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► To cite this version:

mayssa Chebbi, Vincent Chapurlat, Jean-Samuel Wienin, Laurent Aprin, Philippe Girones. Project Engineering for the Depollution of Industrial Sites: a Model-Based and Systems-of-Systems Approach. INSIGHT - International Council on Systems Engineering (INCOSE), 2023, 26 (4), pp.26-29. 10.1002/inst.12466 . hal-04370421

HAL Id: hal-04370421

<https://imt-mines-ales.hal.science/hal-04370421>

Submitted on 10 Jan 2024

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Project engineering for the depollution of industrial sites: a model-based and systems-of-systems approach

Keywords: depollution, depollution system, system of systems, Model Based SoS Engineering (MBSOSE), risk management.

Introduction

Today, the rehabilitation of industrial sites for new uses is considered necessary on environmental, societal, human and financial levels [1]. Depending on the nature and duration of past industrial activities, a site may be impacted by different sources of pollution, with more or less long-term characteristics and effects. Such depollution then requires the design and implementation of projects, hereinafter referred to as depollution projects, whose mission is precisely to clean up the site to a level deemed sufficient for the purpose of the depollution.

These projects are described as complex for several reasons. They seem to have to be seen as different each time, depending on the characteristics, nature, possible recombination factors or even the simple quantity of pollutant. These projects must also take into account the type and architecture of the site, which is itself different each time, for example, in order to assess its accessibility, its extent, and above all, its precise state of pollution. The first observation in the field is that each project therefore seems unique, a special case, unrepeatable or even new. However, many of the numerous activities required are often of the same nature, and there are many points in common between them, for example through the possible sharing of experiences and concepts. The design and implementation of these projects is therefore seen as difficult to industrialize, in order to reduce costs, risks and the often very long lead-times involved. Secondly, these projects require the involvement of several trades with expertise in certain techniques and activities (e.g. measurement, assessment, excavation or waste management). They generally have the appropriate resources or are able to innovate and adapt when necessary. The second observation is that the real collaboration desired between these essential business players currently remains too limited and poorly managed, and is more a matter of working in silos. Finally, the phenomena observed in studies of field feedback (emergence of unexpected behaviors, managerial dependence of operating companies, operational dependence and interactions between the various elements of a decontamination project, etc.) further underline this complexity. The aim of the work undertaken is to develop and implement a method called DEPOSE (DEPollution model based System Engineering – Figure 1) for engineering and monitoring depollution projects. Our aim is to guide and support a group of professional players in the collaborative design, implementation and management of a depollution project perceived as a complex system. The aim is to enable the emergence of a form of industrialization expected of depollution, and a significant improvement in the indicators associated with these projects: shorter lead times, controlled risks, maximized safety and security of operations and players, as well as overall project performance and profitability.

Discussion

Existing depollution methods [3] are essentially aimed at improving depollution techniques by balancing technical solutions, economic constraints and environmental objectives. At the same time, several studies [4] list the difficulties faced by industry players in: describing what their depollution project is, what it involves and what it operates within (i.e. the need to be able to model and exchange project-related models), communicating with each other before launching specific technical activities (i.e. the need to be able to work together in a coherent, planned manner), assessing the effects a priori and then the actual effects in order to validate upstream and then adapt each project according to its dynamics over time. We have made several observations here. First, the absence of shared and well-known systemic concepts, offering a global vision of the depollution, the site, the players and their roles, implications and responsibilities, etc., makes it difficult to formalize and describe the depollution project. This is a systematic hindrance for business players, who often have different

business knowledge and practices, as well as partial use of modeling. Secondly, reuse, or even the simple fact of being able to draw inspiration in confidence from descriptions of past projects, remains difficult or even irrelevant, despite its proven value in many fields. Finally, the work involves a succession of activities (e.g. modeling, risk assessment, or process simulation) to guide and facilitate confident, consistent and, if possible, collegial decision-making. A more rigorous structuring is therefore needed to move towards better collaboration and progressive work, cultivating an environment of mutual trust).

