**Case study 9 :**

**Lessons learned**

**Sensibilities and vulnerabilities of small and medium enterprises in the Upper Rhine Region**

**Impacts and adaptation of the Rhine transport system**

*Work Package 3 – Deliverable 3.1*

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| **Short summary**  In 2018, the Rhine transport sector experienced an unprecedented low-water crisis, during which large cargo vessels were no longer able to navigate on certain sections of the river. This led to a major disruption in the inland waterway transport. The severity of this crisis, which was the result of several months of drought, reinforced by heat waves and low rainfall over the same period, caused a major disruption in the inland navigation sector. Some of the traffic was absorbed by other intermodal providers and the wagon load rail system but it was not sufficient.  This report presents the results of a study where researchers and river transport stakeholders have striven to find sustainable adaptation pathways and how the mixed methodology combining semi-directive interviews and collective brainstorming with the help of a collaborative methodology (particularly deployed into engineering design processes based on the use of a specific software (TRIZ) could help to integrate nuances. This could consequently allow stakeholders to write stronger collaborative narratives for adaptation pathways and to apprehend the impact chain concept. | |

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# Introduction

## Case brief description

In 2018, the Rhine transport sector experienced an unprecedented low-water crisis, during which large cargo vessels were no longer able to navigate on certain sections of the river. This led to a major disruption in the inland waterway transport. The severity of this crisis, which was the result of several months of drought, reinforced by heat waves and low rainfall over the same period, caused a disruption in the inland navigation sector. Some of the traffic was absorbed by other intermodal providers and the wagon load rail system but it was not sufficient.

This report presents the results of a study where researchers and river transport stakeholders have striven to find sustainable adaptation pathways and how the mixed methodology combining semi-directive interviews and collective brainstorming with the help of a collaborative methodology (particularly deployed into engineering design processes based on the use of a specific software (TRIZ) could help to integrate nuances. This could consequently allow stakeholders to write stronger collaborative narratives for adaptation pathways and to apprehend the impact chain concept.

This study was carried out with the INTERREG project, Clim’Ability Design.

**Study areas**

Upper Rhine Region and more specifically Strasbourg and Basel regions. Rhine is an international natural and economic infrastructure. It is managed by a multi-level governance; international and local authorities are involved in the waterway transport system.

Low water phenomenon has consequences on different countries (Swiss, France, Germany), on the supply chains on different sectors and more particularly waterway transport. The main and common problem is the worsening and even the interruption of the inland waterway transport.

**Stakeholders involved**

River and port infrastructure managers, shippers, container carriers and dry and liquid bulk carriers

**Expected results**

This knowledge coproduction was deployed to facilitate and empower stakeholders face to a transborder climate change risk, where the sectoral awareness and the decisions taken at a local level are not sufficient to tackle the different issues raised. It needs a comprehensive understanding of the vertical and horizontal interrelations of the inland navigation and how low waters impact the very optimised socio-economic process.

## Selected Impact Chain

Interruption of the waterway inland transport because of low waters due to drought and lack of shortfalls.

It was ambitioned to better understand the impacts at the individual and collective scale of stakeholders (according to their role in the supply chain or in the regulation regime as the Rhine river is an international-regulated infrastructure).

## Innovation areas and research questions addressed

**Innovation area “Impact Chain Model & Uncertainty”**

1.2. How to identify the relevant system elements and their interrelations when doing impact chain analysis?

5.How to forward the impact chain approach from a ‘linear’ representation of risk components towards more system dynamics-oriented models?

**Innovation area “Co-production of knowledge”**

2. How was results from the climate risk assessment perceived by stakeholders and scientific knowledge providers?

**Innovation area** “Transborder climate change impacts”

1. Methodological approach to case study and related Impact Chain

We intended to develop citizen science to build new processes of common knowledge and decision building. Our research was at the crossroads of the questions, expectations of scientists and of stakeholders involved on the Rhine. The 2018 low-water crisis played the role of a “window of opportunity”, that is to say that different “streams” was gathered to make possible a discussion between the different actors (in parallel of the concept developed by Kingdon (Kingdon 2003), concerning public policies and agenda setting). Changes and particularly the sensitivity to an issue and a common will to find one or many solutions can occur if different streams crop up: a crisis, an identification of the issues which need to be solved, the existence (and the selection) of possible solutions

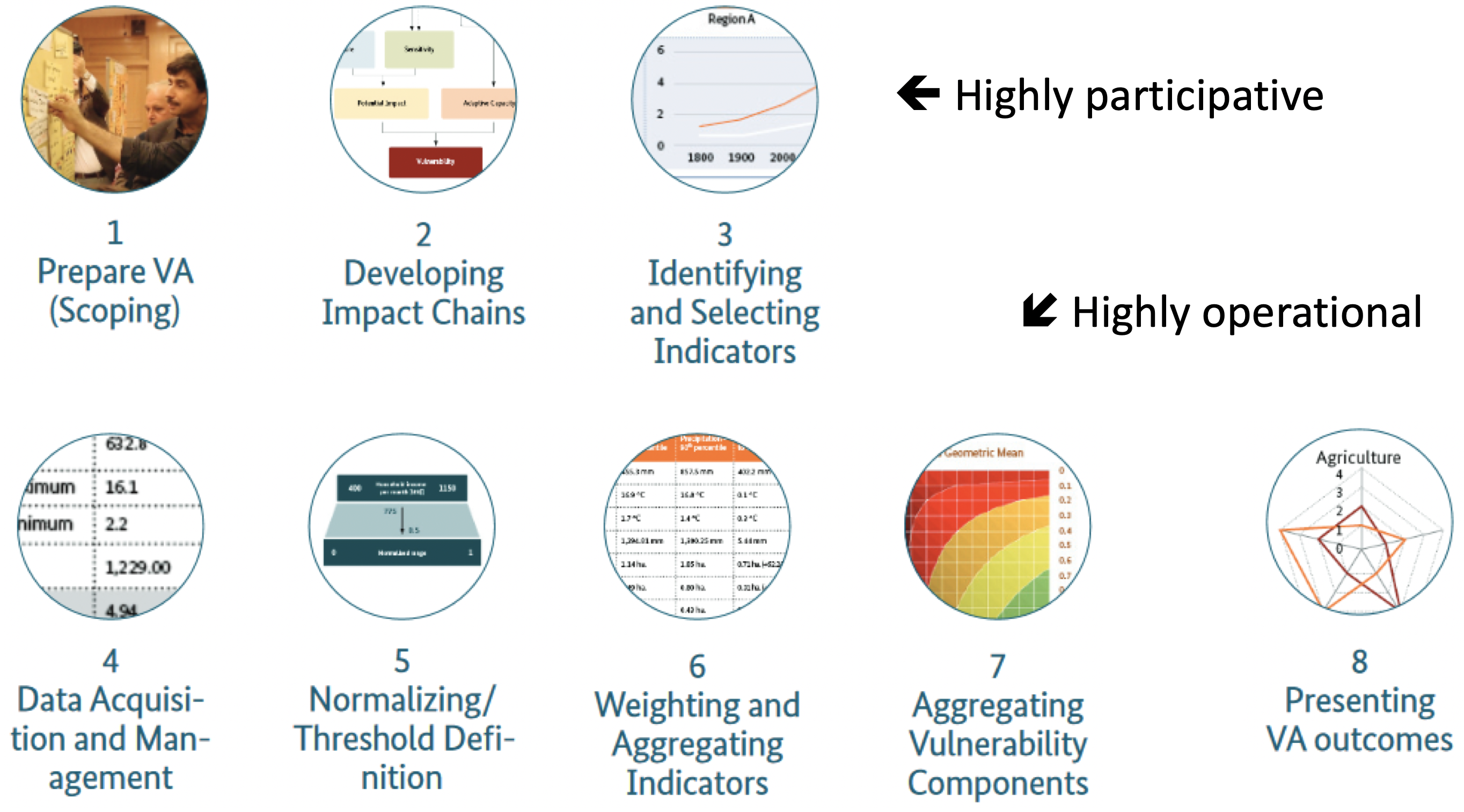
The crises act as an indicator of the significance of some issues, which is more or less known, but not considered as urgent enough to be solved, as serious enough to dedicate time and money to obtain more information. Considering the consequences of climate change on the Rhine, for stakeholders, there is too much information to process. Often, they do not know what studies exist on the Rhine and the impacts of the climate change. Besides individually, they do not feel legitimate to act.

Then the crisis offered an “opportunity” because it revealed the individual and collective vulnerabilities for the inland waterway transport and justified the involvement of stakeholders into new discussion circles. That is why we took this opportunity to make true a cooperation with Strasbourg port authority and to meet with stakeholders.

