown procedures include even the case of unexpected stop of unpredictable duration and the startup procedures include even the restart after a prolonged forced stop
3. The impact of the EMERGENCY measures on the safety procedures (e.g. applicability, time of response) and the impact on safety of organisational changes (including lack of staff and supply outage) are adequately evaluated
4. Permit to work and other recognition and control methods are used as opportunity to address system improvement strategies
5. When outsourcing, the organization has control of the outsourced functions and process(es) to achieve the intended outcome(s) of the OH&S management system and the responsibility for conforming to the requirements is retained by the organization

Performance evaluation and Improvement
1. System response evaluation is done regularly, and often when needed
2. Top management review the organization's OH&S management system at planned intervals, to ensure its continued suitability adequacy and effectiveness
3. The organization establishes, implements and maintains a process(es) (including reporting, investigating and taking action) to determine and manage incidents and nonconformities
4. Continual improvement includes promotion of preparedness culture, safe behavior and resilience

Seveso and process industry and transport

Università di Genova

Università degli Studi di Messina

Preliminary approach

- Harmonising resilience model within SMS-MAH
  - *The application of the SMS-MAH can be conceived according to Italian guidelines or the ISO 31000 approach. Some elements that allows the system reacting to face unexpected difficulties and restoring the previous safety conditions or equivalent conditions are introduced*
- Resilience performance assessment
  - *Evaluation approach to Resilience performances, including suitable assessment criteria retrieved by expert elicitation and calculation of the relative rankings and correlations by using AHP method*