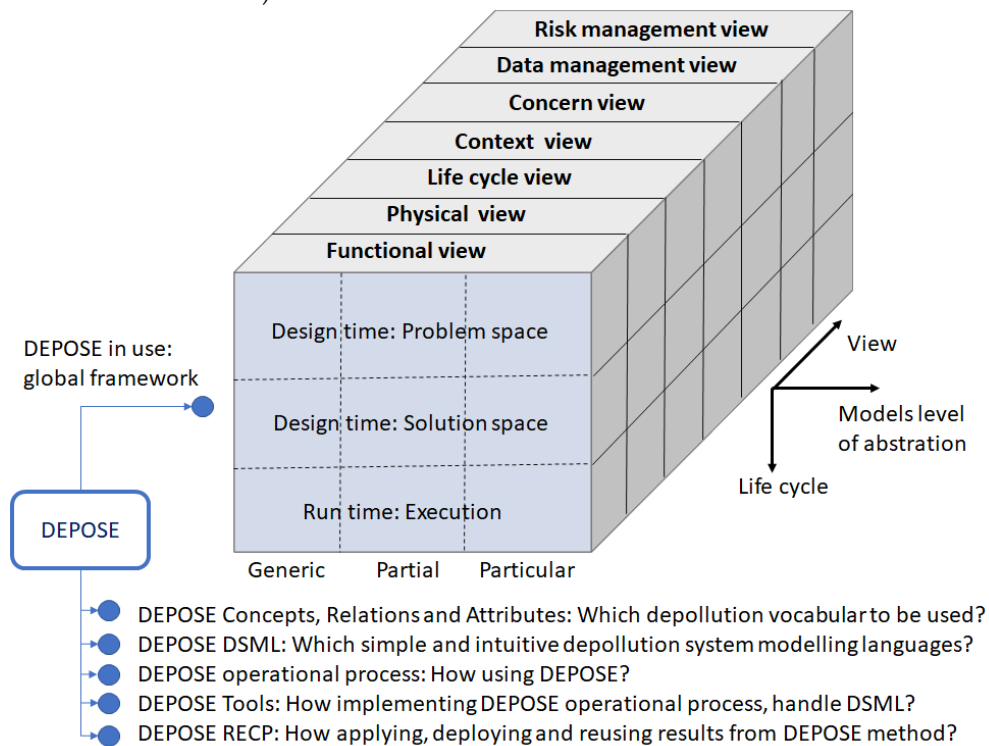


Figure 1 : Overview of the DEPOSE method

Research methodology

The research methodology that led to the development of DEPOSE is based on :

- A top-down, essentially bibliographical approach, from reference works on systems theory and MBSE/MBSOSE principles to the field (how to make these principles understandable, useful and usable? How can we then formalize them so as to plan how to implement them?)
- A bottom-up approach that starts with use cases and targets specific sites to refine needs, uses and habits, and thus confirm or question the top-down approach (how is cleanup carried out on different sites when faced with different types and nature, extent or complexity of pollutants?)

Contribution: the DESPOSE method

The DEPOSE method is based, on the one hand, on strong systemic principles to better perceive and master the inherent complexity of depollution projects. On the second and, it is also based on two assumptions. Firstly, we need to facilitate and equip modeling and model manipulation capabilities as early as possible, for example, to ensure verification or to simulate project behavior based on the content of these models. At the same time, this would make it possible to reuse all or part of, or even standardize, models from past depollution projects. The next step is to structure and organize the engineering work, i.e. the activities that mark out the project. These include activities aimed at defining the requirements to be met, the stakeholders involved, or the activities to be implemented during the project and the way in which they are synchronized over time. Modeling these activities and then analyzing them for the purposes of decision-making and argumentation is therefore crucial.

DEPOSE therefore borrows heavily from the principles and processes of Model-Based Systems Engineering (MBSE [6]), and more specifically Model-Based Systems-of-Systems Engineering (MBSOSE) [7][5][2]. This article focuses more specifically on its conceptual aspects.