In this report we have decoupled what the semi-directive interviews bring us (information about the individual/sectoral forms of vulnerability, the way the crisis was happening and managing, the solutions which were at this occasion created and thought…) and what the TRIZ method achieves (exploring all partial solutions envisaged and identified bottlenecks).

To present the methodology employed we respected the generic framework of the project but decided to employ the word “variables” rather “indicators” as explained in the report, because we consider with stakeholders that indicators’ construction is the result of an aggregation of stabilised variables.

Figure 1 – Impact chain model



1. Prepare Vulnerability Assessment (Scoping)

**RQ addressed**

1. How to identify the relevant system elements and their interrelations when doing impact chain analysis?
2. How to better integrate quantitative, semi-quantitative, qualitative and narrative approaches?

These questions developed in the JPI-Unchain case study protocol were then refined:

* Which institutions and resource exist and should be involved in the vulnerability assessment?
* Which resources could be useful to understand the individual and global vulnerability to the risk of low water?

**Process**

The preparatory phase was based on the reading of the grey literature (literature produced by institutionalised stakeholders like the central commission for the navigation of the Rhine, the port authorities, the national authorities managing the inland waterway transport and flows…), of academic literature (dedicated to the specific impact of droughts and lack of rainfalls on the river levels and then the capacity for transport providers and the associated supply chains) (Parmet, Kwadijk, et Raak 1995; Thirel et al. 2015).

Moreover, after a long approach phase with Strasbourg port authority, a work relation has been built and enabled researchers to identify key stakeholders (transport providers, importers/exporters using inland waterway transport…), and to immerge themselves into an existing network[[1]](#footnote-2). This immersion and consequently the understanding of the issues raised by low waters from operators’ point of view were particularly noteworthy. It progressively opened the access to the operators, not only to organise collective workshops, but also to facilitate the possibility to fix appointments for interviews.

A mixed method was then employed to understand the vulnerability of the firms and the territories to low waters: semi-directive interviews with stakeholders concerned by low waters (1), and the implementation of the inventive design method to stimulate a cooperative understanding of the collective vulnerability to the risk.

1. From July to October 2020, social scientists conducted a series of individual interviews with (French and Swiss) 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.
2. The MCI-Triz Inventive Design Method is a participative engineering approach that allows to propose breakthrough solutions to solve problematic situations or industrial impasses. The process is divided into 6 main steps:

* Collecting information from a sample of firms and operators hint by the issue;
* The construction of a “problem graph” whose root corresponds to the key problem. In this case, because of drought and a lack of rainfalls, navigation on the Rhine is hindered during low water periods and then stopped the inland waterway transport which has consequences on different levels, at the international, local, and intra-firm scales
* The identification of evaluation parameters (EP) and action parameters (AP) which respectively allow the problems to be placed on a scale of intensity (severity) and the possible solutions to remedy them;
* The construction of a graph of contradictions resulting from the evaluation and action parameters and action parameters;
* The resolution of the contradictions, based on Triz (Theory of Inventive Problem Solving), in view of an outline of solutions (Solution Concepts or CS).
* The solution concepts (SCs) are then evaluated in order to identify the most relevant that could be implemented.

This phase demanded a short training to TRIZ and its functions for all participants.

As far as researchers are concerned, very different disciplines were invited to work together (science engineering and social sciences) and obliged to structure a common vocabulary.

Besides, thanks to their immersion, researchers have progressively analysed and learned stakeholders' way of thinking and language. This ‘translation” step is fundamental to build equivalences between the different “worlds”: the universe of social sciences, the universe of TRIZ (and design thinking) and the operator’s universe. Each rationale has to be taken into account so that to avoid misunderstandings.

Figure 2 - Table of the different stakeholders involved in the process and impacted by low waters

**Rhine**

A transport infrastructure - An anthropized river whose regime is changing

**The importing/exporting firms (shippers)**

* Customers of transport services who are asking for more and more spezialised and individualised services (door to door)
* Differenciated needs according to the transported goods and the transport mode (bulk/containers/liquids, refrigeration, …): logistics organisation different according the value chain and crisis

**Consequences of low waters**: additional tax, increasing transport prices that have to be taken into account, order cancellations…

**Adaptation:** can use and arouse competition between transport modes, between inland waterways transport firms (except when contracts exist)

**Infrastructure service providers**

Service providers providing load breaking, storage, etc.

Ports (port authorities, infrastructure managers, handling managers, etc.)

**Impact of low waters** Decrease of their activities of transshipment, increase of the storage activities

**Adaptation:** developing storage capacity, infrastructure facilitating intermodality

**Inland waterways transport stakeholders (carriers)**

* Freight transport agents
* Broker in inland waterways transport
* Bargees firms

**Impacts of low waters:** very slowed or interrupted traffic.

Search for road/rail alternatives

**Constraints:** lack of data

Actors under pressure (competition, low remuneration of the transport part in the global price of commoditie**s)**

**Adaptation**: horizontal coordination, demand for infrastructural work on the Rhine to increase navigability...

**National and international institutions (regulators)**

State and local authorities

VNF (French national institution managing inland waterways transport)

CCNR (International body regulating inland river transportation)

Dilemma : strong promotion of inland waterway transport but this objective have to be reached through a significant improvement of intermodality

Stakholders of the other transport modes

**Outcomes**

After this first phase we had preliminary insights about the global vulnerability to the low water, the solutions which have been evoking for a long time and more recently. We could consequently have a 1st view of the impact chain.

This mutual acculturation between different professional universe and with a specific software is time-consuming and necessary to strengthen the phase.

1. Developing a 1st impact chain

**RQ addressed**

How to draw clear causal links between climate signal and impact / actual risk to the investigated asset?

How to identify and consider interdependencies between climate change risks?

**Process**

We led semi-directive interviews to understand the impacts on the value chain of inland waterway transport. We could therefore have a first overview for all firms and operators of the consequences of low waters.

What is exactly the hazard and its consequences? What does it reveal from the individual and collective vulnerability?

Water levels on the Rhine River fluctuate with seasonal rainfall[[2]](#footnote-3), and both high and low water levels can create problems for barges. As such, barges need to adjust the amount of cargo they carry to balance bridge clearance and deep draft restrictions based on water levels. Low water levels mean barges must carry less cargo, increasing the freight rate per unit of cargo. Low waters are particularly impacting at certain water levels because many vessels cannot anymore move because they need a large draught for loading the goods they carry. The inland waterway transport can event be stopped to avoid accidents and groundings. This was the case in 2018.

The direct economic impact is that low water levels on the Rhine since July 2018 had resulted in increased barge freight rates.Low-water surcharges apply at critical water levels. The additional charges are calculated depending on the water level[[3]](#footnote-4).

