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# Open Inventive Design Method (OIDM-Triz) approach for the modeling of complex systems and the resolution of multidisciplinary contradictions. Application to the exploration of innovative solutions to deal with the climate change impacts

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**Abstract.** This paper aims to propose an approach for Open IDM-Triz oriented analysis for complex systems.

We propose an approach to model a complex system involving multiple points of view. In this way, a complex system is modelled by a meta-graph that is built using partial knowledge graphs based on the viewpoints of the different stakeholders and users around the complex system.

This work is also a contribution for resolving non-conventional pluridisciplinary contradictions by extending the limits of classic Triz patents databases which is mainly focused on technical aspects.

Thereby, we propose an approach to extend IDM-Triz solutions concepts exploration area by using web-scraping and AI reasoning to search for similar contradictions. These approaches are implemented in a TrizAlerts software that scans various databases and websites to find out ideas matching given contradictions. Our Open IDM-Triz approach is applied in the Interreg Clim'Ability Design project, to analyze the climate change impacts on the activities that usually manifest themselves in multiple ways.

By applying the Open IDM-Triz approach to the "Low Water" issue, we are moving away from the classical application domain of Triz because of the context extended to a multi-scalar territory corresponding to a complex system of actors impacted by climate change.

The study is carried out by a multidisciplinary team made up of researchers from engineering and social sciences backed by a network of companies involved in logistics on the Rhine (institutional, shippers, operators, etc.).

**Keywords:** Open IDM-Triz, Open Innovation, Complex system Modeling, Pluridisciplinary contradiction resolution, Climate change impacts analysis, TrizAlerts Artificial Intelligence.

## 1 Introduction

The traditional approach of IDM TRIZ is mainly based on the use of generic design parameters and does not take into account some aspects needed in the analysis of a complex system which, in addition to the technical dimension, includes other dimensions related to the difference in perception and appreciation if we consider several groups of actors. The main motivation of our contribution is to propose an extended approach to these non-technical dimensions.

Indeed, the successful feedback of the IDM-Triz contributes to the extension of its fields of application, from the industrial products to the most complex system involving multiple stakeholders. Our article is part of this dynamic initiated by the request of social science colleagues who work on the scale of complex territories where actors are intertwined in space and time. The colleagues wished to extend their usual survey approach to digitally assisted forms. Their demand arose in the context of the 2018 low water crisis on the Rhine in an Interreg V project. It has allowed an experimentation of the method to complex systems. After presenting the classical way to perform IDM-Triz study, we propose an approach for complex system modeling by taking into account structural and functional viewpoints.

In section 2 the classical way to perform IDM-Triz study is presented [2], then section 3 outlines an approach for complex system modeling by taking into account structural and functional viewpoints. Section 4 presents a Social Sciences methodology for problem analysis. Our Open IDM-Triz approach is described in section 5. Then in section 6 we propose a method for resolution of pluridisciplinary contradiction. Our TrizAlerts software is presented in section 7. And finally, section 8 outlines an application of the proposed Open IDM-Triz approach to analyze the low water problematic and its impacts [11].

## 2 Inventive Design Method based on Triz (IDM-Triz)

The Inventive Design Method (IDM) derives from TRIZ, the theory of inventive problem solving whose goal is to theorize on the act of inventing using the bases of patent's analysis [7].

### 2.1 Solving classical inventive problems

The conduct of inventive design classic study proceeds from a linear approach going from the analysis of the initial situation to the generation of solution concepts through the identification of contradictions and their resolution (Fig. 1).