A strong concept

Any depollution project requires a range of skills, knowledge and techniques that goes far beyond what a single company can offer acting in isolation. Pooling resources, skills and expertise is necessary to ensure the success of a project, from soil analysis and environmental engineering to community relations management and project financing. Collaboration between different, sometimes even competing, companies becomes imperative in this context. Emerging behaviors materialize, and the project's equilibrium requires, at the very least, considering the needs for managerial, organizational, and decision-making independence and the geographical location of each of the companies. The DEPOSE method is based on the concept that a depollution project can be seen as a System of Systems (the stakeholder companies) [5] called a Depollution System. The companies all work together to achieve a common depollution mission for a given purpose, for example, to enable new activities to be relocated to the site in the future.

A structured development process leading to the DEPOSE method

Once this conceptual hypothesis had been validated, the first stage of the research work consisted in identifying the points common to several projects and proposing a set of concepts applicable to depollution. These concepts, their attributes and the relationships to be considered between them were formalized in a single meta-model. This defines the basis of a common vocabulary for all depollution projects. With the aim of promoting a system vision (multi-view and multi-paradigm) and a model-based method, this meta-model has been structured into the following modeling views:

- Contextual view: to model the depollution system's environment in a given situation. It answers the question: "Which actors and elements interact with the depollution system? "
- Lifecycle view: to model the description of the evolution of a depollution system over time.
- Operational requirements view: to model and validate all the requirements (functional and non-functional) of the depollution system, and to model the expected behavior of the depollution system in the form of operational scenarios. The latter specify how the depollution system evolves according to different configurations and situations, events or risk opportunities. They also help to clarify requirements and make them comprehensible, since they can be manipulated by all project stakeholders, from site owners to contractors and regulatory bodies.
- Functional view: to model the overall depollution process, the activities that make it up, the resources that can then be allocated to it and the capacities required for the mission within the framework of the chosen purpose.
- Physical view: to model these resources, i.e. means, tools and techniques, as well as their interactions during depollution operations.
- Data view: to model the various data, information and knowledge [9] that can circulate and be exchanged in the depollution system.
- Risk management view: models the various events and hazards likely to occur and assesses their impact on the project, on the resources involved, and deduces any need to implement barriers [10].

As each concept and relationship in the metamodel is associated with one or more of these views, Domain-Specific Modeling Languages (DSML) [8] are then proposed. In this way, business stakeholders can model their own point of view on projects by manipulating the concepts of each view. Their models can then be shared and understood by other stakeholders throughout the project. These DSMLs therefore need to be understandable and usable by experts from different fields who are not necessarily modeling experts.

In order to implement the method, an operational approach has been developed to guide stakeholders and facilitate the various modeling, simulation, analysis and evaluation stages required to specify and manage depollution projects. This operational approach consists of two stages, which can be juxtaposed. "Design Time" focuses on the actual design and validation of the project as defined. "Run

Time" aims to implement and manage the project during its execution, ensuring the traceability of all modifications, results, operations, etc.

Every methods is ultimately supported, on the one hand, by tools (in this case, computer tools) and, on the other hand, by a Repository of Expertise, Knowledge and Practices (REKP). It enable stakeholders to acquire and rigorously follow the operational approach, to reuse past experience, or draw inspiration, for example in the form of technical activity modeling patterns or depollution technique implementation models. It also allows for the implementation of DSMLs and the unambiguous manipulation of defined concepts in a collaborative and trustworthy manner.

Outlook

The DEPOSE method is an initial proposal. Among other things, DEPOSE will have to propose and evaluate suitable key performance indicators (KPIs) for assessing the project throughout its lifecycle. These KPIs must enable objective measurement of the performance of activities, safety and security of stakeholders and, where possible, verify that the project meets the specific requirements and challenges of the field concerned.

Finally, the computer tools supporting the method are currently being validated in order to test, complete and validate all the elements (concepts, DSML and operating procedure, use and implementation of REKP) of the method. Several use cases are being used for this purpose. The DEPOSE REKP can then be fed with implementation guides, examples of models, or study REX considered reusable to move towards the desired real industrialization of depollution. The aim is also to assess the response of this method to the economic and human challenges identified at the start of our work.

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