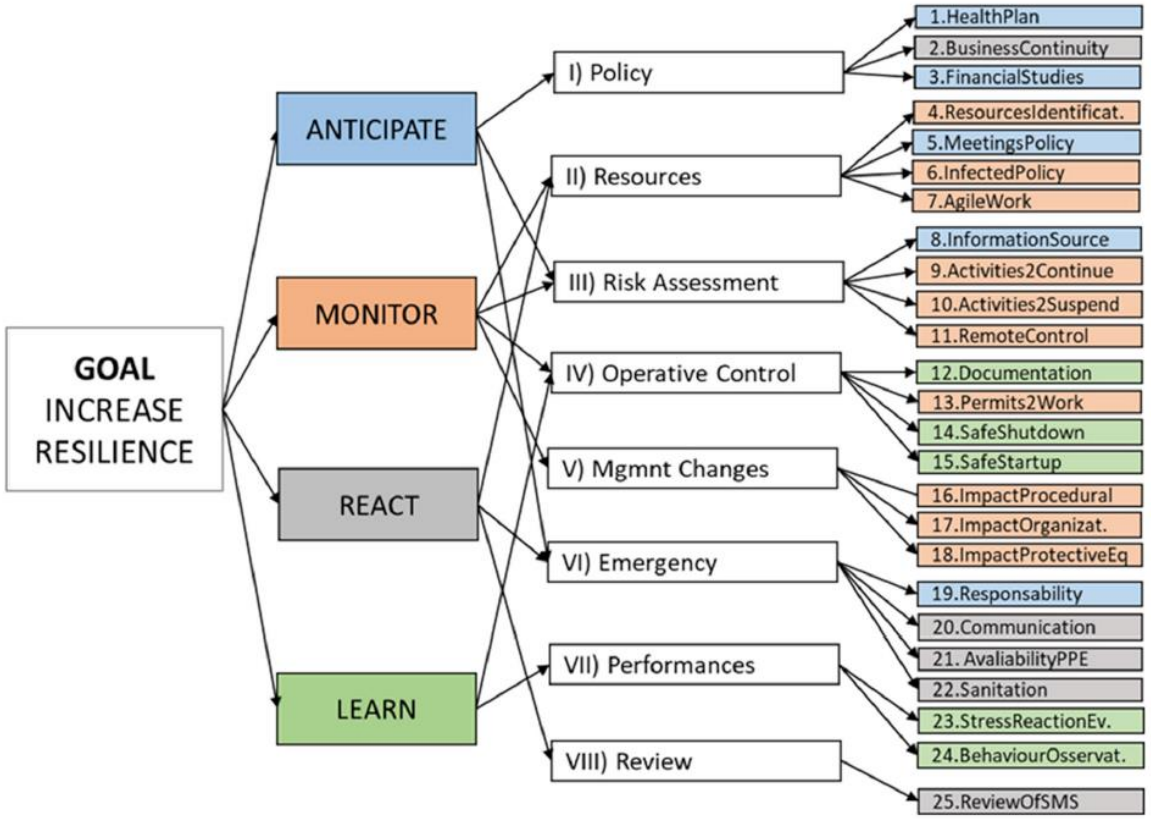
RESilience enhancement MODel

SMS POINT	Health Emergency Resilience Indicators	Four Corners
1. POLICY	1. Higher level strategies, including health plan 2. Business continuity plan (activities essential for safety, recovery times, etc.) in the event of emergencies outside the plant 3. Financial studies on organisational impacts of health emergency	ANTICPATE REACT ANTICIPATE
2. RESOURCES & LEADERSHIP	4. Identification of the resources necessary to support critical activities (people, processes, equipment) 5. Define face-to-face and remote meetings 6. Policies for employees infected or suspected of being infected 7. Agile / flexible work policies and flexibility of working time, including permits, temporary leaves and travel restrictions	MONITOR REACT REACT REACT
3. RISK ASSESSMENT	8. Identification of key sources of information on the epidemic, including trade associations, research institutes, experts 9. Identification of critical activities that cannot be suspended 10. Identification of circumstances in which it may be necessary to suspend operations 11. Possibility of remote process control (e.g., SCADA)	ANTICIPATE MONITOR MONITOR MONITOR
4. OPERATING CONTROL, (INCLUDING MAINTENANCE)	12. Timely documentation of the activities carried out for health emergencies 13. Specific attention to work permits, with extension of measures also to third parties 14. Specific measures for a safe shut-down for a longer or indeterminate period, considering the degradation of hazardous materials 15. Measures for a safe restart after prolonged shutdown, including warehouses	LEARN MONITOR LEARN LEARN
5. MANAGEMENT OF CHANGES	16. Assessment of the effects on safety of the procedural changes introduced to meet the needs of the health plan 17. Assessment of the safety impact of organisational changes, including selected staff and supply outage 18. Assessment of collective and personal protective equipment (C/ PPE)	MONITOR MONITOR MONITOR
6. EMERGENCY MANAGEMENT	19. Assigning responsibility for planning in the event of an epidemic 20. Communications to personnel and other interested parties on the progress of the emergency and the repercussions on the management system 21. Availability of individual and collective protection equipment 22. Sanitation of work environments	ANTICIPATE REACT REACT REACT
7. PERFORMANCE EVALUATION	23. Analysis of the system's reactions to the pressures of the external context (evaluation of strengths and weaknesses) and sharing with all staff 24. Staff behaviour observation system	LEARN LEARN
8. REVIEW & IMPROVEMENT	25. The review takes into account in particular the response of the safety management system to the health emergency	REACT