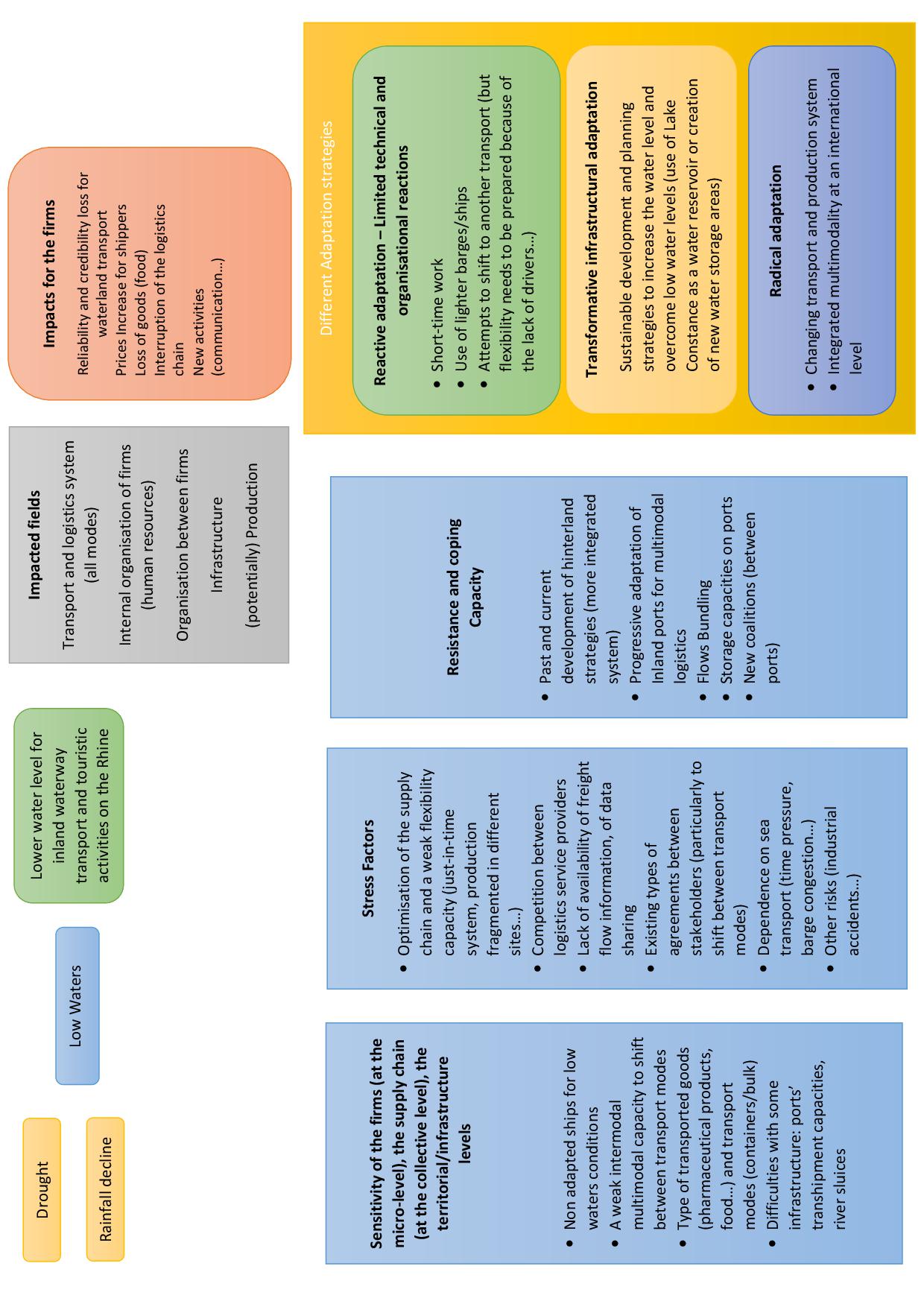
According to the goods transported and the transport modes (in bulk/container), intermodal solutions can be rapidly considered (transferring goods from inland waterway to roads or rail). But the other transport modes have also their own inertia. First and foremost, transferring all containers on roads or rail is impossible because of the considered volumes and the types of goods. **Alternatives to shipping** products on the Rhine River are costly.

It also appears complicated to change the transport mode if the transport providers impacted by the crisis do not have previous contracts with rail or road transport companies. Moreover, some resources may be lacking. The rail paths are considered as not sufficient and overloaded to assure the transferability. The lack of skilled drivers is a European issue[[4]](#footnote-5), which reveals itself particularly symptomatic when a crisis breaks.

That is why reacting face to this kind of crisis requires a collective agility and demands a deeper and longer work between stakeholders: firms which have to transport goods or resources, carriers, port authorities. The port authority with researchers proposed then a process of collective brainstorming to better identify the different issues raised by low waters, the solutions which be draught, the contradiction between them, and to select the best solutions which worth to be explored.

**Outcomes**

Figure 3 - 1st version of the impact chain for low waters



From this perspective it was relevant to deepen this first draft, while integrating a more precise representation of the different problems and the level of support for the solutions outlined (reactive adaptation, transformative infrastructural adaptation and radical adaptation).

1. Identifying and selecting useful and meaningful variables for stakeholders

**RQ addressed**

How to combine a multitude of (sector-specific) information and still present them in a clear and concise manner?

**Process**

During low water periods, logistics and manufacturing operations face shipping capacity reductions that disrupted both inbound raw material and outbound product delivery flows for companies located along the river. But the consequences and the reactive capacity cannot just be calculated through the impacted tonnage and volume of goods to be transported and the extra-charge supported by shippers.

The identification of the variables which have a meaning for stakeholders and on which they based their activities and their vulnerability was worked from interviews, an immersion phase with stakeholders and the reading of grey literature (journal articles, documents written by actors, regulators, infrastructure/service providers).

**Outcomes**

Different variables[[5]](#footnote-6) were significant to take into account at the individual and collective level to then estimate possible common views and contradictions.

The researchers worked on defining statute parameters like:

* Cost-effectiveness of less loaded vessels
* Profitability of smaller barges
* Financial investment in R&D
* Quality/diversity of habitats
* Hindrance to species/sediment migration.

Then were collectively by group designed parameters of actions:

* Deterioration of the image of inland waterway transport
* Part of traffic shifted
* Creation of warehouses/storage areas
* Reduction of loading
* Optimising the working of sluices
* Subsidising boat building

The whole parameters are presented in appendix according to the group of stakeholders.

## Data acquisition and management

**RQ addressed**

How to identify potentially beneficial vs. potentially problematic interdependencies?

**Process**

The data acquisition was carried out by three channels: existing documents, interviews and the TRIZ process.

Firstly, a research of specialised knowledge on the impacts of low water on the firms was undergone. The documents produced by the Central Commission for the Navigation of the Rhine (CCNR) were read as those written by other stakeholders. The port creates its own data. At the first meeting, the port projected a slide show with curves presenting the activity state on the Rhine. On the other hand, they do not mobilise all the studies that point out the interest of exploring qualitative studies on Lake Constance, the digging of the Rhine, etc.

In the interviews, we obtained a certain idea of how firms are impacted.

Secondly, the workshops organised respecting the rules of the TRIZ software produced much information, which was managed by stakeholders and refined as explained below.

The process of building a TRIZ frame is long because researchers have to define in line with stakeholders the preliminary situation, the problems they tackle and the parameters of evaluation and parameters of actions. After these steps, stakeholders have to identify the technical, administrative or physical contradictions.

During July 2020 and March 2021, four workshops were organised with inland waterway operators (managers, container or bulk carriers, exporting and importing companies[[6]](#footnote-7))[[7]](#footnote-8). The stakeholders invited to participate these meetings were chosen by the port authority, which was reluctant to accept the representatives of environmental associations. It was then proposed to meet these actors through individual interviews.

The methodology was defined as follows (see table 1.):

1. These workshops worked in the same way as focus groups.
2. To raise the debate these three groups of operators were formed. The objective was to use the Inventive Design Method (IDM) while employing Triz software. IDM is a participatory engineering approach that enables breakthrough solutions to be proposed to solve problematic situations/industrial or societal deadlock situations.
3. With the support of the Insa team, each group of operators constructed **a graph of problems and partial solutions** Action parameters and evaluation parameters characterising each solution and problem were then assigned by the operator groups. The Triz software then constructed **a network of poly-contradictions** that resulted from the analysis of the action parameters (solutions) and their impact on the evaluation parameters (problems).

Finally, the software resolved the contradictions to identify solutions to the key problem (fig. 2). This resolution was done according to the weighting/scoring given by the operators to each partial solution and their positive and negative impacts on the Rhine system. From this, the tool provides participants with a database that links each of these solutions with case studies, patents, etc. that may inform them. The firms were informed of the results obtained and Strasbourg port authority, particularly involved in the process, validated them.

Figure 4 -Table presenting the workshops

|  |  |
| --- | --- |
| **Number of the workshops** | **Activities** |
| 1 | Kick-off meeting   * Analysis of the initial situation * Introduction to the MCI-Triz approach and familiarisation with the PICC platform * Initialization Problem graph (version V0) |
| 2 | * Development of the Problem and Partial Solution Graph for the Manager, Bulk and Container groups. |
| 3 | * Identification of Contradictions and weighting of problems and partial solutions. * Resolution of Contradictions * Generation of Solution Concepts (SC) |
| 4 | Closing session and recommendations (08/04/2021)   * Solution concepts * Conclusions and perspectives |

**Outcomes**

Results from the 1st and 2nd session were then the collective reflection and building of problems graph and the identification of contradictions (see the different graphs presenting the problems according to the groups (in bulk, containers, and infrastructure managers).

For TRIZ, each problem is translated in evaluation parameters, which allow to assess the negative of positive impact resulting from an issue. For example, if the inland navigation is hindered, the evaluation parameter to be taken into account are the tonnage and numbers of containers which are immobilised. A partial[[8]](#footnote-9) (and potential) solution can emerge: for instance, modifying the barges or modifying (digging) the channel. However, these solutions may only be reached while playing with some actions parameters (barges’ size, the physical profile of the channel – curve, deepness…). Besides, the potential implementation of the solution creates possibilities, contradictions, and new impacts.