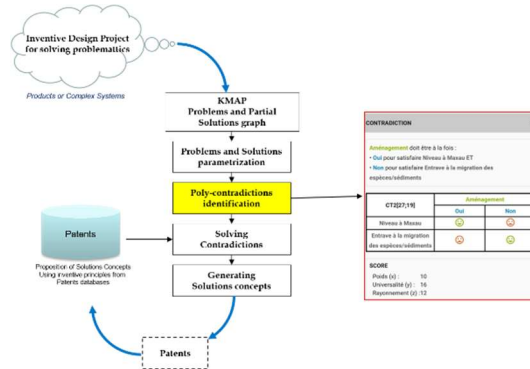


Fig. 1. Classical IDM-Triz project workflow

## 2.2 Semantic limitations in problem graph

In the problem graph, a problem is formulated according to the syntax:

$$\text{Subject} + \text{verb} + \text{complement} \quad (1)$$

and is characterized by Evaluating Parameters.

And a partial solution is expressed in the syntax:

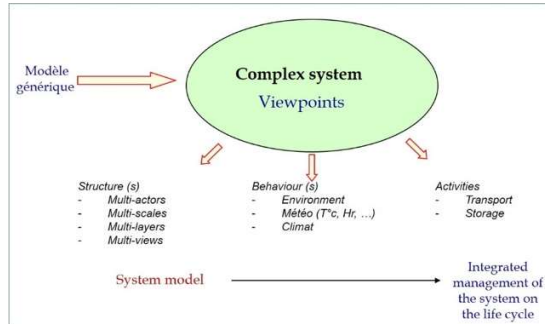
$$\text{Verb} + \text{complement} \quad (2)$$

This formalism is insufficient to analyze a complex system. Indeed, in this formalism, the evaluation parameters are generally defined in relation to the 39 generic design parameters whereas in a complex system the semantic aspects must be taken into account to evaluate a problem. Similarly, for a partial solution is generally formulated by deterministic action verb. Therefore, such parameters do not take into account situations that require the search for consensus with non-deterministic actions in advance. In the next section, we propose an approach for complex system modeling.

## 3 Complex systems modeling

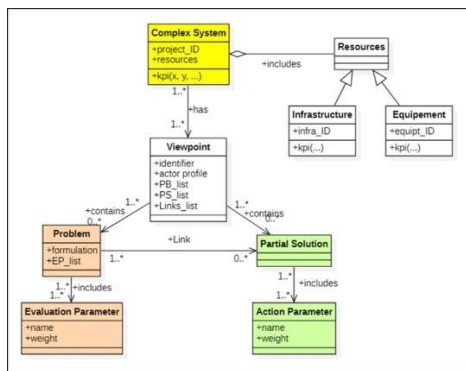
### 3.1 Object-oriented modeling

The complexity of a system is characterized according to different points: structural, functional, static and dynamic [8]. It is also necessary to take into account the level of perception of the system, which implies the multi-scale dimension. Finally, we must take into account the viewpoints of the actors involved in the implementation of the system [3,4]. Fig.2 gives a general perception of different aspects of a complex system.



**Fig. 2.** A complex system modeling levels

Taking into account these aspects, a complex system can be structurally modeled in terms of conceptual classes using UML language formalism (Fig. 3).



**Fig. 3.** A complex system UML class model

The different activities of the stakeholders around a complex system can also be represented with a UML use case diagram (Fig. 4). This allows to identify activities and actors and to structure this knowledge.