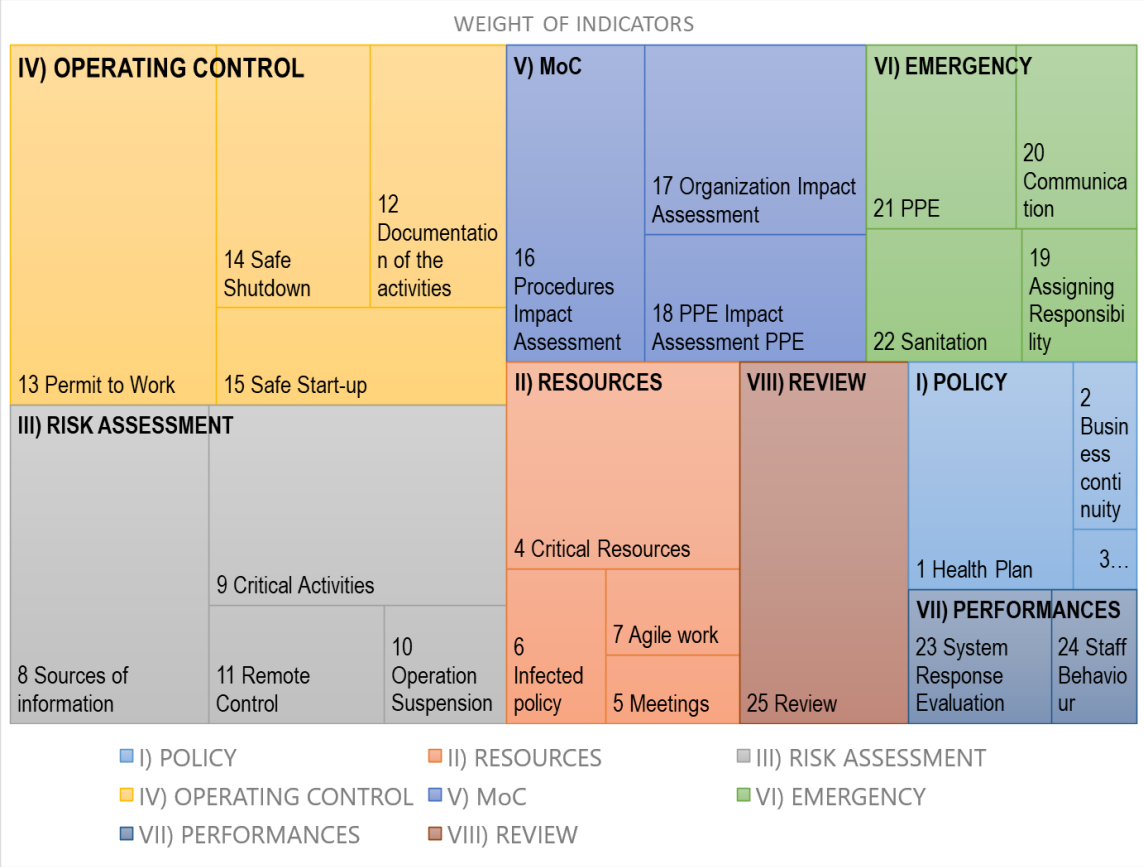
Preliminary approach

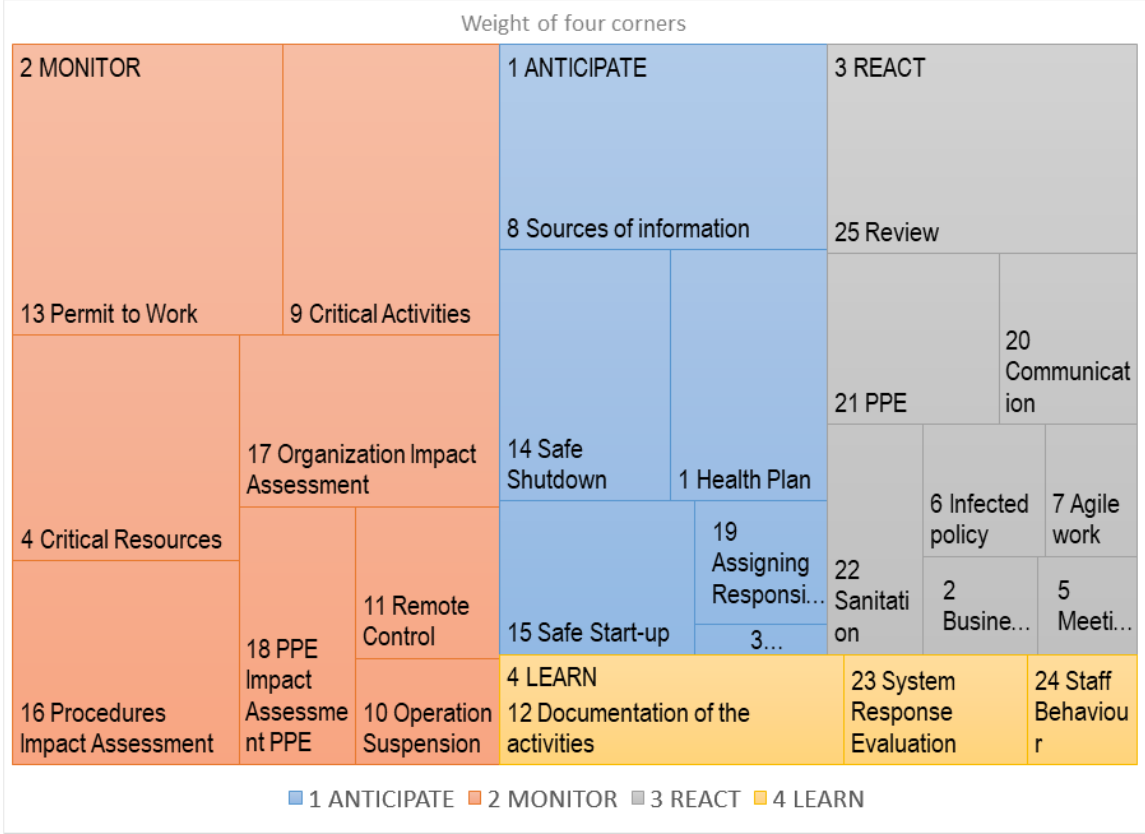
In the framework of Seveso establishments, 25 indicators are reported according to the SMS-MAH scheme with the related link to the four corners of OR.

