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Adapting a participatory modelling method to forecast food system scenarios: a case study on the pork value-chain

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Abstract

For a value-chain to be sustainable, the main challenge is sometimes its durability. When stakeholders are lost in the shifting maze of economic, social and environmental issues, participatory foresight methods help them consider the options and choose a strategy to follow. The aim is to create several scenarios of evolution of the value-chain and select desirable scenarios. Because of the global context in 2020 and 2021, implementing methodological and organizational adaptations in the classic "scenario method" from Michel Godet was necessary. These adaptations are exemplified by the case study of the prospective for the French pork value-chain in the next 5 years. Indeed, this value-chain touches particularly on certain contemporary concerns, with much discussion about its environmental footprint, its human resource challenge and its social acceptability, as is the case for most food value-chains in developed countries.

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Introduction

Complex systems are characterized by a large number of components which may interact with each other and with their environment. The behavior of complex systems is intrinsically difficult to model and to predict due to the dependencies and the various types of interactions between their components, or between the system and its environment (Bar-Yam, 2002). Agri-food chains can be considered as such (Croitoru *et al.*, 2016): they rely on various interdependent actors whose objectives and priorities may be divergent, from producers to consumers, including processors, distributors, managers, professional associations, public authorities (Handayati *et al.*, 2015). The concerns of these actors relate to different criteria (economic, environmental, health, sensory, technical, etc. …). They are also constrained by the pressure of production upstream and consumption downstream, be it climatic, regulatory, economic or social. In addition, their actions are not centralized but distributed, poorly coordinated and in constant evolution (Balmann *et al.*, 2006). Taking decisions in agri-food value-chains can thus seem very challenging.

The problem considered in this paper stems from the necessity of changes in complex agri-food systems. The higher aim is to raise awareness among stakeholders, especially the dominant ones, expecting the value-chain to be managed in a more sustainable way.

To do that, we need to co-construct scenarios of evolution of the food system with its stakeholders: each stakeholder group holds part of the knowledge to understand the situation and to better comprehend how changes may influence not only the operations of its members, but also of the other groups of interest. Gaining such an overall understanding of the situation on all the involved parties certainly helps reach solutions that are more thoughtful and acceptable. In the end, it is up to the stakeholders to choose the best path they wish to follow.

Different approaches have been proposed to help increase stakeholders' awareness of critical situations in agri-food chains and to better understand the different positions of concerned stakeholders (Bourguet *et al.*, 2013; Kopainsky & Stave, 2014; Perrot *et al.*, 2011; Taillandier *et al.*, 2021; Thomopoulos *et al.*, 2018; van Bruggen *et al.*, 2003). We are concerned in our case with prospective-oriented approaches (Cordobes *et al.*, 2004; De Jouvenel, 1964; Godet & Lesourne, 1977; Lesourne, 1989; Meadows *et al.*, 1972) including consensus building between the stakeholders of the supply chain (Susskind *et al.*, 1999). Therefore, we focused on the so-called "method of scenarios" or "Godet method" (Godet, 2007, 2008; Godet & Durance, 2001). This method belongs to the "French school of prospective" and has been implemented with success at different scales for years, e.g. demand

side management of energy at World scale, future of management school in Europe, etc. It fits when dealing with changes at a value-chain level, in the agri-food sector, as was the case for the foresight exercise about the innovative issue of industrial insects supply chains in France (Macombe *et al*., 2019). Another advantage is that this method is a very formal prospective method.

In the situation of Covid-19 pandemic, the traditional face-to-face collaborative way has been proven inoperable. Consequently, we had to consider adaptations in the classic scenario method and jointly, possible biases induced by these adaptations in the results obtained.

The paper focuses on the comparison of the two methods: the classic and the adapted.

We will consider, as an illustrative application, a case study provided by the French SENTINEL project, the French pork meat sector.