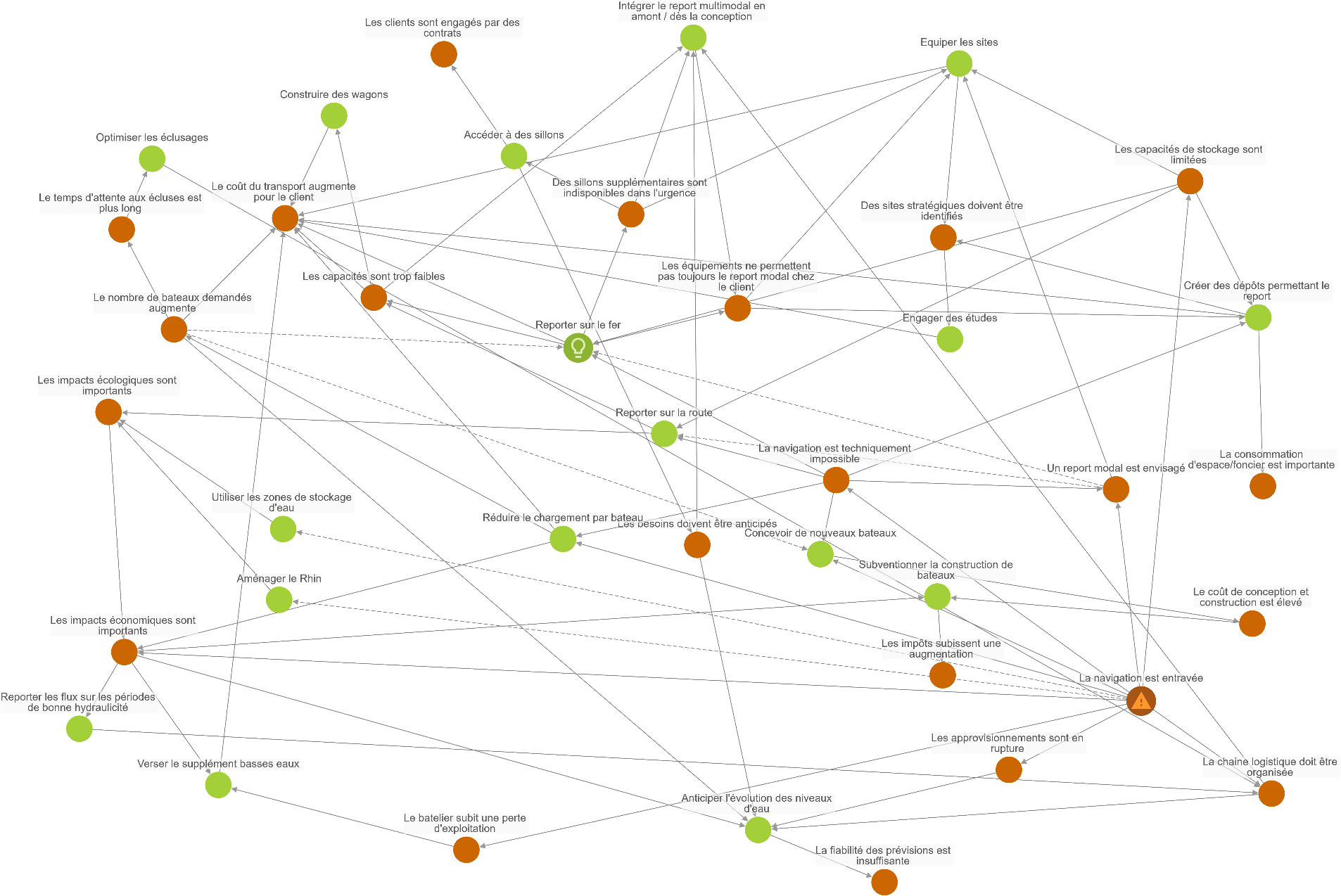
Figure 5 - Problems graph worked by the group of in bulk carriers, storage providers and firms

Figure 6 - Problems graph defined by firms, transporters, storage providers using containers

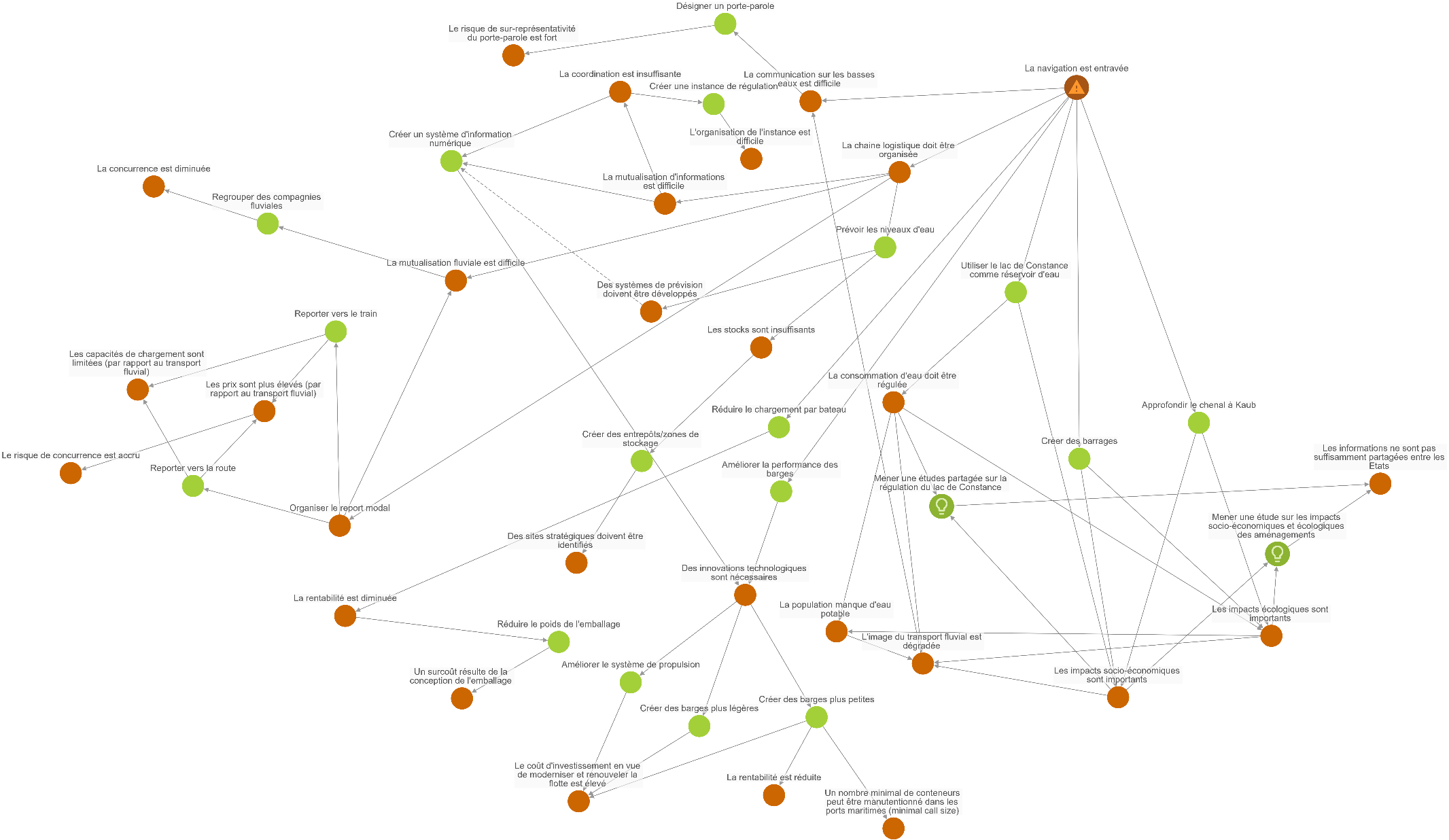
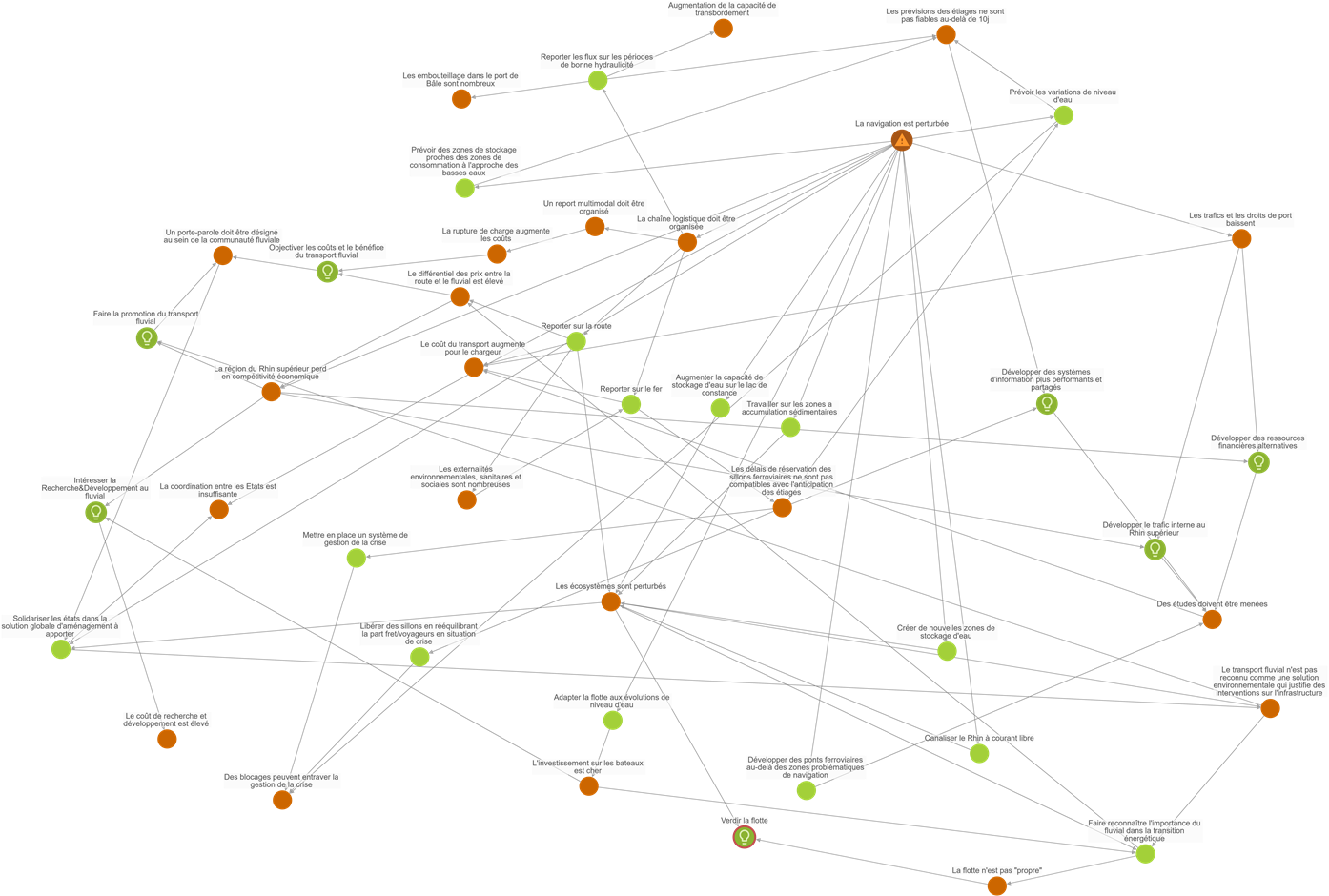