A scoring questionnaire has been developed and distributed at the Seveso sites, to be filled in by the establishment's operator. It allows eliciting quantitative description of trends by AHP, opinions and attitudes from a sample of a given population.



Preliminary approach results





Resilience index

$$I_R = \sum_{i=1}^{25} s_i \cdot w_i \Big/ \sum_{i=1}^{25} w_i$$

$$I_{R,SMS\ j} = \sum_{i=k_j}^{k_{j+1}} s_j \cdot w_i \Big/ \sum_{i=k_j}^{k_{j+1}} w_i$$

Meaning of resilience indicator.

$1 \leq I_R < 1.5$	$1.5 \leq I_R < 2.5$	$2.5 \leq I_R < 3.5$	$3.5 \leq I_R$
Bad	Poor	Adequate	Good

SMS MAH	indicator	SCORE	weight	partial weights A	partial weights M	partial weights R	partial weights L	partial IR A	partial IR M	partial IR R	partial IR L	weighted scores vv	IR overall	3.02
			100.0%	26%	43%	23%	9%	3.3	3.2	2.9	2.8		Partial IR SMS	
I) POLICY	2 Business continuity	4	1.4%			1.4%				0.056		0.056	4.0	
	3 Financial Studies	4	0.5%	0.5%				0.02				0.02		
II) RESOURCES	4 Critical Resources	2	6.3%		6.3%				0.126			0.126	2.0	
	5 Meetings	3	1.2%			1.2%				0.036		0.036		
	6 Infected policy	2	2.0%			2.0%				0.04		0.04		
	7 Agile work	1	1.5%			1.5%				0.015		0.015		
III) RISK ASSESSMENT	8 Sources of information	4	8.3%	8.3%				0.332				0.332	3.4	
	9 Critical Activities	3	7.8%		7.8%				0.234			0.234		
	10 Operation Suspension	2	1.9%		1.9%				0.038			0.038		
	11 Remote Control	4	2.7%		2.7%				0.108			0.108		
IV) OPERATING CONTROL	12 Documentation of the activ	3	4.7%				4.7%				0.14	0.141	3.2	
	13 Permit to Work	3	9.7%		9.7%				0.291			0.291		
	14 Safe Shutdown	3	5.3%	5.3%				0.159				0.159		
V) MGMNT OF CHANGES	15 Safe Start-up	4	3.7%	3.7%				0.148				0.148		
	16 Procedures Impact Asses	4	5.7%		5.7%				0.228			0.228		
	17 Organization Impact Asse	3	5.5%		5.5%				0.165			0.165	3.6	
	18 PPE Impact Assessment F	4	3.7%		3.7%				0.148			0.148		
	19 Assigning Responsibility	4	2.0%	3.7%				0.148				0.08		
VI) EMERGENCY	20 Communication	4	2.9%			2.9%				0.116		0.116	3.5	
	21 PPE	4	3.6%			3.6%				0.144		0.144		
	22 Sanitation	2	2.7%			2.7%				0.054		0.054		
VII) PERFORMANCES	23 System Response Evalua	3	2.5%				2.5%				0.08	0.075	2.6	
	24 Staff Behaviour	2	1.5%				1.5%				0.03	0.03		
VIII) REVIEW	25 Review	3	8.0%			8.0%				0.24		0.24	3.0	