In the remainder of this paper, the "classic method" is the prospective method by Godet that we should have implemented (if there's no pandemic), and the "adapted method" is the approach implemented in reality, because of the pandemic situation. The general questions dealt with are:

1. What are the adaptations of the classic method needed when a face-to-face collaborative way is inoperable?
2. What are the biases of implementing the adapted method instead of the classic one?
3. How do we deal with those biases to ensure proper modelling of the food system to later guarantee adequate value-chain management strategies?
4. What are the scenarios obtained using the adapted method?

To answer these questions is it first of all fundamental that we introduce in Section 1 the classic scenario method and its steps. We will then discuss in Section 2 the problems encountered due to the sanitary context as well as the organizational and methodological adaptations we have made; we provide a detailed description of the calculations performed, so that the method developed can be formally reproducible and verifiable. Examples of the results obtained are presented in Section 3 of this article, before discussing the scientific interest (including possible biases of the method as well as ways of surpassing them) and the business interest in Section 4. Section 5 is a brief conclusion.

1. Background: the "Scenario Method", a Participatory Method for Scenario Building

The theory and the tools underlying the so-called "scenario method" are extensively presented in Godet (2008) and Godet & Durance (2001). The data

are gathered thanks to interviews of prospects, who are stakeholders (in the broadest sense) of the supply chain under study.

An important stage of the scenario method, the so-called "Constructing the base" stage, aims to link the food system variables, to identify the key actors and the key variables, and to build numerous base scenarios, obtained by combining the modalities (values) of the key variables.

In the present paper we focus on **this "Constructing the base" stage**. Several reasons explain why we are focusing on this stage: on one hand, the steps followed in this stage are time consuming and are spread out over several months (12 months in our case study). On another hand, usually, the complete Godet method is not necessarily used in its entirety as it is a very consequential process. Finally, it is essentially this first stage that is centered on interactions with the prospects. Plus, the difficulties faced during further stages are the same as the ones faced in this initial stage. The problems encountered will be detailed in Section 2.

The "Constructing the base" stage consists of building a model, which represents the current state of the system under study, and detects the potential for change. It is composed of the following steps, familiar in system modelling approaches.

Step 1: Delimiting the system under study

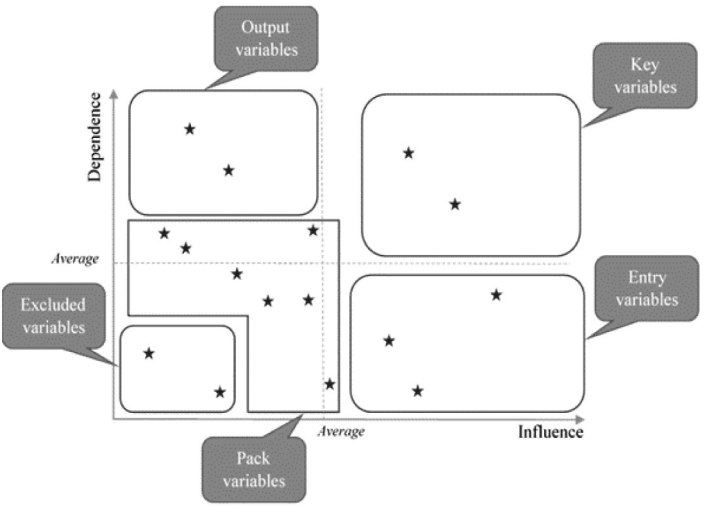
It implies identifying the actors that should be gathered, in order to collectively discuss the variables that will influence the evolutions of the system. In the remainder of the text, these actors are called "prospects".

Step 2: Determining the key variables

It consists of:

- making a list of the variables that the prospects deem to be relevant in influencing the future of the system;
- reducing the number of variables, by merging all the equivalent ones, i.e. those standing for the same concept;
- asking the prospects to consensually design influence relationships between all the remaining variables (pair by pair), whether they are direct or indirect. Determining the key variables. Indeed, identified variables influencing the system evolution can be classified into 5 categories (Figure 1).

