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Contribution of a Risks Management method for depollution projects based on MBSE approach

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Abstract: This paper addresses the challenges in risk management of complex depollution systems, marked by intricate interactions and emergent behaviors. The objective is to develop a comprehensive approach to risk management, accounting for the system's complexity and interconnectedness throughout the depollution project lifecycle. By employing a Model-Based Systems Engineering (MBSE) method using metamodels and models, the representation and analysis of multidisplinary components and their interactions are streamlined. The depollution system is modeled with stakeholders integrated as agents using Domain Specific Modeling Language (DSML). MBSE enables the examination of internal interactions and the evaluation of feasibility. Ultimately, this work aims to enhance depollution management by helping stakeholders assess feasibility, cost, and delay of depollution processes by effectively addressing risk management.

Keywords: Risk management, Depollution system, Complex systems, System engineering, Model-based systems engineering.

1. Introduction

For several years, the remediation and dismantling of industrial sites and brownfields have become a major issue in light of societal, regulatory, and economic expectations. Depollution projects aimed at restoring these sites to a condition that allows their reuse are by definition long, costly, multidisciplinary, and multi-actor. Indeed, they involve heterogeneous stakeholders, means, and resources over periods that can span several years, and with strong requirements for safety, security, and performance. Each project must face societal, environmental, human, economic, and technical challenges. It must also manage a set of complexification factors inherent to each depollution site, such as the nature of the pollutant, the poorly controlled combination effect of multiple pollutants, site geography, professional constraints, and regulatory requirements. Engineers and managers of such projects therefore require well-equipped methods to successfully carry out their tasks, first in the project design (what to do, why, who should intervene, what risks are involved with possible effects, etc.), and then in its management, taking into account the inevitable field feedback and the unique evolving dynamics of each site.

The method proposed in (Chebbi et al. 2023)offers a conceptual and methodological framework to guide these stakeholders and support them in their activities. This method aims to promote a form of industrialization of the depollution and dismantling of industrial sites. To achieve this, it relies on principles that propose to conceptualize and operationalize the project preparation, facilitate the validation of each project as early as possible, assist in the management and traceability of activities, while promoting the reuse of data and past experiences. This method is based on strong systemic principles, the scope and power of modeling, and the processes and concepts of Systems Engineering, drawing in particular on ISO 15288 (ISO 2015). One of the essential components of this method is based on a risk management.

The aim of this article is to propose a comprehensive, model-based approach for managing risks inherent to complex depollution systems, utilizing Model-Based Systems Engineering (MBSE) methodologies and Domain Specific Modeling Language (DSML). Through this approach, stakeholders are enabled to identify, assess, and effectively manage the risks associated with depollution projects throughout their preparation and execution phases.

The remainder of the paper is organized as follows. Section 2 outlines the defined issue, providing a clear understanding of the problem. Section 3 describes the methodology and approach used to address this problem. Section 4 is dedicated to our contributions. In 4.1, we introduce the global abstract syntax, followed by concrete syntaxes in 4.2. 4.3 explores our operational approach, while 4.4 covers the implementation and tooling.The paper concludes with Section 5, summarizing our findings and suggesting future research directions.

2. Issue definition

The inherent complexity factors of this type of project typically lead, as with any complex project, to the emergence of so-called risk situations, or more commonly, risks. To address this, it is necessary to identify, assess, and find solutions or barriers as early as possible to prevent the occurrence of each type of risk or limit its effects. This must, take into account all the technical, organizational, social, and economic constraints at the time (Chilès et al. 2009).