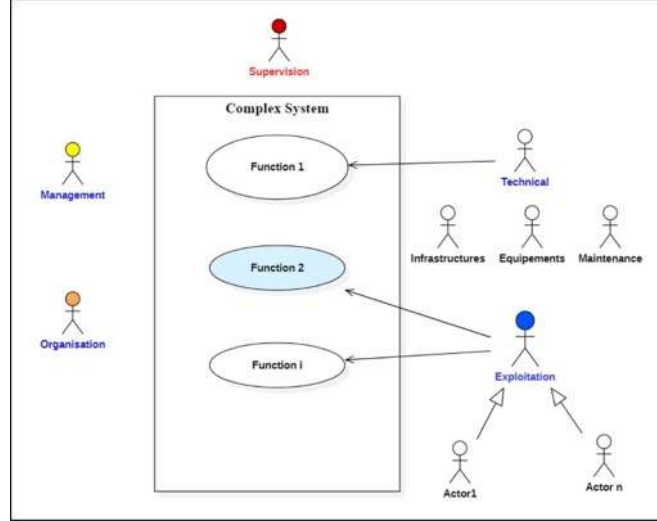


Fig. 4. Multi-scale and multi-actors' perception of a complex system

### 3.2 Multi-views problems graph

The multi-actors' perceptions are modelled as viewpoints that describe the different actors' profiles [5]. Each viewpoint has its own problems graph with specific sets of problems and sets of partial solutions. Thus, a global problems graph of a complex system is made by the superposition of these specific problem graph related to the different actors' profiles. The identification of the interactions between the different evaluation and action parameters follows from this superposition. As hypothesis, we define the following concepts used to elaborate the multi-views problems graph of a complex system:

- *Graph*: a graph is specified as:

$$VP\_Graph (PB, PS, Links) \quad (3)$$

where:

*PB*: is a set of problems ( $PB_1, PB_2, \dots, PB_n$ );

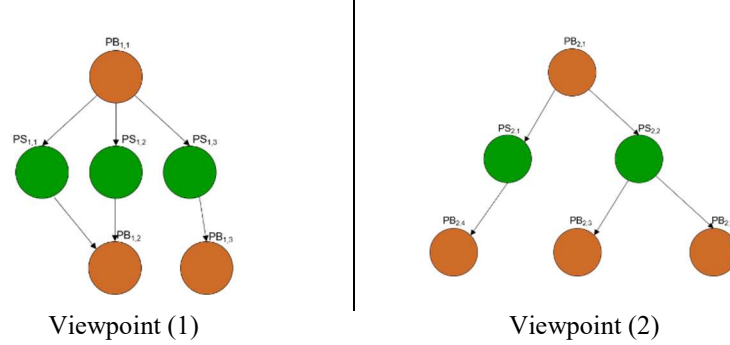
*PS*: is a set of partial solutions ( $PS_1, PS_2, \dots, PS_n$ );

*Links*: are relationships between problems *PB* and partial solutions *PS*.

*VP\_Graph*: is a graph that describes a set of problems corresponding to a specific viewpoint;

$CS_{graph}$ : represents the multi-views graph of the complex system (Fig. 5).

$$CS_{gr} = \sum_{vp=1}^k \{VP\_Graph\}$$



**Fig. 5.** Multi-views problem graph of a complex system

Each viewpoint chart can be selected separately or the charts can be combined. In the latter case, the analysis of the complex system must merge the 2 viewpoint graphs. To do this, it is necessary to make a semantic analysis of the problems and partial solutions in order to identify the identities and the differences. This analysis must be extended to the evaluation parameters (EP) of the problems and to the action parameters (AP) of the partial solutions.

The problems and partial solutions interrelationships may be represented using a semantic matrix. Such matrix allows a more comprehensive and readable representation.

Table 1 is a representation in a matrix form of the relationships between the Problems  $PB_{i,j}$  and the Partial Solutions  $PS_{n,m}$  identified by the different groups of project stakeholders who generally have different points of view on the analysis of the project.

Existence and absence of a relationship between a problem and a partial solution are respectively indicated in a binary way by 1 (one) and 0 (zero).

$EP_{i,j,k}$ : represents an Evaluation Parameter of the problem  $PB_{i,j,k}$ : where  $i$  designates the group of actors,  $k$  is an evaluation parameter numberer,  $k$  represents the number of partial solutions associated with the problem  $PB_{i,j}$ .

Analogously,  $AP_{i,j,k}$ : represents an Action Parameter of the partial solution  $PS_{i,j,k}$ : where  $(i)$  designates the group of actors,  $(j)$  is an action parameter numberer,  $(k)$  represents the number of problems associated with the Partial Solution  $PS_{i,j}$ .

