

Morphological Analysis

Morphological analysis enables users to explore the possible futures of a system based on a combination of hypotheses related to that system's components or variables. Originally employed in technological innovation, this method also lends itself to scenario building in foresight. A scenario plot is essentially a combination of hypotheses about how the variables in a system may develop, each scenario representing a different set of hypotheses. Morphological analysis stimulates the imagination while enabling users to carry out a systematic and transparent scan of the field of possible futures.

FIELD OF APPLICATION

This method is recommended for exploratory work on possible developments within a system containing either several nested or linked levels or several components (economic, technological, societal) or many inter-related influencing variables. At all stages up to the results phase, morphological analysis offers a high degree of transparency.

Domain: all domains.

Number of participants: in general, a working group of 5 to 15 people reflecting the different domains studied meets in person.

RELEVANCE AND USE IN FORESIGHT

This is one of several methods enabling users to construct consistent scenarios of a systemic kind (the whole system is taken into account) in a transparent environment (the way of working and results are visible to all). This highly structured method is used, among other places, in France, Northern Europe, Latin America and some African countries.

TECHNICAL REQUIREMENTS

A database for analysis is necessary (the system, its variables and development hypotheses) and, if possible, spreadsheet or wordprocessing software. For complex morphological analysis there is software available: Scenaring Tools, MACarma™, Parmenides EIDOS.

TIME FRAME

Once the database for analysis has been validated, a half-day meeting to construct scenario plots is needed.

For nested morphological analysis, a half-day meeting per component to draft microscenario plots plus a full-day meeting for the overall scenario plots are needed.

Plus writing time for scenarios and their validation either in a group meeting or remotely.

BASIC CHECKLIST

- Build a trend scenario, contrasting or trend-break scenarios, and scenarios based on participating actors' visions.
- Prefer the power of a few scenario storylines rather than multiply scenarios, but do not fall into the trap of only three scenarios (dark, rosy and trend scenario).
- Never move directly from scenario plot drafts to their description by using a point-form slide (PowerPoint); instead, compose detailed scenarios to ensure consistency.
- One option is to keep a blank 'hypotheses' column ready in the morphological chart: during the building of scenarios new hypotheses may turn out to be necessary.
- Under certain circumstances (e.g., lack of time), construct scenario plots based on the morphological chart before submitting them to the working group.

TOOL IMPLEMENTATION COSTS

Quick to learn, this method's limited cost amounts to the time needed for the organization to hold 2 or 3 working group meetings, once the basis of analysis has been confirmed.

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Morphological Analysis

A Method for Building Futures Scenarios

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Abstract

Morphological analysis was invented by Fritz Zwicky in the mid-1940s as a creativity method within the aeronautics sector. Zwicky wanted to make invention “routine”¹; *i.e.*, a banal process.

Morphological analysis seeks to explore possible futures systematically, based on a study of all the combinations of the various elements found in breaking down a system. The objective of the method is to highlight innovative products or processes by breaking everything up into functions, key variables and hypotheses about the way these variables (or solutions) change. Morphological analysis also serves to construct futures scenarios based on the breakdown of the system into key variables and possible development hypotheses for these variables.

Originally a method used in technology to boost creativity and thus encourage innovation, morphological analysis lends itself well to scenario building in foresight studies. The demographic, economic, technological and social variables may be characterized by a certain number of possible developments, as seen in the hypotheses. In essence, the skeleton of a scenario is nothing more than a combination of development hypotheses for different variables. Highly stimulating for the imagination, morphological analysis enables users to scan the field of possible futures systematically.

In practical terms, the stage of the collective construction of futures scenario plots, using the system of variables which yielded the suggested futures hypotheses, is often based on morphological analysis. This stage of work can be carried out in a half-day meeting.

To perform a morphological analysis, users or practitioners must already have broken down the system into technical components or influencing variables and also already have constructed several exclusive hypotheses for each component.

Morphological analysis is, above all, a useful method for exploring possible combinations among hypotheses, involving a duty to create a coherent narrative when actually assembling them. ■

1. ZWICKY Fritz, “Morphology and Nomenclature of Jet Engines”, *Aeronautical Engineering Review*, 6(6), June 1947, pp. 49-50.

Keywords

Functional Analysis | Combinations of Hypotheses | Creativity
Chart of Hypotheses | Innovation | Scenarios

Description of the Method

Field of Application

This method may be used to innovate — to generate ideas — or to research into future developments for a complex system comprising several parameters, or variables, whose futures hypotheses have been constructed.

In foresight use, practitioners are strongly urged to analyze the system under study and break it down into variables prior to starting. The structural analysis technique for identifying and selecting key variables proves even more useful when the variables are linked or influence one another. Indeed, structural analysis consists in analyzing systematically the influence of a set of variables among themselves with a view to extracting the key variables; *i.e.*, those having the greatest influence within the system.

Requirements

Morphological analysis always requires some structured reflection before beginning.

► **In innovation**, the system studied must be broken down into technical components, or basic functions, and imagined through different configurations or hypotheses for each technical component. These components must be as independent as possible while taking into account the entire system under study. For example, the technical components of a car may be the engine, wheels, and external signalling systems (headlights, indicator, horn), to list just a few. All these technical components or basic functions may be used to create hypotheses in terms of number, material, design, etc.

► **In foresight**, the topic for which users wish to create futures scenarios must be broken down into the key influencing variables and then futures hypotheses for each variable must be constructed before embarking on morphological analysis. Building futures hypotheses relies just as much on rational reasoning and data as it does on imagination. These hypotheses must, as far as possible, be mutually exclusive or incompatible; in other words, if one is true, the others are not possible. Usually two to five hypotheses per variable are constructed. There are different ways to elaborate hypotheses. “The Driver Report” approach² has the advantage of enabling a reasoned, written document that is as objective as possible to be attached to the hypotheses for each variable. Moreover, with this approach, hypotheses are discussed and validated collectively.

Morphological analysis should be carried out in a group, so as to maximize the number of ideas for — possible and coherent — combinations of development hypotheses for the variables. Once the number of variables exceeds 8 or 10, nested morphological analysis is recommended (see p. 8).

2. LAMBLIN Véronique, “The Driver Report: Documenting Variables for Foresight Exercises”, *Prospective and Strategic Foresight Toolbox*, December 2017, Futuribles International.