Figure 7 - Problems graph defined by infrastructure managers and inland waterway authorities

This identification of the problems encountered during a low water period and the solutions which could be considered led to the identification of different contradictions between stakeholders, between solutions.

TRIZ identified three types of contradictions between solutions:

* Administrative contradiction: administrative contradictions related to standards, laws, etc. The question to resolve is: “I know what I can do, but I do not know how to act.”
* Technical Contradiction: contradictions related to technical design parameters. “I know how I can act, but if I do it, another aspect of the issue worsens.”
* Physical Contradiction: contradictions related to physical parameters. “I know how and what I can do, but I have no idea with each tool I can act.”

It was then significant to identify the main variables common for all group and make emerge common solutions.

1. Normalizing variables

**Process**

From the different productions coming from the workshops, we could identify the variables which have a strong meaning for all stakeholder, independently their function in the supply chain.

In a preliminary step, action parameters were developed by researchers in social sciences while treating the data obtained through interviews (number of contracts, their duration, etc.). But they were not very usual for stakeholders. The usual variables employed by actors are: money, capacity in tonnage or in container units, compliance obtained with contracts and with specific and sustainable customer relations... The supply chain compliance is qualitatively and quantitatively assessed through respect of schedules (travel time, trans-bordering capacity to sea ships at due time…), efficient load disruptions (time to transfer goods from one mode to another). For a collective action, some variables are really determining: congestion for the access to ports, locks, number of rail paths, number of available trucks at a given moment (these variables are particularly useful to be able to switch to another mode of transport...

The whole process of workshops enabled to define and refine meaning variables for stakeholders, at the individual and collective levels. These variables are illustrative of the individual and collective vulnerability. From these different variables, it will be possible to define adaptation pathways combining different forms of involvement and individual/collective responsibility.

**Outcomes**

The four main variables which have to be taken into account to identify the vulnerability and the capacity to act is:

* Rhine Water level (Tables identify the tonnage possible according to the water level; when water levels on the Rhine River fall below 135 cm, ships are only able to load as much as 50 percent of their usual capacity to avoid running aground.) The stakeholders emphasize their will to have better and longer forecasts.
* The cost of each solution, when a low water crisis sets off (comparison of the prices generated by different choices possible: storage, transfer to another mode, use of less loaded ships, etc.)[[9]](#footnote-10)
* Respect for the supply chain, which can be explained not only by the dependence on customers (those who place the orders), but also by the dependence on see transport and the degradability of the goods)
* Transport capacity (volumes transported) of each mode at a determined moment (deciding to reduce the ship load or to transfer goods from one mode to another is dependent of the volumes transported and the form of the goods (liquid, in bulk, container…).

Tables are added in appendix to explain which variables were used.

The vulnerability of stakeholders focuses on:

* The lack of reliable information on the water level and capacity to anticipate. The German Administration for Waterways had recently launched a 10-day forecast for gauges along the Rhine River, but this appears not sufficient. Other data should be added to have a capacity to anticipate.
* The price volatility in period of crisis and consequently the need to have previous contracts with road/rail transport providers
* The difficulty to adapt itself when the stakeholders of the inland waterway transport are just one component of a global system. This argues for a good coordination at the supply chain level (from the production site to delivery site), at the international level (from the different Rhine ports until the sea port located in Netherlands), at the horizontal level (between transport providers, whatever is the mode).
* The global and sectoral rigidity of the socio-technical system of the inland waterway transport and the other modes (road and rail transport systems).

According to these findings, solutions gathering a partial or global consensus could be defined through a weighting system.

1. Weighting

**Process**

The stakeholders of each group were invited to weight the solutions to address sectoral and global vulnerability to low waters they preferred.

This weighting process was completed with the coding of the individual interviews while employing a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats). This allows to examine both internal and external factors influencing the vulnerability of each firm and its capacity of adaptation to low water.

**Outcome**

From an operational point of view, three types of strategy emerged from this collective process of design and were prioritised:

* Infrastructural solutions to transform the Rhine (digging), which demand the involvement and the decision of international authorities (CCNR) and of one country particularly (Germany). This is an expensive solution. It will globally lead to a vulnerability reduction of the inland waterway transport system, but increase environmental impacts in some areas. The collective rationale is “to resist to climate change”.
* Transport management solutions in crisis situations (intermodality, better data management...), which require a preliminary cooperation between stakeholders at the horizontal/sectoral level – transporters - and at the vertical level (supply chain) – shippers, carriers, authorities…
* Technical solutions, including research and innovation on the shippers’ fleet, which induce crossed investment and know how. The rationale here is to “live with climate change consequences” without major changes.

In conclusion, crisis management strategies and improved draught are preferred because they allow to continue business as usual, not to change the ways of working and organising. However, the stakeholders underline the importance to work together.

From a qualitative point of view, it is noticeable they have collectively chosen the solutions, which enabled them to delegate their responsibility to other. They thus tried to get themselves off the hook, not to bear the financial, technical or/and administrative burden of the solutions.

They postponed everything related to work collectives (governance, etc.) but this would involve them more and would impact them, would test them. Limiting the costs of entering into collective action.

1. Results
2. Presenting vulnerability assessment outcomes

To present the risk and vulnerability assessment a report incorporating charts, diagrams and an analysis of the interviews was given to the port authority, which supported the knowledge coproduction process. It was written in French language and will be accessible.