In the following, we consider that understanding and mastering these risks require a deep understanding of interactions. By interaction, we mean here any form of exchange between two objects, in this case systems that can be both stakeholder companies in a project that need to collaborate, or technical resources that need to exchange information, material, or energy flows to function and fulfill their mission. These interactions can be intentional, such as desired collaboration that may be hampered by potential mutual understanding issues or synchronization problems between two companies working together on a common technical waste management task. They can also be unintended or even emergent, and therefore more difficult to identify, such as pollutant recombination phenomena. Whether intended or not, interactions involve the various components of the project, its stakeholders, its resources, and also concern the project's environment itself, the site, the pollutants, etc. The failures or errors of any party involved may result in either immediate, benign, or at least controllable effects, or conversely, Harmful consequences that can spread across the entire depollution project and impact multiple components involved in the project process (Ulibarri et al. 2020).The risks in a depollution project can be numerous and of different types. Among these risks, we can mention:

Technical risks: These risks are mainly associated with failures of pollutant treatment equipment, malfunctions of environmental control and monitoring software, inefficiency in integrating the various components of the depollution system, and potential complications during the implementation of innovative contaminant elimination techniques (Gaderer, Herrmann, and Fendt 2016).

Regulatory risks: Legislation regarding depollution is constantly evolving, which can lead to difficulties in complying with current standards and regulations. These changes and constraints can affect the depollution project and create risks related to non-compliance, delays, increased costs, and potential fines or penalties (Raber et al. 2001).

Project management risks: Depollution projects, fraught with complexity, can face issues from poor planning, stakeholder miscommunication, delays, and coordination problems. Unexpected discoveries like additional contaminants could necessitate new strategies and expertise. Disagreements on goals or methods, and hazardous waste disposal challenges may further complicate execution (Guelton 1999).

Health and safety risks: Depollution activities can pose risks to the health and safety of workers and neighboring communities. (Adjir et al. 2018). These risks include workplace accidents, exposure to hazardous substances, and public health issues.

Data loss and domain language risks: Remediation systems often involve collaboration between stakeholders with varying skills and domain-specific languages. Risks associated with data loss and domain language differences may include misunderstandings of information, communication errors, and interoperability issues among the various project participants. (Raber et al. 2001).

Depollution project managers should monitor interactions and their effects, aiming for anticipation over reaction. A comprehensive risk understanding is achieved by balancing environmental, economic, and social goals. Decisions to mitigate risks in one area may unintentionally impact another. For instance, costlier depollution technology may lessen environmental risks but increase financial ones. Therefore, a holistic, systemic approach is crucial. The identified risks have a significant impact on depollution projects. It is essential to be mindful of these risks and possess a thorough understanding of how to manage them meticulously by choosing the appropriate methods.

3. Methodology and Adopted approach

The systemic approach and modeling are indeed two fields that allow us to better define this concept of interactions between systems and to formalize their representation(Hallo et al. 2019). This formalization firstly enables the actual modeling of each interaction or group of dependent interactions, in an understandable, graphical, or textual form. It then allows the analysis of these interactions (characterization of the propagation of effects, traceability, simulation, etc.) to ultimately provide decision-making support for managers to define and evaluate the relevance of solutions called barriers (Hollnagel and Woods 2018).
Still within the framework of the overall method, this formalization is based on a multi-view approach as proposed in SAGACE (Penalva 1990), which particularly focuses on functional, structural, and behavioral views that prove to be too limited in this context. Each view aims to understand and represent a system with minimal ambiguity by focusing on specific details under which the system must be perceived. Thus, each view highlights one or more specific, fragmented models of the system, as they are necessarily incomplete. The overall model of the system, meaning the model that represents the system more realistically (referred to as the system model in (ISO 24641 2020) is then obtained by federating the various models developed in each view. The views selected in the method are explained in the article (Chebbi et al. 2023). This article focuses here on the so-called **Risk Management View.**

4. Contribution

To describe the content and composition of this view, the approach used is described, for example, in (Bourdon et al. 2022)(Gaignebet et al. 2022). The goal here is to identify and formalize a domain-specific modeling language (DSML)(Nastov 2016) (Vincent et al., 2013). This DSML, called Risk Management DSML, is designed to help stakeholders of the depollution system identify potential risks, assess their importance and probability of occurrence, and implement protective measures to prevent or mitigate these risks.
The definition of a DSML follows four essential steps, summarized in Figure 1 and applied here to the definition of a known language contributing to the behavioral view of a system: Petri Nets (Desel and Juhás 2001).