**Table 1.** Semantic matrix representation of a complex system

	$PB_{1,1}$	$PB_{1,2}$	---	---	$PB_{k,1}$	$PB_{k,2}$	
$PS_{1,1}$	1	0	1	0	0	1	$AP_{1,1,k}$
$PS_{1,2}$	0	1	0	1	1		
...	0	0	1	0	1	0	
$PS_{n,1}$	1	1	1	0	0	1	
$PS_{n,2}$	1	1	0	1	0	0	$AP_{n,2,n}$
	$EP_{1,1,1}$				$EP_{k,1,1}$		



## **4 Social Sciences methodology for problem analysis**

### **4.1 Individual and semi-structured interviews & SWOT analysis**

In-depth qualitative interviews favour the identification of the rationality into action of an actor. Each actor we met testimonies about concrete practices situated in specific contexts. Compared to quantitative survey methods based on questionnaires and to collective interviews in form of focus groups, the added value of the individual interview is to precise the respective understanding of the situation which condition their modus of action or agentivity, according to the organisational models they expect to act. Each interview is analysed through the SWOT grid which offers a compact view of the main stakes for an actor. These compact representations make it easier to extract the similitudes and differences between the actors [13].

### **4.2 The gap between SWOT and Focus groups as indicator for the dialectic between individual and society**

Compared to the individual interview method, the IDM-Triz approach aims rather to capture common visions of a shared issue by the members of a group. The focus groups aspire to a common vision instead of many different ones. The consensus won from the focus groups can be compared with the SWOT deriving from the individual interviews to identify the gap between the individual position and the collective one [12].

## **5 Open IDM-Triz approach**

### **5.1 Parameters semantic formulation**

The attribution of state and action parameters constitutes a key moment of interdisciplinary and thus of the interest of crossing engineering sciences with social sciences. In the IDM-Triz approach, the parameterisation step is very useful for placing problems on a scale of intensity or severity and specifying possible solutions to them. However, when this approach is applied to a complex system, it encounters an important coding question because of the distinction between two kinds of variables. Coding is easy when it refers to measurable and quantifiable elements in euros, metres, tonnes or days. This is not the case when it comes to determining the social acceptability of implementing a partial solution, for example, or the extent of its ecological impact on ecosystems. These questions involve the subjectivity and sensitivity of the respondent and can hardly be reduced to a binary code (high/low social acceptability; high/low impact on ecosystems). The coding of these parameters requires the search for consensus. In the application of the IDM-Triz, the step of parametrization of the problems and partial solutions privileges all the quantitative dimensions of the problem and marginalises, or even evacuates, all the elements of a qualitative nature, which are more difficult to weigh up but which are nonetheless fundamental for the identification of solutions that are acceptable to all the stakeholders.

## 5.2 Weighting parameters

When it comes at least to the weighting of the solutions drawn by the stakeholders, the distinction between the variables with calibrated devices and the one without it may discriminate the latter one. Unlike physicians, social scientists are used to encounter variables which are intertwined with esthetical, ethical, political and normative values. This situation obliges them to construct some indicators without established universal equivalents. This consideration put the question of objectivation in the forefront. The objectivation can be win by inquiries which provide some statistics. The statistics may discriminate between some considerations without calibrated measuring device. These situations happen many times in multi-scalar, multi-actor and open systems. The result is a loss of objectivity that can be problematic especially when it comes into competition with variables well equipped. This distinction may minimize the social and ecological acceptance of the solutions when it comes, in the last step, to weight solutions [6].

## 6 Pluridisciplinary contradictions formulation and resolution

### 6.1 Contradiction formulation

A pluridisciplinary contradiction requires more than a simple relationship between an given Action Parameter ( $AP_x$ ) and its effects on a couple of Evaluation Parameters ( $Epi$ ,  $EPj$ ). To overcome this limitation, we propose a more general formulation in order to take into account simultaneously the good, harmful or non-influence effects on various evaluation parameters. These cases are marked respectively by semantic parameters  $Va$  and  $Va'$  with values in  $\{+1, -1, 0\}$  as shown in the following table.