Step-by-step Process to Create Foresight Scenarios

In a foresight system comprised of key variables influencing the subject under study within its environment, the hypotheses for the future of each variable are arranged in a “morphological” chart, or table, as illustrated below.

| CHART 1. EXAMPLE OF A MORPHOLOGICAL CHART | | | | | |
|---|--|--|--|---|----|
| Variable Name | H1 | H2 | H3 | H4 | H5 |
| Environmental policy | Retention and rescheduling of objectives. Ambition achieved but with a delay | Rise in level of ambition regarding water and wetlands | Climate prevails (including adaptation to climate change) | 'Anything goes attitude', economic activity prevails | |
| Green or eco-taxation | Targeted incentive taxation + charges | Green tax revolution (on exploitation and pollution) | Lower environmental taxation (charges maintained) | H1+ Local and property taxation | |
| French environmental values | Progressive development in behaviors (low % consent to pay) | Increase in environmental concerns and consent to pay | Social crisis overrides environmental concerns | | |
| Demographics | Continuous growth (French population at 68.5 million) | Weak demographic growth (French population at 67 million or below) | Strong growth and migration (French population above 70 million) | | |
| Employment, incomes and redistribution | Continuation of current trends; rising inequality | Improvement in employment, decreased inequality | Overall reduction in incomes, increased inequality | | |
| Economy | Moderate growth 1.5% | Stagflation (downward spiral) | Focus on strengths and on exporting (nuclear, transport, agriculture...) | Focus on innovation (health, renewable energy, organic food...) | |
| Population location | Economic hubs + south and west + fertile crescent | Medium-size cities and scattered rural areas | Metropolitization (large and medium-size cities) | Reduced residential mobility | |
| Scenarios | | | | | |

Source: table taken from the *Aqua 2030* project commissioned in 2011 by the French ministry of ecology: CGDD (Commissariat général au développement durable), “Eau, milieux aquatiques et territoires durables 2030. Synthèse de l'exercice de prospective [Water, Aquatic Environments and Sustainable Territories to 2030. Synthesis of the Foresight Project]”, *Études et documents*, 91, August 2013, 46 p. URL: <http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0079/Temis-0079054/20841.pdf>. Accessed August 31, 2020. See detailed example in Case Study, pp. 14-18.

In foresight, unlike in innovation (see insert p. 10), morphological analysis users are not seeking an exhaustive number of possible combinations to build scenarios but only the most contrasting combinations. Another difference between foresight and innovation is that the variables, though not strictly interdependent, often influence one another.

The goal in foresight is to create coherent, plausible scenarios that are truly contrasting. Two scenarios may not be considered contrasting if they use almost the same hypotheses (all except one or two). In this case, one should check whether the two scenarios are not just a variant of the same future. Often one will choose only the futures scenarios that have a different dominant “driving narrative force” (economy, environment, quality of life, etc.) or a different dominant actor, especially during an exploratory phase.

Each scenario is made up of a combination of one development hypothesis per variable. The chart relies on a color code or typographic style, e.g., bold, italics, underscoring. In crafting the first scenario, for example (Chart 2), the boxes with an orange background are brought togeth-

| CHART 2. CONTEXT SCENARIOS | | | | | |
|--|--|--|---|--|------------------------------|
| Variable Name | H1 | H2 | H3 | H4 | H5 |
| Environmental policy | Retention and rescheduling of objectives. Ambition achieved but with a delay | <u>Rise in level of ambition regarding water and wetlands</u> | <i>Climate prevails (including adaptation to climate change)</i> | 'Anything goes attitude', economic activity prevails | |
| Green or eco-taxation | <u>Targeted incentive taxation + charges</u> | <i>Green tax revolution (on exploitation and pollution)</i> | Lower environmental taxation (charges maintained) | H1+ Local and property taxation | |
| French environmental values | Progressive development in behaviors (low % consent to pay) | <u>Increase in environmental concerns and consent to pay</u> | Social crisis overrides environmental concerns | | |
| Demographics | <i>Continuous growth (French population at 68.5 million)</i> | Weak demographic growth (French population at 67 million or below) | <u>Strong growth and migration (French population above 70 million)</u> | | |
| Employment, incomes and redistribution | <u>Continuation of current trends; rising inequality</u> | <i>Improvement in employment, decreased inequality</i> | Overall reduction in incomes, increased inequality | | |
| Economy | Moderate growth 1.5% | Stagflation (downward spiral) | <u>Focus on strengths and on exporting (nuclear, transport, agriculture...)</u> | <i>Focus on innovation (health, renewable energy, organic food...)</i> | |
| Population location | <u>Economic hubs + south and west + fertile crescent</u> | Medium-size cities and scattered rural areas | <i>Metropolitization (large and medium-size cities)</i> | Reduced residential mobility | |
| Scenarios | Scenario 1. Sleeping Beauty | <i>Scenario 2. The Revenge of the Regions</i> | <u>Scenario 3. Green Competitive Liberal Repositioning</u> | Scenario 4. The Downward Spiral | Scenario 5. Green Revolution |
| Source: table taken from the <i>Aqua 2030</i> project commissioned in 2011 by the French ministry of ecology, <i>op. cit.</i> See detailed example in Case Study, pp. 14-18. | | | | | |

er; for the second scenario, the boxes with text highlighted in gray; for the third scenario, the boxes with text underlined in black; for the fourth scenario, the boxes with text in orange, and for the fifth scenario, the boxes with text in italics.

The rules for building the combinations:

- Choose one hypothesis per line;
- One and the same hypothesis may be used in different combinations (scenarios), but each scenario must use one single hypothesis per variable as the hypotheses are exclusive;
- Use the logical expression “If.... then....” to forge the link between variables and explain how the hypotheses are put together. It is important to note the order and causal connections used in compiling the hypotheses to be able to draft each story (scenario) later in a literary style.

The Different Steps

► **Step one** in morphological analysis consists in creating a chart with the names of the variables running vertically from the most influential to the least (or from the most specific to the most general), with the development hypotheses for each variable in columns placed horizontally without color coding or any particular typographical style. Naturally, the last line in the chart “Scenarios” is initially empty, as seen above in Chart 1. A spreadsheet or wordprocessing software is often used to create this chart or table.

It is necessary to ensure that all the participants combining the hypotheses that constitute scenarios fully understand and have in mind the complete definition of the hypotheses suggested for each box, or cell, in the chart. The hypotheses are summarized in telegraphic form, so that the chart remains readable. The terms chosen to define hypotheses within the table must be expressive.

► **Step two** (optional), is designed to help the group get started. It consists in pinpointing the most representative hypotheses of the past trend for each variable in order to see whether or not putting together these hypotheses enables users to build what is called a trend scenario.

This trend scenario enables users to reflect on the coherence of following all past main trends with no changes, not even in the actors' behavior to the time horizon of the foresight exercise. Sometimes the trend scenario must be adjusted to make it coherent or possible. Generally, this scenario provides a convenient and instructive reference point, as it tends to show what would happen if nothing or no one changed and the trends continued in a linear fashion.

► **Step three** consists in constructing alternatives to the trend scenario. Often this entails first questioning the variables and hypotheses which would enable users to think outside the logic of the trend scenario. The opening hypothesis of an alternative scenario may lie on any line in the morphological chart. It is at this point that participants' creativity is really called on to generate alternative combinations that they are able to narrate.

Participants' first two or three scenarios often correspond to their own opinions and representations. Scenarios that are original or involve new conceptions generally appear later. The various combinations of hypotheses imagined by the participants are gathered and entered into the morphological chart with different color codes or typographical styles.

► **Step four** consists in selecting the three to seven combinations or plots of scenarios that participants wish to keep. Actually, the objective is to retain the most contrasting scenarios. Not all possible scenarios should be retained, particularly not those scenarios that are mere variants of others, differentiated only by nuances.

Similar scenarios may easily be picked out from the morphological chart because they combine more or less the same hypotheses (all except one or two). Indeed, if two scenario plots are very similar, the users must decide that one is a variant of the other or, as is often the case, the more evocative of the two scenario options is selected. This choice is based on either the key idea developed in the combination of hypotheses or the scenario's capacity to have the greatest impact on the actor (*e.g.*, company, public authority or research center) for which these scenarios were created.

Scenarios are often distributed outside the working group who crafted them; it is essential, then, that only a limited number (three to seven) are selected so that readers are not drowning in a sea of scenarios and are able to compare them in terms of "desirable" criteria set out by the decision-maker.

