BRINGING DIGITAL AND CIRCULAR ECONOMY TO RISK MANAGEMENT IN MAJOR-ACCIDENT HAZARDS RISK INSTALLATIONS

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Climate change affects many regions of the world. Southern Europe and the Mediterranean Area are nowadays severely hit by the adverse effects of climate change. Eminent studies (JRC) show the impressive growing projection of the huge economic impact caused by extreme weather events and expected on critical European infrastructures of the industrial and social sector for the following decades. Minimizing the negative impacts caused by so-called NaTech (Natural Hazards Triggering Technological Disasters) events is also an objective of Euro- pean policies. On the one hand, the necessity is for a flexible, accessible tool for digitalizing risk management. On the other hand, such automation, cognitive applications, advanced analytics, and pattern recognition at scale require new transversal skills. In this context, the requests for sound data and information foresee specific measurement and monitoring systems to pursue concrete actions and achieve measurable results. It may cooperate with such a vision, the circular economy approach driving towards innovation and the virtualization of activities. In risk management, a DT that entirely recreates state-of-the-art and possible alternatives can be effective in modelling emergencies, especially for heavy and hazardous industries. Also, the ISO 14001 standard remarks the opportunity for the companies to optimize the functionality and performance of the production sites by the commitment to protecting the environment.

Keywords: *risk analysis, Risk management, circular economy, digital twins, NaTech events*

1. Introduction

Global climate change shows each day its heavy environmental and economic impacts on the world. Despite the entire industrial development history and path, poor and developing countries are paying higher prices. At the same time, because of the infrastructure intensification and profound urbanization, the expected economic damages on critical infrastructures will be huge also for the European countries. Regarding the climate change impacts and NaTech events, looking at recent data collections and scenarios for the next future (Fig. 1, source: Euro- stat/EEA), Southern and Mediterranean Europe (Spain; Italy; France; Greece) must be considered as the region characterized by the highest level of risk for critical infrastructures and industries. In a global society still just oriented to prosperity production, if the climatic and environmental crisis would not be enough to move, the economic amount and the potential harm quantification should be able to sweep away any remaining obstacle on the way to a circular economic transition, that is nowadays so essential to permit a genuine cut of the anthropic impacts along the entire production and consumption cycles. With climate change affecting some natural hazards triggers and increasing human development (booming urbanization; rapid industrialization), NaTech risk is expected to increase soon.

2. Methods

European countries have adopted the Seveso Directive to manage and control the major accident hazard at industrial installations involving dangerous substances. National authorities shall implement effective safety policies