Advanced approach: Components to be analysed

	Component		
LSC	Leadership and safety culture (LSC)	→	Mindful Action / Performance optimization (**Anticipate, React**)
RA	Risk awareness (RA)	→	Preventative Control / Mindful Action (**Monitor, Anticipate**)
CI	Communication and information flow (CI)	→	Adaptive innovation / Performance optimization (**Learn, React**)
SC	Skills and competencies (SC)	→	Preventative Control / Performance optimization (**Monitor, React**)
A	Action–decision-making process (A)	→	Preventative Control / Adaptive innovation (**Monitor, Learn**)
C	External and internal circumstances (C)	→	Mindful Action / Adaptive innovation (**Anticipate, Learn**)

LSC
RA
CI
SC
A
C

Identified OR factors

ANTICIPATE

- Higher level strategies, including health plan
- Financial studies on organizational impacts of health emergency
- Identification of key sources of information on the epidemic (trade, associations, research institutes, etc.)
- Assigning responsibility for planning in case of epidemic

MONITOR

- Identification of critical activities that cannot be suspended
- Identification of circumstances in which it may be necessary to suspend operations
- Possibility of remote process control (e.g., SCADA)
- Assessment of the effects on safety of the procedural changes introduced to meet the needs of the health plan
- Assessment of the safety impact of organizational changes, including selected staff and supply outage
- Assessment of collective and personal protective equipment
- Specific attention to work permits, with extension of measures also to third parties
- Identification of the necessary resources to support critical activities (people, processes, equipment)