Of course, scenarios are tools with potentially different aims, *e.g.*, a strategy, future challenges, the skills of tomorrow, avenues of research, to name but a few. However, scenarios never claim to describe the future exactly as it will be. The challenge, then, is to keep only the contrasting scenarios illustrating very different, typified changes, thus indicating the possible choices or room for maneuver, as well as their consequences, to the client commissioning the foresight study.

► **Step five** consists in testing out the deep coherence of the plots crafted in the previous step as sets of hypotheses by composing scenarios in a literary style. Only detailed writing using precisely defined hypotheses and describing development from today to the time horizon set for

the foresight exercise will enable users to judge the internal coherence of each scenario. Moreover, for scenarios to be impactful, they must be presented in clear language. A decision-maker must be able to believe in the scenarios; otherwise, they are useless.

A scenario must not be just a combination of hypotheses representing a possible future, but must describe the path leading from the current situation to a future. This means thinking beyond combinatorial logic and reflecting on this path and blazing the trail with signposts, so to speak, especially when the time horizon is far off. The intermediate states of the system must be specified and a timeline plotted.

In terms of communication strategy, scenarios need to be readable with an appropriate format and vocabulary. The best idea is to align a clear, concise literary description of the scenarios with a morphological chart. Remember to choose catchy titles for the scenarios and provide detailed versions of the selected hypotheses in an appendix.

Even if only one person writes the scenarios in a literary, detailed fashion, several individuals should read them over critically to ensure that there are no internal contradictions and the details of all the hypotheses used are indeed found in the narrative text.

An example of scenarios drafted in a literary style from morphological Chart 2 (p. 6) may be found below on pages 14-18.

Nested Morphological Analysis

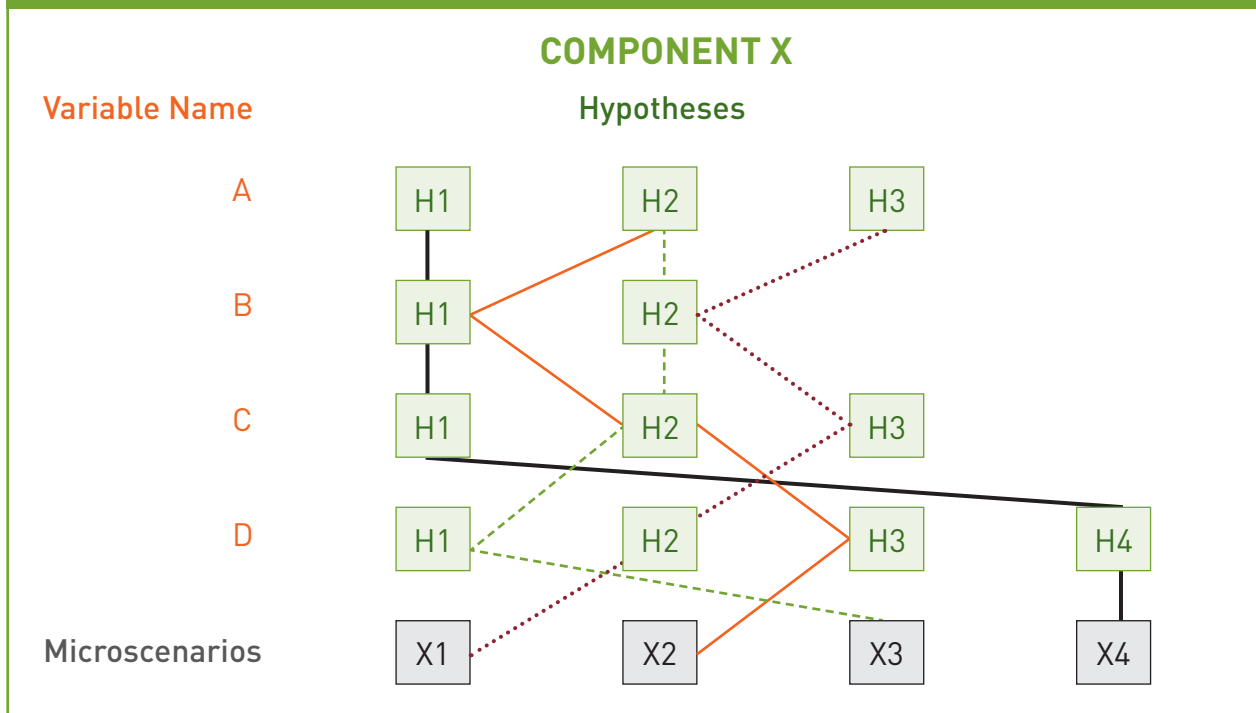
Once the number of variables from the foresight system gets around the 10 mark, it becomes very difficult to build a linked series of hypotheses (with one hypothesis per variable) during one session. A system with 20, 30 or even more variables is very common in regional or sectoral foresight projects, yet combining 30 hypotheses at once turns out to be something our minds find very difficult. In this case, it is wise to group the different variables. These groups are called the components of the foresight system. With a system of 30 variables, for example, an effort will be made to construct four or five components.

Care will be taken to put in a single component the variables referring to the same theme or the variables that are most interrelated (direct impact between variables) and relate to the same actor. This separation into components is never pure because there are always variables which users could have placed in another component category. For example, the “household consumption” variable could be listed under the component heading “Local population and its lifestyle”, alongside variables about demography, employment, income or level of education. Yet “household consumption” could also fit into a component involving the economy of a region, in the same way as corporate expenditure. In practice, it is best to have approximately the same number of variables per component; however, there is no need to spend too much time discussing whether a variable belongs in one component rather than another because, regardless of their classification, all the variables will be taken into account in nested morphological analysis.

A morphological chart is created for each component (Chart 3) following the same principles as seen in classical morphological analysis (see p. 5-8). Combining hypotheses enables users to build scenarios for each component which are known as microscenarios.

Microscenarios are, then, partial scenarios based on one component of the system of variables; i.e., on one group of variables.

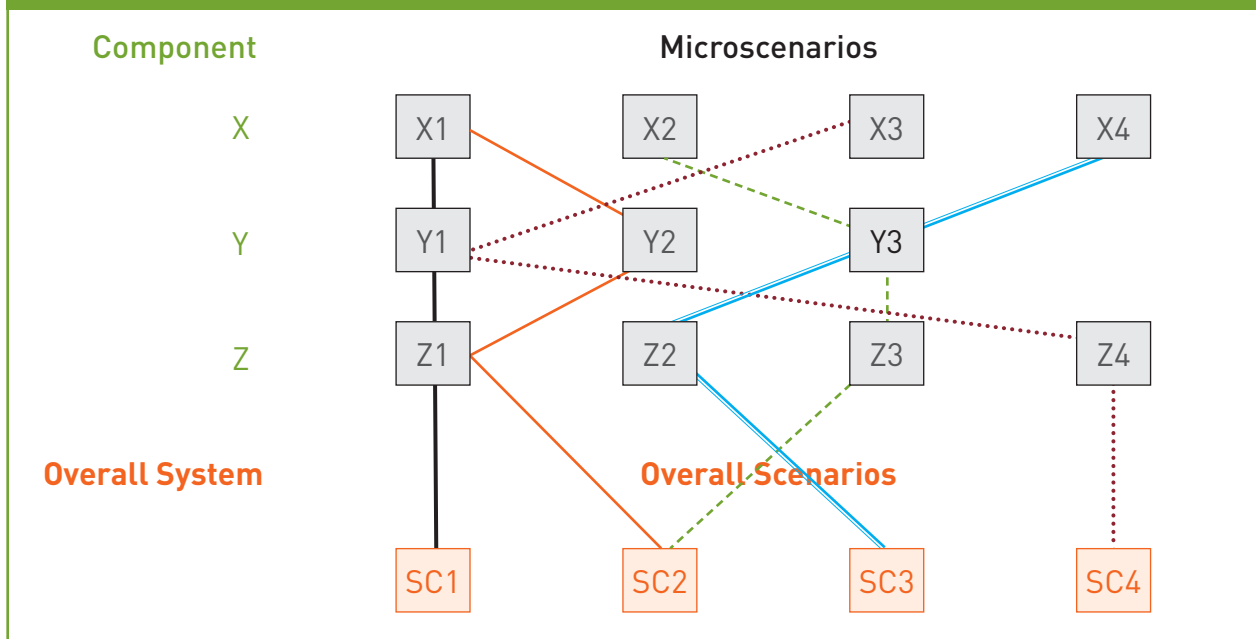
At this point, participants are working component by component. The dynamics of each component depend on how the key variables evolve. Participants go through steps two through five