**Table 2.** Pluridisciplinary contradiction representation

	$AP_x$	
	$Va$	$Va'$
$EP_1$	+1	0
$EP_2$	0	-1
-	-1	0
-	-1	0
-	0	+1
$EP_{1k}$	+1	0

### 6.2 Contradictions resolution

A multidisciplinary contradiction translates the differences in perception of the problems and partial solutions according to the different profiles of project actors. Therefore, the same action parameter ( $AI$ ) could induce contradictory effects depending on the profiles. In such situations, a consensus-building process is needed to validate the action.

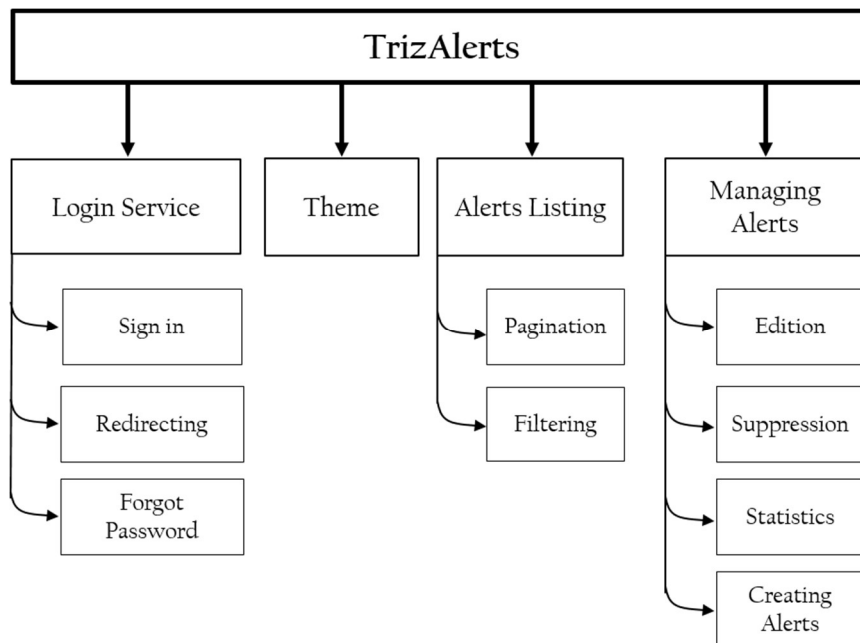
## 7 Extending solutions concepts area

### 7.1 Triz patents databases scope and limitations

The Triz reference patent database [10] is generally inspired by industrial patents. Also, it is not necessarily suited to the study of complex systems with non-technical dimensions such as organizational, sociological, environmental or even political aspects [18].

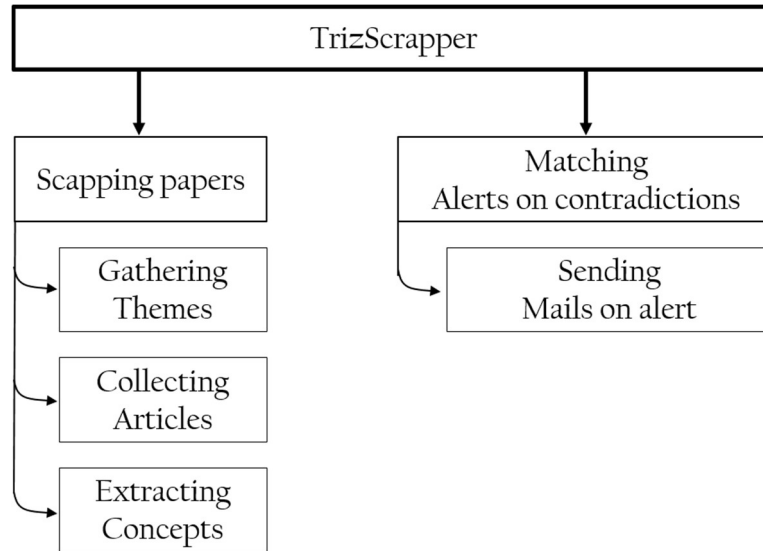
### 7.2 Web scraping and Artificial Intelligence for contradictions resolution

We implement a TrizAlerts software which uses the Web scraping technique for extracting alerts from the content of websites with the aim of identifying articles that match a contradiction formulated by the user. To evaluate the correspondence between the articles and a contradiction, this software implements an algorithm based on Artificial Intelligence which evaluates the coverage rate of the inventive principles eligible to resolve the considered contradiction [1] (Fig. 6).