LEARN

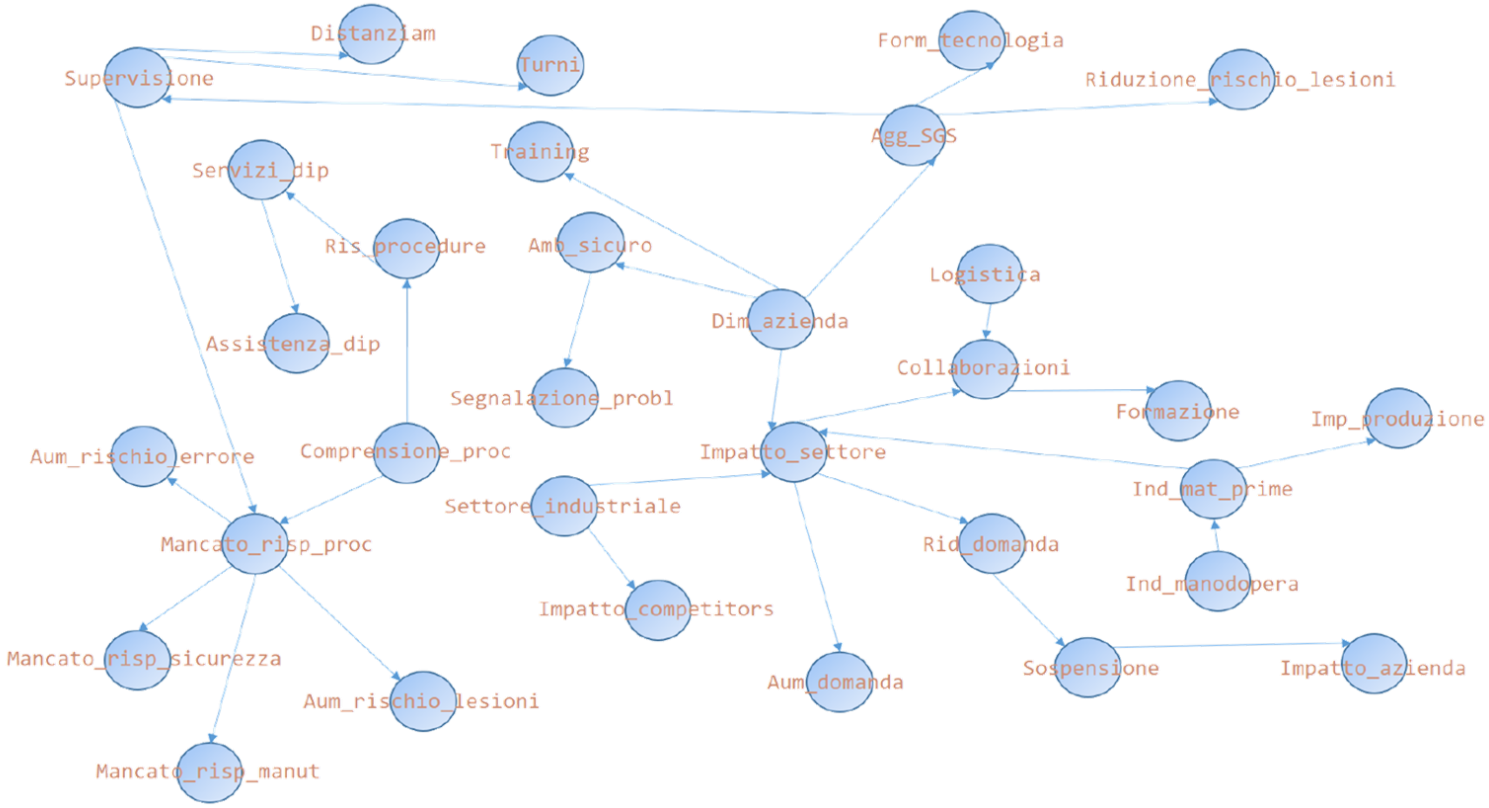
- Timely documentation of activities carried out for health emergencies
- Staff behaviour observation system
- Specific measures for a safe shutdown for a longer or indeterminate period of time, taking into account the degradation of hazardous materials
- Measures for a safe restart after prolonged shutdown, including warehouses
- Analysis of the system's reactions to the external pressures (strengths and weaknesses) and sharing with all staff

REACT

- Business continuity plan (activities essential for safety, recovery times, etc.) in case of outside emergencies
- Review of the response of the safety management system to the health emergency
- Define face-to-face and remote meetings
- Policies for employees infected or suspected of being infected
- Agile/flexible work policies and flexibility of working time, including permits, temporary leaves and travel restrictions
- Communications on the progress of the emergency and the effects on the management system
- Availability of individual and collective protection equipment
- Sanitation of work environment

Causal relations

PC basic algorithm relies on the concept of conditional independence to infer causal relationships between variables. Systematically testing for conditional independence and eliminating spurious relationships by the ah-hoc implemented algorithm allowed obtained a causal network representing the underlying causal structure of the data



Causal relations conclusions

From the learned network structure, it is possible to infer the following insights on organizational causality:

- ***Employee training*** and ***procedural adherence*** were found to have a direct impact on organizational resilience, as evidenced by their strong connections to ***business impact/continuity*** and ***suspension incidents***.
- **Indirect causal paths** were observed between factors such as ***company size, industry sector,*** and organizational resilience, indicating the complex nature of organizational dynamics.

The learned causal network structure underlines that a **fully developed Safety Management System** (SMS) plays a crucial role in ensuring the safety and well-being of personnel, assets, and the environment.

The utmost importance lies in **adhering to SMS procedures** to minimize the likelihood of accidents, incidents, and disruptions that could compromise safety and operational continuity, in particular regarding the approaches to:

- **Risk Management**
- **Safety Culture**
- **Compliance and Regulations**

In face of an unexpected event, such the pandemic, the ability **to update** and innovate within the SMS framework is essential for maintaining safety while optimizing organizational performance. This facet involves:

- **Real-time Monitoring and Reporting addressing early warning**
- **Continuous Improvement**

Transport and mining companies

UNIVERSITY OF BELGRADE

Organizational resilience modelling e results

- To assess organizational resilience at different organizational levels in transport and mining companies in Serbia, a questionnaire was created based on previous research.
- Aspects of organizational resilience later on have been modelled by AHP are Anticipation, Monitoring, Reaction and Learning.
- The weight coefficients obtained with the AHP model, were used to calculate the resilience index.