Figure 1 - Denomination of the different kinds of variables at the end of step 2



If the variables are very influent and little dependent, they are the input or "entry variables", so the built scenarios use them at the beginning of the prevision. At the contrary, the very dependent and little influential variables are "output variables": their value is given at the end of the scenario elaboration, as a consequence. "Pack variables" are moderately dependent and influent, so they are seldom included in the scenarios. As for the "excluded variables" they are neither dependent nor influential, so they are not taken into account when constructing the scenarios. Finally, the "key variables" have the particularity of being both more influential and more dependent than the averages calculated. Consequently, it is impossible to anticipate in which direction they will evolve. This means that they represent important issues, since despite fairly small changes, they can make the situation evolve in very different directions.

Step 3: Elaborating the general base scenarios

The role of the key variables is crucial when it comes to building the foresight. Indeed, the general base scenarios are built by the systematic combination of the modalities taken by the key variables. It is therefore of the utmost importance to make a rigorous and meaningful selection of the key variables as well as their modalities, which is a central topic of this paper.

Each step is based on appropriate tools which we summarize in Table 1.

Table 1 - Different steps of the 'Constructing the base' stage of the scenario method

Step	Who does what?	Tools used in the classic method
1. Delimiting the system under study	*Researchers:* identifying the prospects. *Researchers:* make individual and collective interviews with specialists. *Prospects:* provide variables influencing the system evolution.	No specific method. **Brainstorming**, **workshops**, etc. to determine the main variables influencing the system evolution.
2. Determining the key variables	*Researchers:* make a list of the variables quoted by the prospects; merge the variables standing for the same concept; organize groups (e.g. 3 groups of 10 prospects). *Prospects:* each group of prospects builds a consensus about the relationships between the variables. *Researchers:* build the matrix of relationships between variables for each group, and provide a synthesis matrix to be discussed by the group of prospects as a whole; select the key variables as those which are at the same time more influential than the average, and more influenced than the average (see Fig. 1); implement new surveys of experts if reduction of the number of key variables is needed.	The relationships between variables (influences and dependences) are built by consensus during **collective workshops, by small groups, then all together**. '**Survey of experts**' methods such as Delphi, Régnier's Abacus, or Smic-Prob-Expert allow the team to reduce the number of key variables.
3. Elaborating thebase scenarios	*Prospects:* build a consensus about the main modalities that can be taken by each key variable. *Researchers:* envision the different possible combinations of modalities.	Collective **workshops**. The general base scenarios are built as combinations of the possible modalities for all key variables.

2. The Remote Context

2.1. *The problems encountered*

The global pandemic that started early 2020 in France rapidly changed the way people worked as it forced remote-work on a great number of them. However, this way of working dates back to decades especially in scientific fields (Krämer-Flecken *et al.*, 2010; Stepanov *et al.*, 2011; Sun *et al.*, 2017). Nevertheless, other sectors are absent from the scene. Users' experience in the fusion sector was addressed in 2002 by Suttrop *et al.* (2002). In medical education, remote participation was very recently addressed by Kopp *et al.* (2021) in the context of the Covid-19 pandemic. Although the sectors

and considerations of these two latter studies strongly differ, both converge on several points and in particular: (i) personal communication remained of good quality and (ii) large meetings were to be excluded in the remote context.

In our case, remote work was not only an option, it was a necessity considering the sanitary context. However, since the scenario method is primarily based on face-to-face interactions, adjustments had to be made throughout the 3 steps of stage (1) of the classic method. In fact, as shown in Table 1, the first step can be easily adapted. Nevertheless, our specific problem concerns steps 2 and 3 of the classic method: those two steps are particularly problematic because they require mutual interactions between prospects in addition to the interactions with researchers.

Different choices had to be made to adapt the classic scenario method. They are presented in the following paragraphs.