CHART 3. MORPHOLOGICAL TABLE FOR ONE COMPONENT (NAMED X)

of morphological analysis for each component as outlined above (pp. 7-8). For each component, three to seven microscenarios are constructed, often one trend scenario while the others are contrasting scenarios.

As soon as the microscenarios for each component are ready, it is time to review their possible combinations in an overall morphological chart to build the overall scenarios (Chart 4).

Once again steps two through five of morphological analysis are followed to generate the overall morphological chart. The nesting technique applied to the variables in components enables

**CHART 4. OVERALL MORPHOLOGICAL CHART:
FROM MICROSCENARIOS TO OVERALL SCENARIOS**

USING MORPHOLOGICAL ANALYSIS IN INNOVATION

The function under study must be broken down into basic parameters (technical components) that enable it to be performed.

Let's take shaving (removal of beard/whiskers/hair) as a function that may evolve according to parameters like energy source, shaving agent, and type of movement on the surface being treated.¹ To imagine the different ways of carrying out this function, we can construct the following chart.

| | Hypothesis 1 | Hypothesis 2 | Hypothesis 3 | Hypothesis 4 | Hypothesis 5 |
|-----------------------------------|--------------|--------------|--------------|-------------------|--------------|
| Parameter 1. Energy | Electrical | Chemical | Manual | Mechanical | |
| Parameter 2. Shaving agent | Heat | Electricity | Blade | Chemical products | Bacteria |
| Parameter 3. Movement | Circular | Linear | Static | | |

When looking for innovative ideas, all the possible combinations will be tried in order to analyze each option in terms of its interest and feasibility.

The simple table above yields 60 possibilities of shaving systems: 4 energy sources x 5 shaving agents x 3 types of movement.

Morphological analysis enables participants to record all possibilities, including existing solutions (linear manual blade, electric razor with rotating blade, chemical products applied manually and statically). These can be compared to new possible solutions or alternatives to shaving like the selective burning of whiskers and other body hair (which exist today in the form of pulsed light systems). However, when listing combinations, the aim will be to retain only the combinations with no technical incompatibility or only those combinations that are technically possible.

It remains to test all the sets of new hypotheses by considering the following:

- advantage for the user;
- feasibility;
- safety;
- cost;
- and any other criterion selected.

It is clear that the number of possibilities to be analyzed can explode, since multiplying six technical parameters by four hypotheses per parameter ($4 \times 4 \times 4 \times 4 \times 4 \times 4$) yields 4,096 possibilities! The whole exercise can quickly become unwieldy. It is a good idea to limit the number of technical parameters, but without forgetting any that might be essential. ■

1. Example taken from GODET Michel, *Manuel de prospective stratégique. L'art et la méthode*, Paris: Dunod, 2007, pp. 222-226. URL: http://www.lapro prospective.fr/dyn/francais/ouvrages/la_prospective_strategique/t2--manuel-de-prospective-strategique-dunod-2007.pdf. Accessed September 1, 2020. From SAINT-PAUL Raymond and TÉNIÈRE-BUCHOT Pierre-Frédéric, *Innovation et évaluation technologiques : sélection des projets, méthodes de prévision*, Paris: Entreprise moderne d'édition, 1974.

participants to not limit themselves to a reduced number of variables and hence to achieve greater depth and precision in their scenarios.

Nevertheless, building the overall scenarios implies that participants possess adequate knowledge of the possible microscenarios for each component. Moreover, in the overall morphological chart, microscenarios appear in the form of titles or short phrases. However, what the title or phrase covers is much more difficult to memorize than the hypotheses for the variables. As a result, when participants combine the microscenarios for each component into overall sce-

narios, they absolutely must have a detailed, written document reminding them of the content that is conveyed only in the form of a title in the overall morphological chart.

Tips and Best Practices

Make sure the morphological chart fits on a sheet of A4 (A3, if need be). Use a spreadsheet or wordprocessing software.

Web-based software support for morphological analysis is also available, *e.g.*, Scenaring Tools <http://scenaringtools.com> (see p. 12).

Below are a few tips to lead a scenario-building session using morphological analysis:

- ▶ Make the morphological chart (variables and hypotheses) available to all participants.
- ▶ Draft the plot of the trend scenario as a group, testing to see if the compiling of the trend hypotheses is indeed possible within the time horizon of the foresight exercise.
- ▶ Ask each participant to think individually about the combinations or plots of alternative scenarios. Start by suggesting that participants ask the following question: “Which variable, which alternative hypothesis can take us out of the trend scenario?” Once the group has found this alternative hypothesis, no matter where on the chart, they should build an alternative scenario plot by putting this hypothesis together with the hypotheses for other variables which seem to be the most consistent and logical. Each participant can easily build two or three alternative scenarios.
- ▶ If the intention from the outset is to retain only the most contrasting scenarios and not all the combinations identified by the group, ask one participant to suggest one of his alternative scenarios to the trend scenario. This should be recorded. Group members are then asked if they have found a very similar one: *i.e.*, a scenario sharing most of the hypotheses of the alternative scenario presented. The group may then debate the topic to decide which combination seems the most coherent and expressive of the key idea of that scenario. The group may also retain one scenario and, at the end of the narrative text describing that scenario, offer the other option as a variation.

Errors to Avoid

To jump from scenario plots, created using morphological analysis, to descriptions in point form on a slide (PowerPoint) would be a mistake. A scenario must absolutely be fleshed out in detail to ensure that there are no inconsistencies and only then can a summary of the different scenarios be drafted and published in a simplified and illustrative form.

Building only three scenarios — the negative/dark scenario, the rosy scenario and the in-between scenario, which is often the trend scenario — is to be avoided. The decision-maker would be in danger of considering seriously only the intermediary scenario when developing strategy. It is important that the scenarios reveal real choices. When four or more scenarios are on offer, this problem becomes less common.

Constructing overall scenarios collectively in nested morphological analysis based only on the morphological chart would also be an error. Participants absolutely must have to hand a document detailing the content of the microscenarios. The microscenario titles reappearing in the morphological chart are not in themselves sufficient.

Frequently Asked Questions (FAQs)

► If there are more variables, are there more scenarios?