Table presenting sensibility, vulnerability and adaptation capacity according to the types of stakeholders

|  |  |  |  |
| --- | --- | --- | --- |
| **Stakeholders** | **Variables of sensibility** | **Level of vulnerability to low waters** | **Adaptation capacity** |
| Ship owners | - Water level (and singularly in Kaub and Maxau)  - Fleet type: number of vessels, number of large vessels, vessel size, lifetime of the boats | Very strong because of water level dependency  Tonnage limited by water level, even inability to move | Transforming the ship flee  ≠ investment capacity  ≠ impossibility to “displace” the cost on the ex- or importing firms |
| Transport providers (carriers) | * Water level (and singularly in Kaub and Maxau) * Contract with different transport modes 🡪 flexibility | Strong | Capacity to use other transport modes (horizontal coordination)  ≠ unavailable train path  ≠ not previous contracts/relationships with train or road transport firms  ≠ not sufficient skilled truckers  ≠ not adapted to all products |
| Port authorities | * Water level * Number of storage capacities * Available infrastructure to facilitate the modal transfer (intermodal connectivity) | Medium | Capacity to develop new storage spaces  Capacity to promote multimodality while investing in new platforms and materials  ≠ competition between ports (private and public transport) |
| Firms (exporters/importers)  Shippers | * Transport prices (comparing to the product price) * Volumes of goods * Types of goods transported * Conditioning mode (in bulk or in containers) * Optimisation of the supply chain (each little spanner in the work may be difficult to overcome) | Strong if their goods are rapidly degradable (edible goods)  Medium if their goods are less sensitive to degradation | Capacity to adapt its contracts with carriers  Storage possibility on the production location |
| Firms specialized in storage of bulk liquid products (proposing rental storage capacity)[[10]](#footnote-11) | * Storage capacity (number of storage sites) * interconnexion with different modes of transport | Medium | Capacity to increase the storage capacity in building more storage infrastructure on the port |

What was appeared determining is the possibility to have access to information about water levels but also about the way of acting of other stakeholders to identify the margins of manoeuvre. This need of information can be declined in different variables:

* Degree of reliability of forecasts.
* Anticipation of water level changes in Kaub and Maxau.

This information is necessary so that stakeholders could be able to take the useful decisions and have time to coordinate all stakeholders of the supply chain and the transport system. The stakeholders expect a very precise information to be able to plan new transport solutions and to make predictions on the travel-time[[11]](#footnote-12). They therefore can select travel routes and modes, which can be used.

The different graphs of solutions and the weighting of solutions give insights on which aggregating indicators (combining the vulnerability components exposure and sensitivity) worth for all stakeholders and how they incite them to adopt predefined adaptation strategies.

1. Presenting adaptation strategies issued from the common work

Adaptation strategies

Different adaptation strategies have been analysed, discussed and weighted thanks this work. From an analytical point of view, we distinguish three main strategies. Each strategy is based on specific technical, organisational, institutional modalities and a certain degree of knowledge and know how: That is why we firstly display the possible strategies and secondly the organisational and technical solutions which may be mobilised by the different strategies.

* The **reactive adaptation strategy** corresponds to an immediate response to the crisis. This adaptive answer is limited to technical and organisational reactions (like short-time work, decreasing of the volumes transported…).

Stakeholders may attempt during the crisis period to shift to another transport but flexibility needs to be prepared because of the lack of drivers, because confidence between transport firms has to be structured through agreements.

This reactive adaptation is symptomatic of stakeholders and community of stakeholders not very sensitive to climate change and specific hazards. They do not consider the issue as a regular one or suppose they can tackle it without more investment and involvement than necessary during a crisis. So, the trans-organisational dimension stays at micro level, because the concerned firms can take measures in their own organisation, without expecting actions from other and without being solicited to act outside their own limits of competence. In crisis period, this trans-organisational dimension can be requested (to find new transport modes) at a meso level (between organisation). But this coordination necessitates some preliminary preparation, as the 2008 crisis highlighted it.

The stakeholders of a same supply chain could have very different sensibilities and vulnerabilities (according to their proximity to the natural elements hit by a hazard, for instance) (Rudolf, Gobert, et Averbeck 2019) and then very strong or weak motivations to act. Some of them may push to action (and deploy an internal strategy) whereas others may slow down.

* The **transformative infrastructural adaptation** is the kind of solution which convinces the most the stakeholders involved, that is to say planning strategies to increase the water level and overcome low water levels (use of Lake Constance as a water reservoir or creation of new water storage areas; deepening of the channel at Kaub and Maxau).

This solution extends the vision that business as usual is possible but with major changes. This adaptation pathway improves the existing situation, makes more efficient the inland waterway transport and the associated logistics for all stakeholders (except the Rhine, as these solutions are considered as impactful).

These infrastructural solutions are a means to redistribute the responsibility between stakeholders and to discharge individuals from a to heavy financial and organisations changes. But these most appreciated solutions in collective coproduction processes are however softened, when they are discussed individually during semi-directive interviews.

The deepening of the channel at Kaub and Maxau (dredging) in order to increase the water level is frequently mentioned, but the difficulty of this decision to take away the two main bottlenecks is not under the responsibility of one or more French entities but of the German authorities, or even of an international agreement. In fact, deepening the Middle Rhine was already set on the agenda of the German Federal Transport Infrastructure Plan ("Bundesverkehrswegeplan 2030") before the low water crisis of 2018. But the decision process is very and depends of a myriad of environmental decisions.

A less environmentally impacting solution is mentioned: The creation of additional dams (e.g. rock dams) and locks. More specifically, according to a craftsman, the installation of movable (or flap) dams at Kaub and Maxau could limit the environmental damage caused by the channelling or deepening of the channel, but also the problem of stagnation and heating of the stored water. These dams are composed of very large gates that are lowered during periods of sufficient water flow and allow the passage of boats. In periods of low water, the gates are raised to retain the water and a lock makes navigation possible.

* The **radical adaptation** (a change which does not only concern production and transport firms, but society) appears principally in the discourses of some regulators or representatives of the “river” as a natural component when they are personally asked (during interviews). Changing transport and production system at an international level would ask a deep transformation of the “industrial” system. Moreover, this adaptation pathway strongly recognises the agentivity of non-humans: the Rhine and the natural components, the limits of technical solutions.

These diverse strategies lean on organisational and technical solutions:

* The “technical solutions” focus at first on technical aspects of a problem at a micro-scale. In our case, this could be: transforming ships and adapting them to low waters (retrofitting) or designing lighter boats and widening mid-size boats. This kind of solutions can also aim at facilitating the information system and the data share between operators. They are highly dependent on the intentions of transport providers and their investment capacities. However, some cooperative agreements can be signed to share the costs for studies and researches. They could be deployed for each strategy, previously displayed.
* The organisational solutions essentially based on the inter- and multimodality. The principle is: when the water level does no more allow the inland waterway traffic, the transport provider switches to another mode of transport. These solutions are based on a collective reflection, but do not need a global consensus. Arrangements can be made bilaterally or multilaterally, at the scale of transport providers or more largely at a regional scale.

The objective is to increase the cooperation between the different transport providers and to enable to use one transport system or another (water, train or roadways), according to the climate events and the availability of the transport system.

There is a need to access to train paths and to make coherent these train paths management between the different countries. Besides, the port and firms proposing storage capacities would have to create new storage facilities to create buffer zones and times and enable transfers when the water levels become normal.

Limits of the methodology

A time-consuming methodology

The TRIZ method is not totally completed, as it is time-consuming. Besides, we were in a COVID period which had a lot of consequences on the organisation of meetings and workshops.

To really document the parameters with figures, a real technician work is necessary.

We will have to go and see each stakeholder to obtain their figures. It certainly would be easier for a data manager, specifically hired for that than for researchers... However, a person dedicated to gather information about the process performance has assessed how people involved in the process perceived it. This solution and a better share of information and data could be made permanent via a facilitator who knows the companies, the processes... This organisation would increase the implementation of the collective solutions drafted by stakeholders.

Stakeholders’ involvement and the long-term perspective

The actors make you feel that this is for your benefit and not theirs. This raises a common issue of action research to give insights for stakeholders and researchers and create a long-time cooperation, which can have interesting results for both and particularly for a better apprehension of climate change and adaptation challenges. Even if stakeholders accept being part into our “story”, our project, they did not tell us how they reasoned, how they work with this kind of thing, once the project is closed. When we assessed in 2022, how the process was felt and the results appropriated, we had however good feedback.

Indeed, the project manager of the Autonomous Port of Strasbourg in charge of issues related to sustainable development and more particularly low water and low water phenomena said in January 2022:

“The intention is to maintain the form of cohesion that has been structured [during the project], because it is a source of federation. The economic players, VNF and the DREAL have been very involved. The challenge is to take this expression of the players to an extra-local level, and to bring it to the attention of international bodies in the light of what we know. It will not stop there. We have to prepare for new episodes of low water, the degree of intensity is still unknown. This is a unifying subject: we have launched an internal information letter, coupled with a newsletter on governance, technological innovations and agendas related to low water.