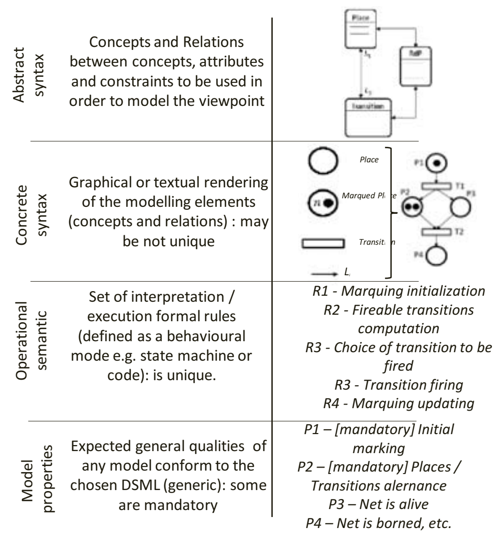

Figure 1: Ordinary Petri Nets DSML specification steps

4.1 Global abstract syntax

The abstract syntax of the Risk Management DSML is presented here in the form of an eCore metamodel (ECLIPSE) (Steinberg et al. 2008) given by Figure 2. In a depollution project, the concepts chosen for the Risk Management DSML are closely related to one another, enabling efficient risk management meta-model.

Risks are identified and characterized based on their nature, severity, and probability. **Effects**, which are the direct or indirect consequences of risks, are also characterized to better understand their implications on the depollution project. **Events**, on the other hand, are incidents or situations that can trigger or reinforce these **risks**. **Operational scenarios** describe the various operating situations of the depollution system, allowing for the anticipation of events that could lead to **risks**. **Indicators** are used to track the evolution of these **risks** and the effectiveness of the actions implemented to manage them. **Barriers**, which can be human, organizational, or technical, are measures put in place to counter identified risks. They are designed to reduce the likelihood or impact of risks on the project. **Components** encompass all the systems, processes, and resources involved in the depollution project. **Interfaces**, as connection points between these elements, enable the identification of critical points where risks can be transferred or amplified. **Organizational units**, such as teams, departments, or external organizations, play a crucial role in governance and communication for efficient risk management. **Concern**, is defined to represent various concerns of stakeholders. This class would be "abstract" as it wouldn't have any direct instances. In a DSML for risk management, this "concern" class would be necessary for several reasons. Each concern could potentially be associated with one or more risks. Concerns could also play a role in risk assessment. Finally, concerns could help inform risk management strategies.

Thus, the concepts chosen for the Risk Management DSML are interdependent and complementary, providing a comprehensive and structured view of risk management in depollution projects. By considering the interactions between these concepts and integrating them into a coherent approach, it is possible to better identify, analyze, and mitigate the risks associated with these projects. Figure 2 illustrates the various interactions among these classes and demonstrates the different connections necessary to form a comprehensive meta-model for risk management.

4.2 Concrete syntaxes

Figure 3 illustrates how to obtain five concrete syntaxes, and thus ultimately propose five DSMLs for the risk view. These five DSMLs share the same abstract syntax presented in Figure 2, called Risk Management meta-model.