Paradoxically, given the logical links between variables, an increase in the number of variables does not lead to an increase in the number of possible scenarios (unless the variables are completely independent, which is rare). The more logically linked the variables, the more limited the number of contrasting and consistent scenarios that it is possible to construct.

► Once the variables and their hypotheses have been defined, how long does it take to build the scenarios?

Drafting the plots of the scenarios (or microscenarios for a component) with a group may easily be done in a half-day meeting. However, after this meeting, one full day is needed for a named writer to write up the scenarios (or microscenarios). Next, the group which created the storylines must have time to read over the texts describing the full scenarios and to correct them. The scenarios may then be validated.

If the number of variables requires the use of nested morphological analysis, one half-day meeting should be allowed per component to draft the plots of the microscenarios, plus a full day for a writer to compose the microscenarios. Then there is the phase of correction and validation by the participants who drafted the plots. Lastly, a final morphological analysis using the overall chart (components and microscenarios) should be carried out. That meeting generally runs longer than half a day because participants need to review and recall microscenarios that are far more complex than hypotheses. Writing up the overall scenarios also takes much longer. The technical text for a single scenario (including a maximum number of details drawn from the basic hypotheses) for a system with 30 variables easily runs from six to ten pages and entails several days of work for one person. Once the technical validation of the scenarios is complete, more communicative versions of the scenarios must be prepared and, more importantly, used to deduce impacts, compare them, etc.

Further Reading

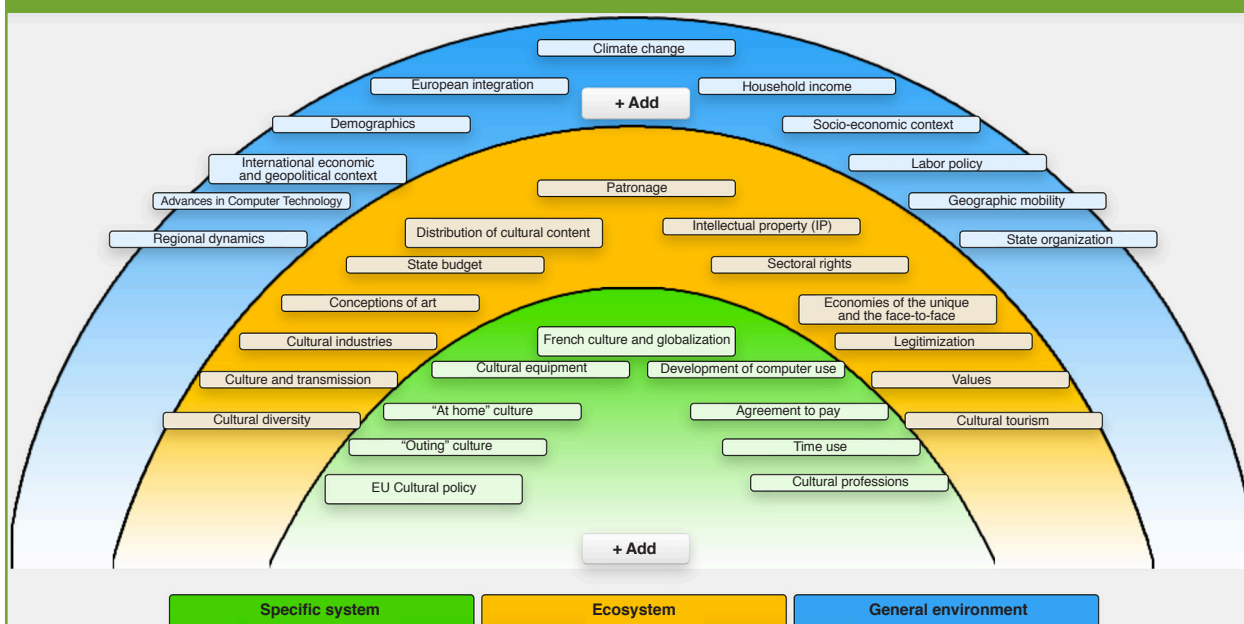
► Key phases in morphological analysis as applied to foresight are defining the variables of the system under study and building development hypotheses for each variable. Both phases are outlined in **“The Driver Report”** published in December 2017 in the *Prospective and Strategic Foresight Toolbox*. This particular tool enables users to document and build hypotheses using a given time horizon for each variable.

► Scenaring Tools Software

Available online at <http://scenaringtools.com>, this software assists practitioners in morphological analysis. Developed in 2015 by François Bourse and Michel Godet, Scenaring Tools is based on Zwicky’s morphological analysis and includes two modules “Prospective Radar” and “Morphol”.

1) **The first module, “Prospective Radar”**, enables users to create, share, debate, as well as build on the variables (factors, actors) of a foresight (or prospective) system. This is a mandatory step in creating scenarios. Two types of representation are suggested: either in a foresight system with a visual for the different nested levels (global environment, ecosystem or related context, specific system or internal variables) plus the related components, or in tree structure (levels, components, variables, hypotheses).

CHART 5. EXAMPLE OF A PROSPECTIVE RADAR FROM STUDY *CULTURE & MÉDIAS 2030*, FROM SCENARING TOOLS



Source: free access (after signing up and creating an account) on <https://scenaringtools.com>, session Culture & médias 2030 (source: DEPS [Département des études, de la prospective et des statistiques], *Culture & médias 2030: Prospective de politiques culturelles*, Paris: ministère de la Culture et de la Communication, 2011, 208 p.).

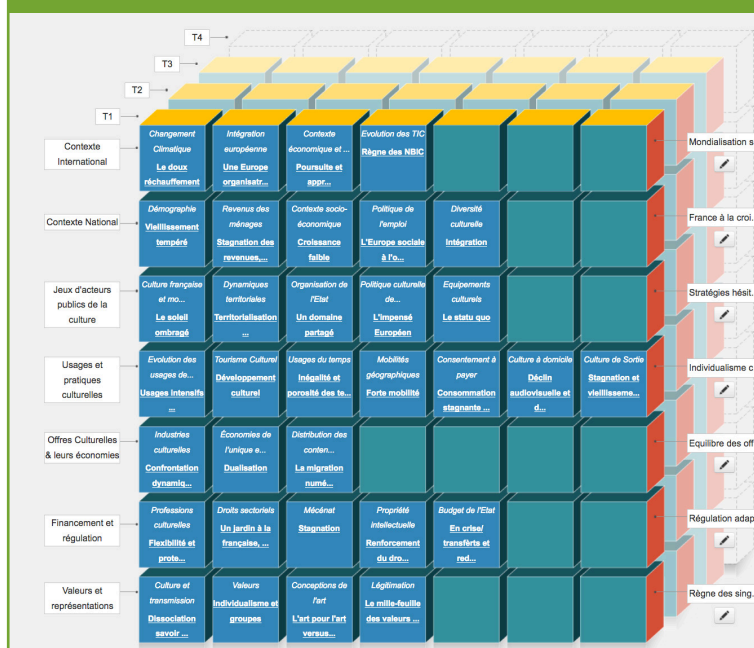
For each variable, the retrospective elements, trends, uncertainties, discontinuities, hypotheses and key messages may be generated, discussed and then completed collaboratively online or in a group meeting after initial suggestions have been made.

2) Second module, "Morphol"

"Morphol" enables users to construct foresight scenarios using nested morphological analysis in an intuitive and interactive way. The levels, components, variables and hypotheses are presented in a 3-D parallelogram/matrix. All the data may thus be easily accessed.