As a multimodal port, it is essential to think about alternatives to river transport, by seeking to strengthen the rail mode. The Multimo Day organised in September 2021 was dedicated to this objective, in order to open a discussion between river and rail operators, to discuss the blocking points. At present, studies are being financed by European funds to develop this axis.”

Sidelining of environmental stakeholders and challenges

The civil society and the environment were side-lined and not integrated in the process and in the reflection (the impacts on the natural components were not really considered during workshops). The living aspect of the river was evacuated. As a matter of fact, the climate change is instrumentalised (used as an argumentative tool and also as a motive to act) to push environmentalists and spokesperson of the natural components away. The crisis functions as a way to move towards the infrastructural solution and opens an expected window of opportunity. Then the social and environmental acceptability are not structural elements of the method.

For example, infrastructural solutions like deepening the Rhine channel raise deep questions of social acceptability and environmental impacts. Even if it was evoked, this does not appear as a hindrance.

# Key lessons learned per innovation area

## [Research innovation relating to Impact Chain method](#_Toc54703357)

1. Have you extended your methodology beyond what is described in the Vulnerability Sourcebook (this can be related to the 5 Innovations, but does not have to)?

Yes.

1. How does your methodology extend the original Vulnerability Sourcebook methodology?

Our way of extending the impact chain method is based on three combined actions:

* We used a mixed methodology to be able to better apprehend the individual and collective vulnerability to a risk. We employed a software usually employed by designer to resolve their design issue and carried out semi-directive interviews.

Knowledge coproduction process can be hindered or limited, while some actors may “impose” their point of view in collective situations or strongly influence the collective decision because of their charism or their power/authority on other stakeholders. On the contrary, during semi-directive interviews, stakeholders may have an opinion that they would not dare to defend in front of colleagues or other stakeholders.

That is why a combination of collective workshops respecting the TRIZ procedure with individual interviews led with representatives of each “profession” of inland waterway transport brings complementary data and enable to differently weight significant variables for stakeholders.

* We mobilised very different experts to implement our method procedure and analyse the data obtained.

1. Which Sourcebook modules do your methodological extensions refer to (Which Sub-research question relates to which module can be looked up in the Case Study Protocol D2.1)?

We consider we developed the impact chain methodology (m2): How to integrate the individual, the territorial and the organizational (the perspective adopted by a group of stakeholders having the same activities points of view? How to better integrate the collective sensitivity to a hazard and the reaction to the other stakeholders?

1. d) How do your rate your methodological extensions in terms of the following validation criteria (short written reflections). Please repeat the filling of the table for each Sourcebook module that you have methodologically extended.

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Requirement** | **Answer** |
| ***Relevance*** | Supports the identification of climate risks with the option to identify climate change adaptation measures - based on impact chains - with the aim to derive a quantitative and qualitative (or both combined) climate risk assessment | Yes |
| ***Applicability*** | The method is generic in its application as well as not limited to exclusive/commercial toolsets | The methodology is generic and commonly used by designers. The originality to employ this software combined with semi-directive interviews asks for a combined community of researchers in social and engineering sciences. However, the software TRIZ is not free. |
| ***Comprehensibility*** | The method is documented and guidance is provided | The method is accessible but demands a significant involvement and time. |
| ***Scientific Validity*** | The approach is scientifically valid (and re-producible) and has undergone a review (e.g., by another expert round, review etc.) | Yes (the methodology was deployed by a set of researchers and then methodically analysed by another researcher in social sciences. |
| The impact chains are based on a diverse set of stakeholder knowledge together with scientific findings | Yes |
| ***Effectiveness*** | The method can be implemented without primary data collection (i.e., it can build on existing datasets) | It is necessary to have some knowledge prerequisites to understand the environmental and professional environments. |
| The method allows the integration of data from heterogeneous data sources (quantitative, qualitative, expert, stakeholder...) | This a co-production process, which uses and creates different kind of data. |
| It can be implemented within a feasible timeframe and practicable team size | Timeframe = 11 months (but we had to adapt ourselves to the software) |
| It involves stakeholders in all its main phases | Stakeholders are involved into the workshops and the results validation. |
| ***Transferability*** | The method can be transferred to other application/sector contexts | Yes (it is already the case) |
| It can be transferred to other geographical settings | Yes |
| ***Scalability*** | The method can be applied at different geographical scales (local, provincial, national, regional...) | Yes |
| It can be scaled across varying numbers of assessment units (e.g., 3-4 admin units vs. 15-20 admin units) | ? |

**Would you suggest this extension to be integrated into an updated version of the Vulnerability Sourcebook?**

YES. I think it would make sense as we are writing a paper about how our partnership with the CESI (Informatics School of Strasbourg) increased the method with Triz Alert (AI). The TrizAlerts software 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. 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.

## [Research innovation relating to uncertainties](#_Toc54703360)

Different uncertainties exist and effort are made and asked to reduce them (notably through collective interaction), but it does not systematically appear as an argument for not involving and acting (adapting to current climate vulnerability through technical solutions and reactive strategies).

The uncertainties are of different forms and affect one or many levels:

* Scientific uncertainties about the hydraulic changes on the Rhine because of the climate change and the specific hazards which more frequently hit the Rhine basin.
* Informational uncertainties to be warned sufficiently early, to be able to anticipate what actions can be deployed (at the micro-level, the firm level; at the meso-level, the inter-organisations level to make possible the transfer of goods from one transport system to another; at the macro-level, the transborder Upper Rhine region).
* Organisational uncertainties. As a matter of fact, the internal adaptation to a crisis and even to a well-perceived risk may be discordant with the adaptation strategies of other actor. More globally, the suitability between internal strategies necessitate previous efforts of discussion, preparation, understanding of the concerns of other stakeholders all along the supply chain.

An organisational flexibility is often antonymic with the supply chain optimisation, insofar as the smallest grain of sand can stop the machine. That is why it is necessary to create the opportunity of discussions and to maintain them under a certain form.

* The institutional uncertainty: how to govern the CC risk and “to increase the institutional capacity”? Is it relevant to create a new governance structure, to base the effort on the pre-existing ones (at the international level, at the port level, at the local authorities’ level) or to promote regular “informal” exchanges, focusing on topical and long-term questions?
* The societal uncertainty. Even if solutions can emerge and be negotiated by stakeholders, they have to be submitted to the civil society and confronted to the non-human entities (Roelich et Litman-Roventa 2020). As they are not incorporated in the discussion circles, both could resist. Some semi-directive interviews with representatives of environmental NGOs give us insights to integrate these dimensions. Besides, the involved stakeholders are conscious that these elements have a real strength of action.

Through this research, we could not answer all these questions and reduce each aspect of uncertainty. But through the deployment of the methodological protocol mixing individual interviews and collective workshops (and workgroups defined according to the type of activities), we could seize which role these uncertainties play for each type of stakeholders and how they could attempt to tackle them at their own and at the collective levels.

For the institutional aspect, stakeholders are aware of their limit for acting concerning their preferred strategies that rely on infrastructural works. They are convinced they have to call out to national (Germany) and international authorities (CCNR) to achieve them.

For the actions matching their competence level, they will strive reducing uncertainties by strengthening the relationships and their knowledge about the other transport system to improve the interoperability and intermodality between modes.

For the informational uncertainty, new studies have to be launched and new tools of communication have already been created, following the collective workshops. One of the important feed-back of the manager (Port authorities) is the willingness to stay informed by the new productions (state of art). The last session we had with them on March, 24th., made clear that our partnership is still going on with them. They showed a great interest for Triz Alert.

## [Research innovation relating to co-production of knowledge](#_Toc54703365)

The crisis was an opportunity for the research. It accelerates the willingness of the stakeholders to work with researchers. Nevertheless, the hybrid collective composed by stakeholders and researchers stayed asymmetrical considering the flux of information, the trust and confidence between the members involved in the impact chain process. This configuration influenced the governance. The stakeholders asking for less time’s consuming procedures. They engaged themselves in the process but seemed not very convinced by it. When we sent the report back with all the explanation and the analysis made from their individual interviews only 30% answered to our email.

The manager of the harbour and the infrastructures are more convinced by the process as we could notice it at our last meeting in marsh 22. They definitively proposed to continue especially because of Triz-Alert, which makes the following of the state of art easier.