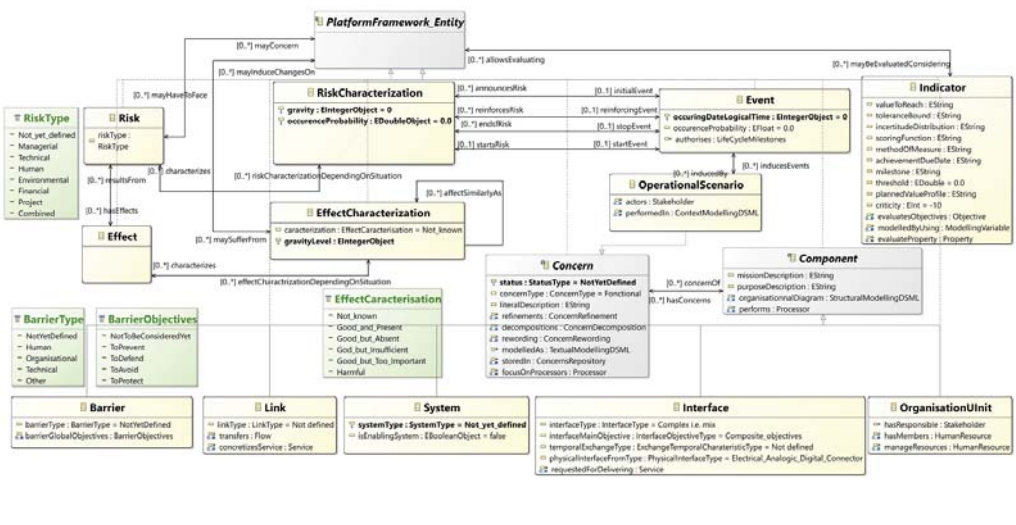

Table 1: Concrete syntaxes associated with Risk Management DSML

Aims	What	How
Risk identification	Risk identification diagram	By adapting the Ishikawa diagram (Wong, Woo, and Woo 2016) , we have developed a risk identification diagram conform to the meta-model. This diagram categorizes risks (such as human, technical, project, environmental) into specific causes, with the fishbone head showing the risk's impact.
Risk Analysis	The Fault Tree Analysis diagram	The Fault Tree Analysis (Xing and Amari 2008) assesses the risks of a depollution project by visually representing the chain of events leading to an undesired outcome using a hierarchical, logical structure of gates and events, in the form of a tree diagram.
Risk Prioritization	Risk matrix	The risk matrix (Dumitran, et al.2010) prioritizes the risks of a depollution project by associating the probability of occurrence with potential impact. Which consists of two axes: the x-axis, or abscissa, where the likelihood or probability of risks is plotted, and the y-axis, or ordinate, which represents the potential severity or impact of these risks.
Risk Management planning	Decision tree diagram	The decision tree diagram facilitates risk management planning by modeling options, uncertainties, and outcomes of a project. It visually represents decisions, risks, probabilities, costs, and benefits of each scenario.
Risk management implementation/ Risk Monitoring	Risk control diagram	Drawing on the MADS-MOSAR methodology (Hamzaoui et al. 2019), we have proposed a graphical syntax , shown in Table 2. This Risk Control Diagram effectively illustrates the risks that influence depollution activities. It allows for the representation of events that cause these risks, along with the potential barriers that can be implemented to avoid or mitigate them.

In fact, each DSML corresponds to a specific phase of the risk management process associated with depollution. In this way, engineers can use the appropriate DSML to model, analyze, and effectively manage the type of risk involved. This not only allows for a better understanding of specific risks, but also optimizes risk mitigation strategies, thereby improving the overall safety and efficiency of the depollution project. These concrete syntaxes, which are derived from this abstract syntax, are synthesized in Table 1.

4.3 Operational approach

To effectively utilize abstract and concrete syntax, it's essential to outline the operational approach associated with risk management DSML (Lamine et al. 2020). This process follows the steps indicated below and is visually represented in Figure 4:

1) Risk identification: This may include interviews with stakeholders, workshops, scenario analyses, or the study of past incidents. It is important to use diverse and reliable information sources to gain a comprehensive understanding of potential risks.

2) Risk analysis: Once the risks have been identified, it is essential to assess their likelihood of occurrence and their potential impact on the project or organization. Analysis methods can include qualitative and quantitative estimates, as well as using appropriate tools and techniques to evaluate risk levels.

3) Risk prioritization: This step involves ranking risks based on their significance and potential impact. A systematic and objective approach should be used to determine which risks require immediate attention and which can be managed in the long term. Prioritization enables efficient allocation of resources for risk management.

4) Risk response planning: After prioritizing risks, it is necessary to develop strategies and action plans to address them. This may include risk avoidance, reduction, transfer, or acceptance. Planning should take into account available resources, budget constraints, and the goals of the organization or project.