Morphol users can build nested scenarios by selecting hypotheses, first by component (a set of hypotheses per group of variables attached to one dimension), and then by level, and lastly the overall scenarios. The resulting scenarios may be shared and debated on line.

CHART 6. NESTED MORPHOLOGICAL ANALYSIS, 3-D PARALLELOGRAM/MATRIX EXAMPLE FROM MORPHOL MODULE



Source: free access (after signing up and creating an account) on <https://scenaringtools.com>, session Culture & médias 2030 (source: DEPS, op. cit.).

Case Study: Aqua 2030

We present here an example of both a morphological chart and written-up microscenarios, taken from the French General Commission on Sustainable Development's *Aqua 2030* program which investigated water, aquatic areas, and sustainable regions in France with a time horizon of 2030. The morphological analysis was carried out by Futuribles in 2011.

Morphological Chart Example: the “Context” Component

This table (see Chart 7) may be read by following one color or typographic style (bold, italic...). All the boxes with an orange background are grouped together to create the first microscenario. All those with orange text serve for the second microscenario. The boxes containing text underlined in black are for the third microscenario, and those with text in italics relate to the fourth. Lastly, those with text highlighted in gray are for the last microscenario.

Written-up Microscenarios

Microscenario 1: Sleeping Beauty

Environmental issues are becoming an increasing concern, but so are social issues. The employment rate holds up, but remains low for youths and seniors, work is more precarious (part-time jobs, fixed-term contracts) and the gap between those with inherited wealth and those without is widening. Meanwhile, average annual economic growth holds up, hovering around 1.5% on average.

The frequency and intensity of extreme climate events is increasing as researchers had foreseen at the beginning of the millennium. All this contributes to incentive taxation, based on waste generated and resources consumed, which encourages virtuous behaviors, being well accepted by households with an adequate income and/or a job. However, the fear of curbing fragile economic growth produces a lax attitude toward the environmental goals to which France committed itself alongside its European partners. The environmental objectives, both with regard to energy and climate and to water are not achieved by the deadline. The goals are maintained but re-scheduled to a later target date.

French demographic growth continues as predicted (68.5 million people in 2030).

Tourists, as well as young retirees with means, still prefer the coast and the South (for the sun) and wish to move there, creating a local residential economy for the working-age population (in the so-called “fertile crescent”, from Rhône-Alpes to the South-west). The current economic hubs (major cities) remain strong and attractive even to the lowest income groups because of the plentiful casual employment opportunities there.

Microscenario 2: The Downward Spiral

The economic crisis continues. Major French industrial sectors are more inclined to invest in emerging countries which are “building up their base”, rather than in France or Europe where consumption has stagnated. Certain French sectors of activity remain competitive in exports, namely those with cultural or heritage advantages, like luxury products, high-end agrifood items (e.g. wine), and tourism. Economic growth is weak (0% to 1% on average annually) with inflation making a comeback.

As a result, the average French citizen's income falls, both income from work, because of lower employment levels, and from redistribution, because of weak economic growth. Capital

CHART 7. MORPHOLOGICAL CHART FOR THE “CONTEXT” COMPONENT

| Variable Name | H1 | H2 | H3 | H4 | |
|---|--|--|---|--|---|
| Intensity and frequency of extreme weather events | Increase | <u>Accelerated increase</u> | | | |
| Environmental policy | Retention and rescheduling of objectives. Ambition achieved but with a delay | <u>Rise in level of ambition regarding water and wetlands</u> | <i>Climate prevails (including adaptation to climate change)</i> | 'Anything goes attitude', economic activity prevails | |
| Green or eco-taxation | <u>Targeted incentive taxation + charges</u> | <i>Green tax revolution (on exploitation and pollution)</i> | Lower environmental taxation (charges maintained) | H1+ Local and property taxation | |
| French environmental values | Progressive development in behaviors (low % consent to pay) | <u>Increase in environmental concerns and consent to pay</u> | Social crisis overrides environmental concerns | | |
| Demographics | <i>Continuous growth (French population at 68.5 million)</i> | Weak demographic growth (French population at 67 million or below) | <u>Strong growth and migration (French population above 70 million)</u> | | |
| Employment, incomes and redistribution | <u>Continuation of current trends; rising inequality</u> | <i>Improvement in employment, decreased inequality</i> | Overall reduction in incomes, increased inequality | | |
| Economy | <i>Moderate growth 1.5%</i> | Stagflation (downward spiral) | <u>Focus on strengths and on exporting (nuclear, transport, agriculture...)</u> | <i>Focus on innovation (health, renewable energy, organic food...)</i> | |
| Population location | <u>Economic hubs + south and west + fertile crescent</u> | <i>Medium-size cities and scattered rural areas</i> | <i>Metropolitization (large and medium-size cities)</i> | Reduced residential mobility | |
| Microscenarios | Microscenario 1. Sleeping Beauty | Microscenario 2. The Downward Spiral | <u>Microscenario 3. Green Competitive Liberal Repositioning</u> | Microscenario 4. Green Revolution | Microscenario 5. The Revenge of the Regions |
| Source: Aqua 2030. | | | | | |

revenue stagnates in constant value terms because of inflation. This decrease in average income goes hand in hand with greater inequality, primarily because the wealthy have revenue in the form of assets or heritage which do not depend only on the national economy and can increase.

The worsening economic crisis is exacerbated by an ageing population. Higher unemployment and greater precarity do not foster environmental values. The economy prevails. Climate change becomes tangible, e.g., heatwaves, but social concerns win out over environmental.

Given the persistent economic and social crisis, plus the rising price of energy and raw materials, environmental taxation is reduced, e.g. lower domestic taxes on petroleum-based products, the French national tax on petroleum products (TIPP), for example, which can be seen as an environmental tax. Only the payment of charges relating to services that are more clearly identifiable and easily justified is maintained or even reinforced.

The population increase follows the prior growth trend and populations tend to cluster around economic hubs, in “rurban” (rural+urban) areas, near large- and medium-size cities where

access to services remains possible and the cost of housing affordable (health, postal and similar urban services are lost in rural areas and small towns). This engenders greater ‘metropolitization’: the Parisian region, Bordeaux/Toulouse, the Rhône-Alpes region and the Mediterranean coastal area. Casual work, even undeclared, is more easily found in cities.

Increased urbanization has consequences on the environment, notably the water supply.

National tourism decreases, as fewer French people travel, a development linked to the fall in their incomes. Those able to take holidays opt for seaside destinations in the south which are less busy during summer and hence far more attractive.

Microscenario 3: Green Competitive Liberal Repositioning

France relies on exports to spur its flagging economy, in the hope that this formula will work as well as it did for Germany. France relies on traditional assets (nuclear energy, transport, agri-food sector, urban services, tourism). Immigration is encouraged as a means to control wages and maintain competitiveness. This strategy enables economic growth to remain at an annual average of 1.5% from 2010 to 2030.

Demographic growth is thus significant (over 70 million people in 2030) with migration exceeding 150,000 annually in some years. The areas most affected lie near major urban economic centers and consumer zones. A typical French example is the so-called “fertile crescent” area running from Rhône-Alpes to the Southwest.