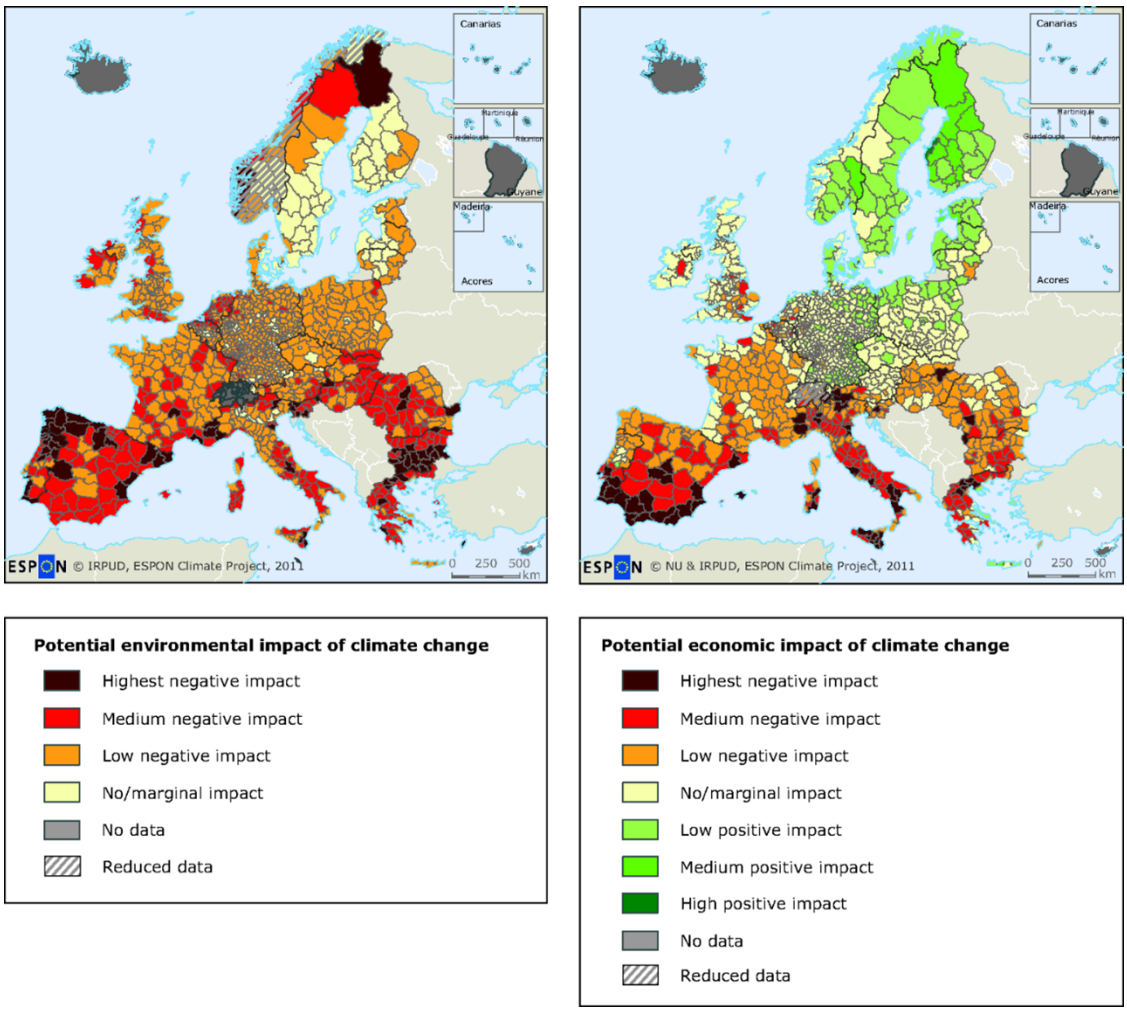

Figure 1: Potential impacts of climate change on environment and on economical infrastructures. Source: Eurostat/EEA; Impact calculated as combination of regional exposure to climatic changes and recent data on regional sensitivity.

by the last law application (Dir. n. 2012/18/EC). The circular economic transition should be able to reduce the impacts linked to production and consumption cycles and minimize risks connected to industrial/chemical plants. Regarding this, two main circular economy pitches could play an important role in NaTech risk management:

1. the introduction of biological elements (often from waste) in the production cycles to replace the use of traditional raw materials [1];
2. digital information, communication, and consultation.

This work aims to describe the fundamental role of digital information and communication in industrial risk management. Experiences show that many past NaTech accidents could have been prevented if only better awareness and understanding of the risk had existed [2].

As represented in the following figure describing the risk management process (Fig. 2, “the process of risk management”, source: ISO 3100:2009), communication, consultation, monitoring, and review of data set and information is ever present in the considered risk management process. Moreover, access to the European market is allowed if the substances produced and marketed comply with the requirements of the REACH Regulation (”No data, no market”). For the chemical industry sector, the BAT conclusions, according to Directive 2010/75/EU, identify the best available techniques for the plant operation.

The circular economy allows exploiting “digital technologies” potential, NaTech accidents, with improved knowledge of potential risks.