Area	Safety performance	Job satisfaction	Pravila i procedure	Security policy	Safety training	Safety measures and accident prevention	Risk assessment	Manager support	Organizational environment	Safety communication	Security awareness and competence
Chief	0.039	0.028	0.046	0.026	0.043	0.062	0.040	0.049	0.053	0.035	0.034
Sampler	0.052	0.056	0.062	0.065	0.049	0.032	0.105	0.039	0.078	0.053	0.061
Welder	0.073	0.075	0.086	0.081	0.074	0.056	0.049	0.063	0.000	0.070	0.068
Maintenance manager	0.043	0.032	0.030	0.047	0.044	0.044	0.042	0.069	0.067	0.053	0.040
Excavator manager	0.046	0.042	0.054	0.045	0.023	0.070	0.028	0.054	0.023	0.040	0.030
Executive manager	0.049	0.061	0.058	0.061	0.074	0.054	0.040	0.075	0.069	0.066	0.051
Operator	0.057	0.059	0.060	0.049	0.060	0.049	0.054	0.056	0.033	0.057	0.059
Foreman	0.042	0.032	0.007	0.012	0.043	0.032	0.012	0.038	0.069	0.017	0.020
Overconcentration	0.055	0.066	0.074	0.078	0.070	0.067	0.059	0.080	0.087	0.060	0.061
Manager	0.051	0.050	0.057	0.062	0.066	0.056	0.051	0.057	0.061	0.052	0.057
Handler	0.058	0.050	0.054	0.057	0.046	0.053	0.053	0.065	0.051	0.069	0.052
Mechanic	0.000	0.039	0.000	0.000	0.000	0.061	0.049	0.000	0.093	0.034	0.040
Storekeeper	0.073	0.075	0.086	0.081	0.074	0.048	0.077	0.042	0.007	0.066	0.068
Crane operator	0.055	0.047	0.043	0.040	0.043	0.044	0.053	0.027	0.054	0.040	0.041
Engineer	0.048	0.036	0.053	0.050	0.039	0.052	0.057	0.054	0.054	0.040	0.044
Electrical engineer	0.055	0.038	0.052	0.053	0.043	0.040	0.053	0.050	0.030	0.040	0.047
Electrician	0.044	0.051	0.055	0.052	0.062	0.056	0.056	0.063	0.049	0.051	0.056
Dumpster	0.054	0.064	0.036	0.024	0.049	0.041	0.000	0.025	0.029	0.070	0.068
Locksmith	0.055	0.038	0.043	0.046	0.049	0.035	0.051	0.030	0.069	0.035	0.037
Excavator	0.054	0.064	0.050	0.073	0.052	0.052	0.077	0.063	0.021	0.056	0.068
Model Weights	**0.042**	**0.054**	**0.066**	**0.047**	**0.045**	**0.060**	**0.055**	**0.030**	**0.068**	**0.056**	**0.057**