The employment rate stays at around 65% but with an increase in part-time work and limited-term contracts. Income from work stagnates, but household revenues rise on average by 0.4% annually, thanks essentially to increased capital revenues (primarily real estate). The gap between those owning property or assets and others, even between generations, grows wider while family solidarity becomes more important.

The major role of tourism in the national economy (tourist activities and real estate) means landscapes and the environmental quality of the country are preserved. Businesses take part in this green movement through sponsorship and charitable foundations, in order to promote their image as socially responsible corporations. This further enhances the value of French exporting companies: they are also selling an image of environmental quality with the ‘Made in France’ label. National ambitions regarding water are raised with:

- the emergence of a new European directive to halt the loss of biodiversity, notably aquatic biodiversity;
- zero tolerance (law suits, sanctions) to ensure implementation of the environmental water and flooding framework directive, with water to be in “good ecological condition” at the latest by 2027, particularly in terms of minimum water flow rates.

The intensity and frequency of climate events increases faster than had been imagined. This makes households more aware of the environment, so they agree more readily to pay for environmental issues — except where, in some cases, they radically change their consumption patterns. Increased tax pressure on both the consumption of resources and the generation of pollution, *e.g.*, the carbon tax, which replaces a portion of the social benefit deductions from labor, is applauded by companies and accepted by the average household.

One variant of this scenario could be that local government is granted additional room for maneuver in taxation to increase property tax pressure, notably in tourist zones, so as to control urban planning better.

Microscenario 4: The Green Revolution

The intensity and frequency of extreme climate or weather events increases faster than expected, doing so as early as 2011-2015.

As a result, coping with climate change appears to be a more important environmental objective because it shapes the future of all ecosystems. Moreover, adaptation to climate change is clearly necessary. An international agreement reinforces the energy-climate couple. All measures designed to reduce greenhouse gas emissions are favored, including hydroelectricity or biomass energy. It is first and foremost by reducing polluting agents that efforts are made to achieve desirable water conditions and less through sufficient flows.

Both the general population and corporate world worry about how the climate is changing. Companies focus, with help from government, on innovative sectors, anticipating future market demands. Examples include healthcare (especially with an ageing population), renewable energies, bio-organic agri-food business and robotics.

To ease this shift in national activities, taxation is completely reformed. Fiscal pressure is increased on the use of resources (materials, energy, water) and pollution, *e.g.*, carbon tax, while social benefit deductions on labor are decreased.

Eventually, once all the new types of activity are structured *circa* 2020-2030, the employment rate rises, which helps reduce inequalities. New industries and sectors, which often start up in cities near R&D centers, plus new employment opportunities attract people to medium-size and large cities or their outskirts. The demographic change is as anticipated: 68.5 million inhabitants in 2030.

French environmental awareness favors leisure and tourist activities that put people in touch with nature. Ecotourism is becoming sought-after so there are more off-season vacations with destinations more often in country or mountain areas, where visitors recharge their batteries far from city crowds.

Microscenario 5: The Revenge of the Regions

The state delegates more responsibilities to local communities from 2015-2020 to escape from Scenario 2: *i.e.*, economic stagflation and more frequent and intense extreme climate events that were unthinkable at the beginning of the century. In fact, given disparities across the country, finding solutions suitable to all French regions is no easy task.

The state also reviews its taxation system to grant more autonomy in terms of resources to local communities. Besides targeted incentive taxes and charges, which are set on a national scale, local collective groups acquire new scope for fiscal action. As a result, greater pressure is applied to property taxes, enabling local communities not only to control urban planning but also land use in general and thus promote the activities that are important to them.

Large cities manage to control their sprawl through property taxes in order to limit expenditure on urban services and networks. Inversely, medium-size towns and small municipalities benefit from the difference in property taxes to develop further. The population, whose demographics are following a growth trend, tends to settle in medium-size cities or scattered rural settlements. This development is accentuated by an increase in households' ecological concerns, given the sense of runaway climate change and the economic crisis of 2008-2010.

Indeed, for many households it is easier to live in harmony with ecological values, favoring a relative self-sufficiency, in the country than the city: there is more space (and less shade from adjacent buildings) to equip oneself with solar or photovoltaic power sources, to achieve better exterior home insulation, cultivate one's organic vegetable patch, retrieve rain water etc.

In tourist areas especially, local communities foster this trend “back to the countryside” by improving telecommunications network coverage and thus enabling residents to work partly from home. The presence of residents in fact makes it possible to safeguard and maintain natural environments. Moreover, some households use their rural advantage to develop extra income-streams by offering meals and accommodation for weekend getaways near the city.

Increasingly, tourism becomes, for the French, a militant act of solidarity. Visiting French cities and rural areas is a way of revitalizing them.

Elsewhere, local communities harness their control of property taxes and the revenues generated to develop new activities linked to their local skills: from mechanics to robotics, from the manufacture of cutlery to surgical instruments, from agriculture to *terroir* agri-food business and local energy production.

The employment picture brightens, thanks to double employment which becomes increasingly frequent and helps reduce inequality. However, economic growth remains relatively low (1.5% on average) from 2020 to 2030, because second or casual jobs are not always declared.

Overall, as of 2020, economic activity takes off again in France thanks to local development, but the situation varies widely from one region to the next: it depends on local advantages both in terms of human skills that can potentially be mobilized in synergy and on heritage assets both tourism-related and cultural. Some areas recover better than others.

The microscenarios of context in Chart 7 are indicated by name and are placed on the first line of Chart 8. In this nested morphological analysis, they are combined with the microscenarios for other system components to build overall scenarios. The microscenarios for each component (context, water management, water and region, agriculture and energy, domestic water cycle and industry, biodiversity) become the hypotheses of the overall system.

CHART 8. MORPHOLOGICAL CHART FOR THE COMPONENTS AND THEIR MICROSCENARIOS

| Component Name | H1 | H2 | H3 | H4 | H5 |
|-----------------------------------|--|--|--|---|---|
| Context | Steering by sight/ Sleeping Beauty | Downward Spiral | Green competitive liberal repositioning | <u>Green Revolution (climate and taxation)</u> | <i>The Revenge of the Regions</i> |
| Water management | Still the same government targets = heading for disaster | <u>Green = Local (The crisis be praised!!)</u> | Democratic and environmental centralism | The crisis | |
| Water and region | A few drops of water in urban development | <u>Water's status revived: it limits urban development</u> | <i>Flooding limits damage</i> | <i>The concrete state</i> | |
| Agriculture and energy | Heading for water crises | <u>Green Baden- Württemberg, eco-activists' dream</u> | <i>Regional governance</i> | <i>“Après nous le déluge”</i> | The Logical route |
| Domestic water cycle and industry | <i>Improvement at the margins</i> | Rapid deterioration | <u>We're improving</u> | <i>Differentiated local management</i> | |
| Biodiversity | Amenities preserve the quality of natural milieus | <u>Pro-active reaction to climate crisis</u> | The environment, getting to be a bit too much | | |
| Overall scenarios | The environment, among other things? (trend scenario) | “Down the drain, this crisis!” | <i>“Techno-garden”, anthropization</i> | <i>The regions alone or inter- dependent? The local</i> | <u>Choice of ‘soft’ technology to control risks</u> |

Source: Aqua 2030.