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Requirement** | **Answer** |
| ***Relevance*** | Outputs and outcomes address stakeholders’ and societal needs and expectations. | The whole process was structured with stakeholders and then highlights their collective concerns. |
| Stakeholders perceive the science products as relevant for achieving/having led to (or potentially leading to) more accurate, informed decisions, planning and policy processes. | Yes. The work is considered as a first step to inform better stakeholders on the low water risks and to call out national authorities. |
| The co-production process contributes to improved decision-making and policy (e.g., agendas, capacities and decisions) that respond to goals co-defined by stakeholders and researchers. | The process has set the significance of the issues on the agenda (at the individual and collective) and allowed to apprehend the different scales of action. |
| ***Applicability*** | The method is flexible, iterative and sensitive to decision-contexts. | Yes, because it is really responsive to stakeholders’ expectations. |
| ***Comprehensibility*** | Expert groups to depart from and learn from existing practices and guidances available online and in the literature. | Even if experts fed their reflections with literature, they before all based their work on a previous immersion in the context to understand the inland navigation organisation and stakeholders’ rationale. |
| Make use of professional facilitator and/or knowledge broker in the co-production process. | Strasbourg port authority plays the role of intermediation. |
| ***Scientific Validity*** | Starts from state-of-the-art and has undergone a peer review process | Yes. The involvement of different scientists at each step of the project allows to strengthen the scientific process. |
|  | Validity and reliability have been tested and secured on a cross-case study basis | NA |
| ***Effectiveness*** | The impact chains are based on a diverse set of stakeholder knowledge together with scientific findings | Yes |
| Science-user interactions and co-production leads to demonstrated outcomes, e.g. building trust, new insights, mutual understanding, relationships, and social networks. | Yes. |

## [Research innovation relating to transborder climate change risks](#_Toc54703375)

**RQ addressed**

2 . How can different levels of governance identify and then adapt to transborder climate change risks?

3. Who (private/public actors, at different levels and within different sectors) are most accountable for managing different sub-categories of transborder climate change risks?

4. What are the most important factors that limit the capabilities of policymakers to address transborder climate change risks?

**Context**

Even if the first part of this study, presented in this report focuses on the French reception of the Rhine low waters, this risk is a transnational one. The vulnerability reduction of all the Rhine system suppose open-ended and multiscalar processes accounting for uneven connectedness spatially and organisationally (supply chain coordination and intermodality) (Mika et Kelman 2022).

The inland water at the level of the Upper Rhine Region, distributed through three national/international harbors (Basel-CH; Weil am Rhein, Kehl, Karlsruhe- D and Strasbourg, Ortmarsheim -F) present a specific configuration in regard to the Rhine taken as a unique waterway and entity. This specificity is due to the physical ("natural" one as well as artificial one) characteristics. The profile of the Rhine river is changing from the south to the north. As more as approaching the North, the inland water is less vulnerable to climatic hazards, especially to the low waters. However, the low water crisis from 2018 functions as a climate change alarm for all the stakeholders of this region. Observing the relation between local authorities and national/international authorities is very relevant here due to the weight of this economy on the global economy and the national PIB.

Despite this crisis, the understanding of the low water as a transborder risk which worth attention and the capacity to involve the different levels is particularly challenging:

* French stakeholders, who have activities in the Rhine inland waterway and Alsatian local authorities, do not have sufficient influence to mobilise the national government. They have not succeeded in interesting and enrolling national authorities to their questioning about low water. Some national structures like VNF are committed into the reflection but some adaptation pathways for this transborder risk have to be concretised with the government.

This sideling is probably due to the marginal contribution of this portion of the waterway in the French economy which is more connected to the River Seine and the Paris basin. However, the decisions that should be taken up- and down-stream (that is to say in Germany or in Switzerland) to tackle the issue of low waters would have consequences for French stakeholders at national and local levels.

* Another aspect which plays a pretty important role for the reception of a global issue at the local level is the economic governance model. How are the local stakeholders involved into the global competition? How are they able to organise themselves to tackle the different challenges raised by low waters? How do local authorities try to build new arrangements with private stakeholders to define properly which issues have to be dealt with and which solutions have to be selected according to their financial/technical/social viability?

**Outcomes**

Through the applied methodology, the stakeholders could:

* work together to identify their common difficulties and the possible inconsistencies between individual and collective adaptive actions
* define common adaptation pathways, they favoured,
* particularly become aware of that their individual difficulties are shared along the supply chain, the hazard can have cascading effects at different scales. So, the necessity to combine a scalar reflection and to define the good level of action demand to better know the decision processes, the competences of each organisation, with which it is suitable to involve, to identify where/for what kind of issues a governance level lacks.

For example, it appeared that the port authorities are a good level to inform, to improve exchanges between firms, to think and structure the possibilities of an improving intermodality. However, the most important infrastructural work should be decided and implemented at the international level and therefore fully seized by the countries. That is why the involved actors have chosen to create advocacy tools.

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# Appendix:

Figure 8 - Table of the status parameters (PE) and action parameters (PA) defined by infrastructure managers



Figure 9 -Table of the status parameters (PE) and action parameters (PA) defined by container carriers



Figure 10 - Table of the status parameters (PE) and action parameters (PA) defined by bulk carriers (problems/solutions)





1. The port authority had already organised groups of stakeholders concerning other issues and some of these collective workshops had already resulted in actions (and the transformation of these groups into coalitions of action) to work on industrial ecology and find synergies between firms for example. [↑](#footnote-ref-2)
2. Since the early 90’s, it was studied that because of climate change, the Rhine changes towards a rain-fed river (Parmet, Kwadijk, et Raak 1995). The winter discharge increases, which can have consequences for safety, and summer discharge decreases with consequences for shipping, industry, agriculture and ecology. This climatic and hydrological consequences of these unpredictable weather patterns include prolonged periods of heavy rainfall, dry conditions leading to drought as well as the continuous melting of glaciers in the Alps that feed into the river. Increased rainfall and snowmelt in the Alps, with water levels rising, seasonally cause river shipping to be suspended at several sections between Karlsruhe and Koblenz. Low waters have consequences for inland navigation, where the river is shallow. [↑](#footnote-ref-3)
3. When water levels stand between 131-150 cm, surcharges of 30€ for a 20-feet container and 40€ for a 40-feet container apply, while shipping can no longer be guaranteed if water levels at Kaub fall below 81 cm (Revised inland tariff; from Hapag-Lloyd). [↑](#footnote-ref-4)
4. A shortage of skilled drivers is affecting the freight and logistics sector at the European scale. This could affect the transport prices and is considered as a major challenge for national and international carriers. [↑](#footnote-ref-5)
5. We constructed our work on variables and not indicators, which suppose a social construction from available data. We guess they may be the result of a collective work on sensibility and adaptation to define the characteristics to be measured, identify the target audience and the purpose of the indicator, to choose a framework (based on goals, issues, sectors or stress-condition-response), to define criteria for selecting indicators, to pilot and test the indicator and choose the final set. [↑](#footnote-ref-6)
6. The low water levels cause ripple effects through downstream manufacturing supply chains and also have consequences on the quality of the goods transported. [↑](#footnote-ref-7)
7. This group of operators was previously created by the authorities of the Autonomous Port of Strasbourg and regularly reflect and share information on Rhine river issues. [↑](#footnote-ref-8)
8. If the issue lasts and is not totally solved, even if the solution has been deployed, this is considered as a partial solution. Moreover, a hazard has multiple and often cascading impacts, that raise issues that can be partially resolved. [↑](#footnote-ref-9)
9. This variables prioritisation is not an exception to the usual way in which customers looking for a transport solution act (Flodén, Bärthel, et Sorkina 2017). Price is most important when choosing transport services as well as quality. [↑](#footnote-ref-10)
10. The Rhine river is a major transportation corridor for fuel. Then **the transport increasing price are reported to the final product: distillate fuel prices at distribution terminals (rack prices) increase in tandem with the higher freight rates at points upriver (Energy Information Administration, 2018).** [↑](#footnote-ref-11)
11. Transit time is the interval needed for a shipment to be delivered once it has been picked up from the point of departure. The transit time vary according to route and the mode of transportation used. The exact time is mostly measured in hours and days. Even if the choice of inland waterway transport induces longer travel-time, constraints exists, notably for containers, which have to be transferred to maritime carriers. As Lin and Zito (2005) underlined it, the travel-time information helps improve reliability through the selection of travel routes pre-trip and en-route. In the application of logistics, travel-time information could reduce the delivery costs, increase the reliability of delivery, and improve the service quality. For traffic managers, travel-time information is an important index for traffic system operation. Different data have to be managed to have reliable projections and a continuous adaptation of the transport. [↑](#footnote-ref-12)