5) Implementation of risk treatment measures: At this stage, the action plans developed during planning are put into place to minimize the impact of risks on the organization or project. It is crucial to effectively communicate with all relevant stakeholders and ensure that responsibilities are clearly defined and assigned.

6) Risk monitoring and review: Risk management is an ongoing and dynamic process. It is important to regularly monitor identified risks, evaluate the

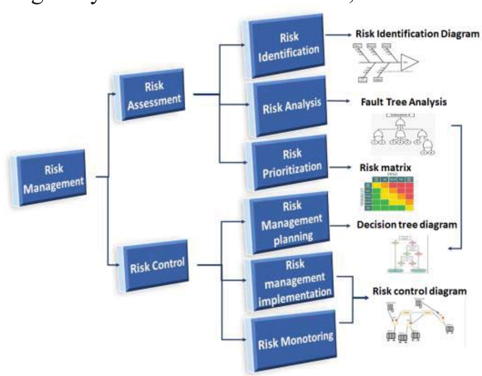

Figure 3: Five DSMLs are developed based on the abstract syntax of the Risk Management DSML.

effectiveness of implemented risk treatment measures, and adjust action plans accordingly. Periodic review allows for adaptation to changes in the environment, new information, and lessons learned from past experiences.

Indeed, this operational approach is specifically dedicated to the management of risks process. However, it still falls within the broader context of the global method defined in (Chebbi et al. 2023), which orchestrates and streamlines the professional undertakings of engineers and depollution project managers.

Figure 4 illustrates the integration of the risk management process within the overall depollution process. It highlights how models are exchanged between the different processes. One of the main strengths of this approach lies in the use of a single metamodel. The involved models thus share the same concepts, thereby reinforcing the connections between them.

4.4 Implémentation/tooling

In order to promote information sharing among the various modeling stakeholders and reduce modeling errors, the implementation of the DSMLs was done within the Obeo Designer environment (Juliot and Benois 2009). In addition to providing modeling and analysis support, this tooling will ensure traceability of changes made to the models, guarantee their consistency, and automate certain repetitive tasks, thereby improving the overall efficiency of the modeling process. Finally, the use of this tool will contribute to the standardization of modeling practices within the team, fostering a more harmonious and professional working environment. Figure 5 illustrates an example of the implementation of the Risk Control Diagram. In particular, the Risk Control Diagram is not intended to display the dynamic behavior of the depollution system. It provides a static perspective of the latter. Therefore, it will not be simulated and an operational semantics is not necessary. In the absence of an operational semantics describing how to interpret a model compliant with this DSML, only some of the model properties, ensuring the conformity of the model's construction, can be considered, for example:

-P1: An activity can be affected by at least one risk

-P2: An event generates at least one risk

-P3: A barrier can be allocated to address multiple risks

-P4: A risk must affect one or more activities

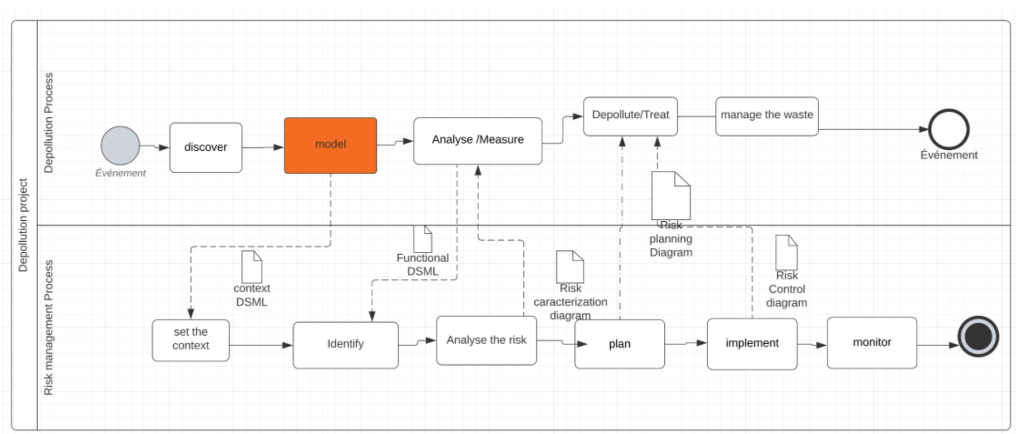

Figure 4: Operational approach proposed to help in deppolution project

Table 2: DSML Risk Management Concrete Syntax for the Risk Control Diagram

Graphic elements	Description of the graphic element
	Activity/function
	Event/ An event arising from a system's environment or component behavior, potentially causing changes in other elements or the entire system.
	Risque/ The possibility of a situation affecting an asset
	Barrière/ Activities planned or executed in order to face a risk.
	Association between function
	Affect association which outlines that a given risk acts on a given business process concepts (process, activity, and object).
	Causality relation between an event and a risk situation
	Treatment relation between risk and barrier.

5. Conclusion

In conclusion, this article has identified the risks associated with depollution projects and proposed the use of Model-Based Systems Engineering (MBSE) and system Engineering (SE) to address these challenges. An abstract syntax has been introduced, followed by the development of five DSML that represent the concrete syntax. The operational approach has been demonstrated, and a computational tool for risk management DSML has been proposed. In essence, this proposition provides a structured and flexible framework for modeling and managing risks in depollution systems by identifying key concepts. This approach enables researchers and practitioners to systematically analyze problems and design effective solutions for depollution and associated risk management. By efficiently addressing and mitigating risks, we can ensure optimized resource allocation, reduced operational costs, and minimized adverse environmental impacts. Furthermore, robust risk management enables stakeholders to make more informed decisions and develop proactive strategies for potential challenges. Ultimately, these improvements contribute to the implementation of sustainable depollution solutions, fostering a cleaner environment, enhanced public health, and a more resilient society.

As a future perspective, we plan to confront this DSML with real-world application cases to verify and validate its effectiveness and applicability. This will ensure that the proposed framework is capable of addressing the complexities and risks associated with depollution systems, ultimately contributing to more efficient and reliable solutions in the field.

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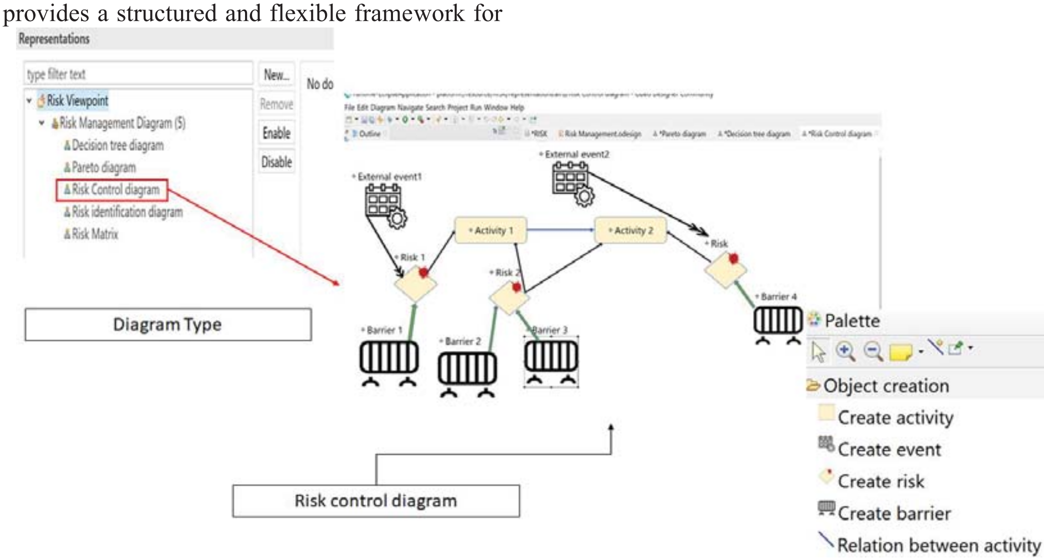

Figure 2: Tooling example

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