**Fig. 6.** TrizAlerts functional structure

As shown in figure 7, the TrizAlerts is a web service dedicated to the creation of alerts based on the Triz contradictions to detect the publication of research articles on scientific sites and to inform by sending regular emails.



**Fig. 7.** TrizAlerts Scrapper

Based on the different CSIP's services, particularly in artificial intelligence, the performance of TrizAlerts is mainly based on the reliability of this software ecosystem. With its friendly user interface, TrizAlerts allows an easy way to formulate multidisciplinary contradictions and adjust the emails sending frequency.

## 8 Application Open IDM-Triz to low water problematic

### 8.1 Clim'Ability Design project

In the continuity of Clim'Ability (2016-2019), the Interreg Clim'Ability Design (2019-2022) project offers companies in the Upper Rhine region devices to outline solutions to deal with the climate crisis. The project is engaged with companies willing to contribute to in-depth studies on the scale of specific branches or clusters to improve adaptation strategies [14].

In this context, we apply our Open IDM-Triz approach to study the problematic of low water and their impacts on various activities related to the navigability of the Upper Rhine.

### 8.2 Freight transport on inland waterways and the Rhine low water crisis in 2018

The low water crisis on the Rhine draws a complex system by its linear through different countries and their different national jurisdictions. These national stakes are redoubled by economic stakes depending on the importance of navigation on the Rhine for each country. Dependence on the Rhine is greater for Germany than for France, and is

crucial for Switzerland, whose port is both the only sea and river port [16]. However, the severity of this crisis, during which large cargo vessels were no longer able to navigate certain sections of the river (CIPR 2018, 2019), was a wake-up call for the inland navigation sector. Transport operators and infrastructure managers have been forced to question their practices and organisational models by reintegrating them into a context of tensions and strong uncertainties linked to the future climate and its consequences on the water levels of the Rhine. Conducted as part of the Interreg Clim'Ability Design project, our study aimed at outlining, together with river transport stakeholders, sustainable adaptation paths for both the river and the economic activities associated with it and for the territories [17, 18, 19].

### 8.3 Process of the study and the multi-actors' problem graph

From July to October 2020, social scientists conducted a series of individual interviews with French river operators regarding the impacts of the 2018 low water crisis on their activities. They met with river and port infrastructure managers, shippers, container carriers and dry and liquid bulk carriers. The study provided a clear picture of the internal and external factors that affect the ability of companies to cope with low water. In order to structure a common vocabulary and avoid misunderstandings, the implementation of the inventive design method took place from September to March 2021.

Figure 8 gives an overview of the multi-actors' problem graph co-constructed by the different teams of actors made up of carriers (containers and bulk) and managers.