Bibliography

References

- ÁLVARES Asunción, and RITCHEY Tom, “Application of General Morphological Analysis: From Engineering Design to Policy Analysis”, *Acta Morphologica Generalis*, 4(1), 2015. URL: <http://www.amg.swemorph.com/pdf/amg-4-1-2015.pdf>. Accessed September 1, 2020.
- BISHOP Peter, HINES Andy, and COLLINS Terry, “The Current State of Scenario Development: an Overview of Techniques”, *Foresight*, 9(1), 2007, pp. 5-25. DOI: <https://doi.org/10.1108/14636680710727516>
- DUFOURT Daniel, FORAY Dominique, and GARROUSTE Pierre, *Méthodologie d’observation des changements techniques et des dynamiques industrielles. Analyse des systèmes. Économie des changements technologiques (ECT)*, Lyon: Presses universitaires de Lyon, 1986.
- GODET Michel, *Manuel de prospective stratégique. L’art et la méthode*, Paris: Dunod, 2007, pp. 221-246. URL: http://www.lapro prospective.fr/dyn/francais/ouvrages/la_prospective_strategique/t2--manuel-de-prospective-strategique-dunod-2007.pdf. Accessed September 1, 2020.
- GODET Michel, and DURANCE Philippe, *Strategic Foresight: for Corporate and Regional Development/ La Prospective stratégique: pour les entreprises et les territoires*, Paris: UNESCO/Dunod, 2011, pp. 74-78.
- JOUVENEL Hugues (de), *Invitation à la prospective/An Invitation to Foresight*, Paris: Futuribles International (Perspectives), 2004. URL: <https://www.futuribles.com/viewer/pdf/3901>. Accessed September 1, 2020.
- LAMBLIN Véronique, “The Driver Report: Documenting Variables for Foresight Exercises”, *Prospective and Strategic Foresight Toolbox*, December 2017, Futuribles International.
- RITCHEY Tom, and ARCISZEWSKI Tomasz (eds.), ‘Special Section: General Morphological Analysis: Modelling, Forecasting, Innovation’, *Technological Forecasting and Social Change*, vol. 126, January 2018, pp. 76-185. DOI: <https://doi.org/10.1016/j.techfore.2017.02.036>
- YOON Byungun, and PARK Yongtae, “A Systematic Approach for Identifying Technology Opportunities: Keyword-based Morphology Analysis”, *Technological Forecasting and Social Change*, 72(2), February 2005, pp. 145-160. DOI: <https://doi.org/10.1016/j.techfore.2004.08.011>
- ZWICKY Fritz, *Discovery, Invention, Research: Through the Morphological Approach*, New York: MacMillan, 1969.

Examples of Foresight Exercises using Morphological Analysis

- AGRIMONDE-TERRA, *Foresight: Land Use and Food Security in 2050. Scenarios of Land Use and Food Security in 2050*, Paris: CIRAD (Centre de coopération internationale en recherche agronomique pour le développement)/INRA (Institut national de la recherche agronomique), Working Paper, June 2016, 38 pp. URL: <https://inra-dam-front-resources-cdn.brainsonic.com/ressources/afile/355677-d1563-resource-agrimonde-terra-scenarios-en-anglais.pdf>. Accessed December 1, 2017.
- AMÉRICO DE FIGUEIREDO PORTO Claudio, MARQUES Eduardo, and BELFORT ANDRADE SANTOS Andréa, “Prospective in Brazil: The Power to Build the Future”, *Technological Forecasting and Social Change*, 77(9), November 2010, pp. 1550-1558. DOI: <https://doi.org/10.1016/j.techfore.2010.07.010>

BUREAU NATIONAL DE LA PROSPECTIVE ET DE LA VEILLE STRATÉGIQUE, *Étude nationale prospective 'Côte d'Ivoire 2040'*, Abidjan: ministère du Plan et du Développement, final report, January 2016. URL: <http://www.plan.gouv.ci/assets/fichier/RAPPORT-SYNTHESE-ENP-CI-2040-version-finale-du-10-mars-2017-1-5-.pdf>. Accessed September 1, 2020.

CEP (Centre d'études et de prospective), *Prospective, agriculture, énergie 2030. L'agriculture face aux défis énergétiques*, Paris: ministère de l'Agriculture, de l'Alimentation, de la Pêche, de la Ruralité et de l'Aménagement du territoire, 2010, 166 pp. URL: <https://agriculture.gouv.fr/prospective-agriculture-energie-2030-lagriculture-face-aux-defis-energetiques>. Accessed September 1, 2020.

CGDD (Commissariat général au développement durable), "Eau, milieux aquatiques et territoires durables 2030. Synthèse de l'exercice de prospective [Water, Aquatic Environments and Sustainable Territories to 2030. Synthesis of the Foresight Project]", *Études et documents*, 91, August 2013, 46 p. URL: <http://temis.documentation.developpement-durable.gouv.fr/docs/Temis/0079/Temis-0079054/20841.pdf>. Accessed August 31, 2020.

DEPS (Département des études, de la prospective et des statistiques), *Culture & médias 2030. Prospective de politiques culturelles*, Paris: ministère de la Culture et de la Communication, 2011, 208 p.

JOHANSEN Iver, "Scenario Modelling with Morphological Analysis", *Technological Forecasting and Social Change*, 126, 2018, pp. 116-125. URL: <https://www.sciencedirect.com/science/article/pii/S004016251730656X/pdf?md5=62bd83d000696c2e92728181ca9foe7c&pid=1-s2.0-S004016251730656X-main.pdf>. Accessed September 1, 2020.

JOUVENEL Hugues (de), and ROQUE Maria-Àngels, *La Catalogne à l'horizon 2010*, Paris: Economica, 1994.

LAMBLIN Véronique, and MASSOT Marie-Hélène (eds.), *Prospective de la mobilité dans les villes moyennes*, Paris: Futuribles International, IFSTTAR (Institut français des sciences et technologies des transports, de l'aménagement et des réseaux), 2011. URL: <https://www.futuribles.com/fr/groupe/prospective-de-la-mobilite-dans-les-villes-moyenne/>. Accessed September 1, 2020.

PILORGÉ Étienne, DAOUHADI Ahmed Karim, MUEL Frédéric, and TREMBLAY Anne-Marie, *Prospective huiles et protéines végétales 2030. Quatre scénarios contrastés pour 2030*, Paris: Terres Inovia, 2016, 48 p. URL: https://www.lafranceagricole.fr/r/Publie/FA/p1/Infographies/Web/2016-12-13/synthese_prospective_huiles-proteines2030_Terres-Inovia.pdf. Accessed September 1, 2020.

SEPPÄLÄ Yrjö, "The Futures Table (Morphological Matrix) Method: Case Report: Care for the Elderly", in *How Do We Explore Our Futures? Methods of Futures Research*, Acta Futura Fennica, 10, Finnish Society for Futures Studies, first English edition, 2017, pp. 139-155.

TZEZANA Roey, "Scenarios for Crime and Terrorist Attacks Using the Internet of Things", *European Journal of Futures Research*, 4(18), 2016, 7 p. URL: <https://link.springer.com/content/pdf/10.1007%2Fs40309-016-0107-z.pdf>. Accessed September 1, 2020.

Software and Platforms for Morphological Analysis

MA/Carma™ (Computer-Aided Resource for Morphological Analysis): <http://www.swemorph.com/macarma.html>

Parmenides EIDOS: <https://www.parmenides-eidos.com/eidos9/us/offer/eidos-blog2/262-scenario-based-strategizing-using-eidos>

Scenaring Tools: <https://scenaringtools.com> ■