Organizational resilience modelling e results

			Partial weight				Partial aspect				IR overal l	
Workplace	Resul t	Weigh t	R	A	M	L	R	A	M	L		
							3.3	2,5	2,5	1,6		
Overconcentration	0.068	6.79%	2.32 %	1.86 %	1.69 %	0.91 %	0.07 0	0.05 8	0.05 4	0.03 0	0.180	Good
Welder	0.066	6.57%	2.07 %	1.59 %	1.69 %	1.21 %	0.06 2	0.04 9	0.05 4	0.04 0	0.170	
Storekeeper	0.063	6.29%	2.02 %	1.46 %	1.60 %	1.21 %	0.06 1	0.04 5	0.05 1	0.04 0	0.162	
Manager	0.060	5.98%	2.05 %	1.67 %	1.45 %	0.81 %	0.06 1	0.05 2	0.04 7	0.02 7	0.159	
Excavator	0.058	5.80%	1.68 %	1.76 %	1.47 %	0.90 %	0.05 0	0.05 4	0.04 7	0.03 0	0.150	
Low manager	0.057	5.66%	1.75 %	1.54 %	1.40 %	0.96 %	0.05 2	0.04 8	0.04 5	0.03 2	0.147	Adequate
Foreman	0.056	5.56%	1.91 %	1.38 %	1.42 %	0.85 %	0.05 7	0.04 3	0.04 5	0.02 8	0.147	
Operator	0.055	5.49%	1.79 %	1.37 %	1.38 %	0.94 %	0.05 4	0.04 3	0.04 4	0.03 1	0.143	
Sampler	0.054	5.42%	2.04 %	1.27 %	1.25 %	0.86 %	0.06 1	0.03 9	0.04 0	0.02 8	0.144	
Electrician	0.054	5.36%	1.84 %	1.40 %	1.38 %	0.73 %	0.05 5	0.04 3	0.04 4	0.02 4	0.142	
Engineer	0.048	4.76%	1.63 %	1.25 %	1.08 %	0.81 %	0.04 9	0.03 9	0.03 4	0.02 7	0.125	Weak
Maintenance manager	0.047	4.71%	1.47 %	1.51 %	1.02 %	0.71 %	0.04 4	0.04 7	0.03 3	0.02 3	0.123	
Electrical engineer	0.046	4.61%	1.48 %	1.20 %	1.02 %	0.91 %	0.04 4	0.03 7	0.03 3	0.03 0	0.119	
Dumpster	0.045	4.55%	1.34 %	0.84 %	1.47 %	0.90 %	0.04 0	0.02 6	0.04 7	0.03 0	0.116	
Excavator operator	0.045	4.46%	1.25 %	1.06 %	1.38 %	0.76 %	0.03 8	0.03 3	0.04 4	0.02 5	0.115	
Crane operator	0.043	4.33%	1.42 %	0.88 %	1.13 %	0.91 %	0.04 2	0.02 7	0.03 6	0.03 0	0.111	
Locksmith	0.043	4.26%	1.48 %	0.94 %	0.92 %	0.91 %	0.04 4	0.02 9	0.03 0	0.03 0	0.110	Bad
Chief	0.042	4.18%	1.37 %	1.07 %	1.09 %	0.65 %	0.04 1	0.03 3	0.03 5	0.02 2	0.109	
Foreman	0.030	2.99%	1.16 %	0.63 %	0.50 %	0.70 %	0.03 5	0.02 0	0.01 6	0.02 3	0.078	
Mechanic	0.023	2.26%	1.27 %	0.34 %	0.65 %	0.00 %	0.03 8	0.01 0	0.02 1	0.00 0	0.067	

Volunteer fire brigade units

VSB TECHNICAL UNIVERSITY OF OSTRAVA

VÚBP

Czech approach

- COVID-19 crisis in clear form impacted emergency rescue system
- Consultation of firefighters:
  - Open discussions
  - Consultations with lectors
  - Anonymous web-based questionnaire

Results

Remarks to the resilience of emergency response system extracted from questionnaire:

- Communication gaps:
  - One-directional
  - Not enough form “above”
  - Information chaotic and contradictory
  - Power-play instead of leadership
- Local unit felt to be “abandoned” by headquarter and government
- Real resilience was observed much more at local level that at central level

Conclusive remarks

Conclusions

- Industrial plants can be described as complex systems, whose overall management is mainly related to the interactions of the sub-systems, rather than the management of the sub-systems themselves.
- The main issue is, indeed, the need of understanding the complex interactions amongst the single parts. Accidents and incidents are often due to poor interaction understanding, or to the inability to deal with them.
- Nevertheless, the safety management of complex systems can be optimised by identifying and analysing all threats that undermine them.
- The crux of the project proposal is the anticipation of situations that can lead to accidents or incidents, in order to intercept them before they will become critical.

THANKS FOR YOUR ATTENTION

Maria Francesca Milazzo
Department of Engineering
University of Messina, Italy
mfmilazzo@unime.it

22nd April 2024, Vienna (Austria)