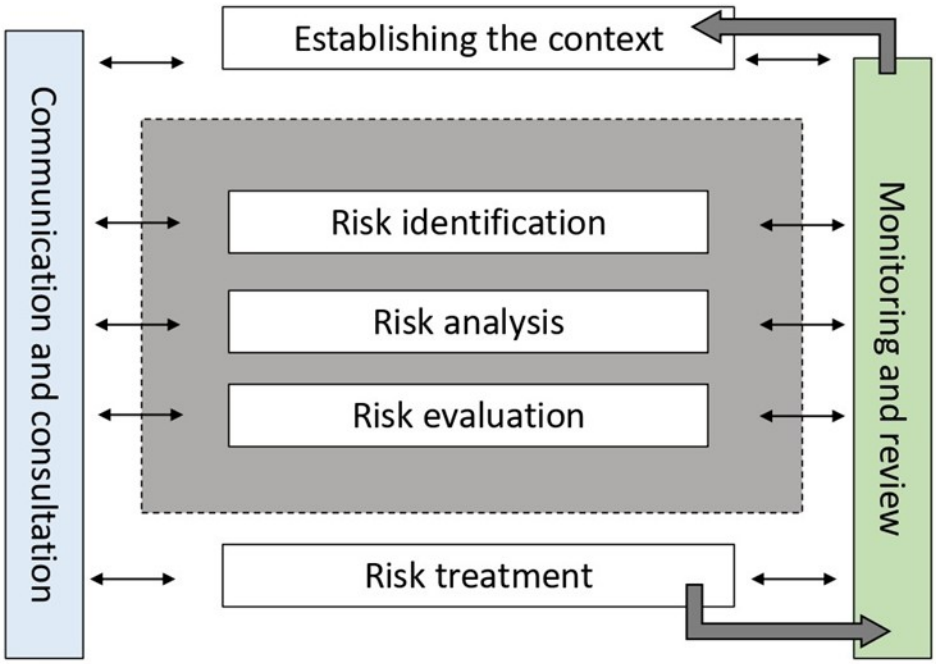

Figure 2: The process of risk management. Source: ISO 3100:2009; JRC Technical Report 2022 "NaTech risk management"

3. Discussion

The fundamental role of digital technologies and digital data is clear and undeniable in each phase represented of the risk management process:

1. Communication and consultation with internal and external stakeholders are essential to ensure taking into account all interests related to risk;
2. Establishing the context is headed by the definition of internal and external parameters to be considered in the risk analysis;
3. Risk assessment is a complex risk identification, analysis, and evaluation process. NaTech risk assessment requires an amount of input data, such as information on the natural hazard, the vulnerable equipment, damage models and data linking damage to releases, consequences analysis models, likelihood estimates, and information on the risk receptors [3];
4. Risk treatment aims at selecting and implementing actions to reduce risks; this phase requires an evaluation analysis of benefits/costs;
5. Monitoring and review are an integral part of the process, implemented by audits or inspections, ensure the effectiveness of controls and help to obtain additional information for risk assessment.

So digital risk management should help in each described phase of the process, providing in-depth analytics to help the organization to monitor the compliance status by the chosen indexes and current threat level for all risk factors. The correct digital risk management will provide, in fact, clear visibility of current threats as well as remediation actions that may be needed, shortening the time to respond to threats. Adequate controls and specific monitoring are activated to satisfy the requests for data and information foreseen by the law simultaneously as effective communication guided by an appropriate communication strategy. Also, the 2015 ISO 14001 standard cooperates with such a framework allowing the companies to optimize the functionality and performance of the production sites through the commitment to protecting the environment. The reporting must be addressed to the interested public and internal company operators to make them more aware and involved, for example, by dis-