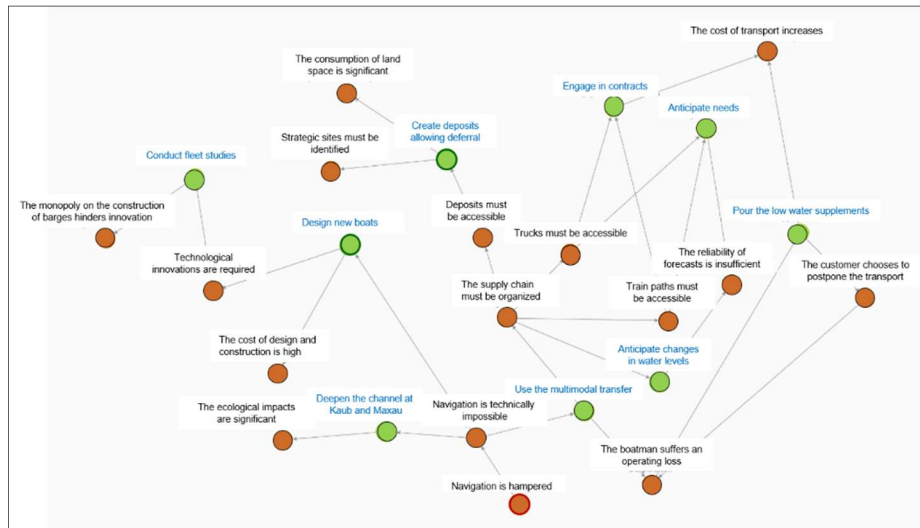


Fig. 8. Co-constructed multi-actors' problem graph

## 8.4 Results

To solve the contradictions identified from this problem graph, we analysed the system by combining the sociological inquiry and the inventive design method. This permitted to identify 3 types of solutions: The infrastructural one, the organisation one and the technical one. The transformative infrastructural adaptation is the kind of solution which convinced the most stakeholders involved.

The organisation one which is mainly based on the inter- and multimodality attract some attention. The technical solutions which focus on the vessel didn't win much attention because of previous progresses made in this sector.

## 8.5 Using TrizAlerts for solutions concepts exploration

In order to extend the search domain of solution concepts, we use the TrizAlerts software to explore open databases containing scientific articles or documents dealing with contradictions similar to those we wish to resolve.

Figure 9 and 10 show the editor for contradiction formulation and submission.

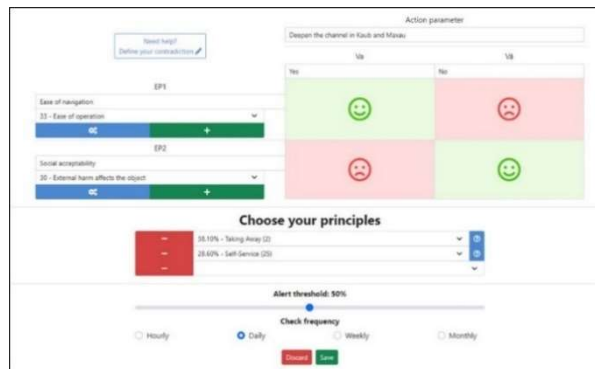


Fig. 9. TrizAlerts Editor

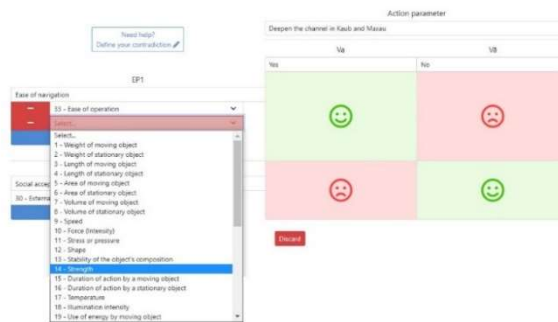


Fig. 10. TrizAlerts Editor (Inventive principles)

Search tests in the documentary databases were carried out over 3 months and made it possible to identify 31 documents, including 6 articles dealing with issues similar to our project on low water.

## 9 Conclusions

In this article, we have proposed an approach to model a complex system in order to apply the inventive design method to it. To achieve this task, we combine different scientific cultures. The parametrization and the weighting of the solutions imagined by the stakeholders was a stimulating momentum of this interdisciplinary experience which conducted to a method for the resolution of multidisciplinary contradictions. The differences between the individual priorities and the one drawn by the focus groups was another important result. We observe that the delegation's solutions were largely elected instead of the options which necessitate to reorganize their production collective. Finally, in order to strengthen the concept of solutions, we have developed Tri-zAlerts, an internet search software based on the formulation of contradictions resulting from the analysis of the effects of planned actions.

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