seminating information that non-experts can use. Therefore, an initial effort for monitoring is required, together with the necessary resources for acquiring and storing the essential data and information for assessing the impact of systems and infrastructure reliability. Virtual and Augmented Realities can effectively display emergencies and critical situations, especially for large industries. Training, system monitoring, preventive machine maintenance, logistics, and other uses may use digital applications may be used to improve the process [4]. While virtual reality uses an entirely computer-simulated environment and allows the evaluation of different options, augmented reality technology represents the overlay of digital information over the actual company background. Virtual Reality (VR) has brilliantly been used in some functional applications for risk and predictive management, enabling companies to plan maintenance tasks and minimize the consequences of accidents. Quality Assurance is also systematically provided by quick checks of the operating systems. The implementation of VR entails the improvement of the Operational Expenditures - OPEX budget based on virtual close supervision, sapient distribution of tasks, and cost reductions. On the other hand, augmented Reality (AR) guides operators through standardized processes by showing each step to follow with audio and visual instructions using video and animations, staying away from the site where the operations occur. It can be effectively used for manufacturing training [5] and in a more rapid change of productive activities. In complex installations, for instance, chemical installations, some safety devices for preventing accidents connected with the formation of explosive atmospheres, such as the systems for conveying and venting unwanted or excess gas streams to the oxidation system, also take the form of measures for preventing the release of polluting emissions into the atmosphere. Diffuse emissions will therefore be considered during the design phase of the new installations by assuming possible plant solutions and subsequent management activities (lifecycle thinking). Usually, in the chemical industry, the periodic monitoring of diffuse emissions is in the lines of accessible components, such as valves, safety valves, connectors, pumps, flanges, pipe ends, agitators, and compressors. The measurement applies the LDAR methodology according to the following technical standards: EPA 453/R-95-017 “Protocol for Equipment Leak Emission Estimates”; EPA Method 21 (Annex F of EPA protocol 453/R-95-017); UNI EN 15446 “Measurement of emissions from leaks of gaseous compounds from leaks from equipment and pipes”. With the increased possibilities of applying a system of sensors at reasonable costs, especially in critical operating systems. Such measurements can guide operators in Safety Inspections under challenging situations (network malfunctions) by preventing risky situations and providing useful indications for faster remediation actions [6]. However, Digital Technologies implies an increase in CAPEX (Capital Expenditure) budget. Finally, the combination of Digital Technologies (VR and AR) favours the choice of industrial processes that are ever less polluting, intending to prevent and eliminate pollution from production cycles as part of the general framework of the circular economy driving toward innovation and the virtualization of activities. It will provide transparency across the supply chain, ensuring traceability, ethical sourcing, and more effective material flows.

4. Conclusion

The present paper investigates the framework of the risk management process in light of the innovation and the virtualization of industrial activities. The circular economy aims to accelerate the transition to circular business models and practices. The exploitation of Digital Technologies brings higher levels of transparency and provides valuable information on risk for critical infrastructures and industries. Sustainable and digital options can provide relevance under risky challenging situations. From a circular economy perspective, Digital Technologies improvements can also minimize the negative impacts caused by so-called NaTech events.

REFERENCES

1. Mari, M., Millucci, L., Fardelli, A. and Mazziotti Gomez de Teran, C. Circular bioeconomy growth to face the increasing industrial risk, *Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference*, (2020).

2. Necci, A. and Krausmann, E., (2022), Natech risk management. *EUR 31122 EN*, Publications Office of the European Union, Luxembourg.

3. Krausmann, E., Salzano, E., et al., (2017), Lessons learned from natech events. *Natech Risk Assessment and Management-Reducing the Risk of Natural-Hazard Impact on Hazardous Installations*, pp. 33–52, Elsevier Inc.

4. Gualtieri, L., Revolti, A. and Dallasega, P. A human-centered conceptual model for integrating augmented reality and dynamic digital models to reduce occupational risks in industrial contexts, *Procedia Computer Science*, **217**, 765–773, (2023).

5. Arana-Landín, G., Laskurain-Iturbe, I., Iturrate, M. and Landeta-Manzano, B. Assessing the influence of industry 4.0 technologies on occupational health and safety, *Heliyon*, **9** (3), (2023).

6. Ramos-Hurtado, J., Muñoz-La Rivera, F., Mora-Serrano, J., Deraemaeker, A. and Valero, I. Proposal for the deployment of an augmented reality tool for construction safety inspection, *Buildings*, **12** (4), 500, (2022).