2.2. *Organizational Adaptations of the Scenario Method*

The classic scenario method is based on collective sessions (usually face-to-face interactions with chosen prospects), particularly during the first two steps, as shown in Table 1. Several choices were available to us:

2.2.1. Replacing collective face-to-face sessions by **collective remote sessions**, such as video calls

Although more straightforward, this solution was not retained for the different reasons:

- Availability reasons: although it might seem easier to find common slots suitable for everyone during remote work, in practice the constraints related to the Covid context have reduced availability for reasons ranging from the management of the domestic daily life (children, meals, shopping with constrained schedules…) to the lack of motivation and a decrease in the implication in long distance projects while time spent on communicating with colleagues is increased. Last but not least, the last-minute cancellation facility is not to be overlooked: it is much more pervasive than for a long-standing trip which requires heavier logistics and leaves the participant with the feeling of taking part in group events and direct interactions.
- Technical reasons: possible connection problems can prevent the reunion, or prolong its duration and thus affect people's concentration (Roos *et al.*, 2020).

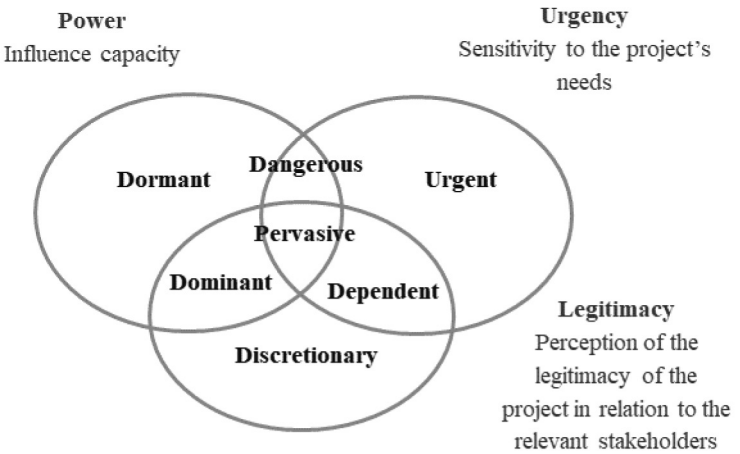
- Concentration reasons: remote discussions can hamper productivity. The longer the reunion, the less effective it can be. Long distance discussions can also affect people's ability to understand others' opinions (Simons *et al.*, 2000).
- Involvement reasons: when the number of participants in remote meetings is quite high, prospects may feel less involved (Simons *et al.*, 2000).
- Confidence-related reasons: confidence can be degraded since the risk of losing information is higher in long distance reunions (Roos *et al.*, 2020).

2.2.2. Multiplying the diversity of sources

Even in the classic method, the researchers seek gathering prospects from various domains, in order to generate original scenarios and breakdown scenarios. This issue is even more important in the adapted method. If the researchers interview only people with the same background, they will probably always receive always the same key variables, which is an impoverishment.

To mitigate this effect, we seek interviewing stakeholders with backgrounds and opinions as diverse as possible. There are several ways to classify the actors of a value-chain to improve the diversity of the interviewees (Clarkson, 1995; Sobczak & Girard, 2006). Mitchell, Agle and Wood (1997) classify the stakeholders according to 3 categories which are power, legitimacy and urgency. They then identify 7 types of stakeholders based on whether they possess one, two or all 3 characteristics (Figure 2 below).

Figure 2 - Classification of the stakeholders of a value-chain according to Mitchell, Agle and Wood's classification



We also added documents from literary reviews which provide factual and substantial information about the agri-food chain studied. Each document read is considered as an interview done.

2.2.3. Replacing collective face-to-face sessions by multiple **individual remote sessions** (video calls) whilst using other tools to complete the analysis of the interviews

Although increasing the time spent on the project for the team, this solution was retained. The semi-structured interview method is indeed often used in sociology studies (Chevalier & Meyer, 2018). It has the advantages of individual interactions referred to in Suttrop *et al.* (2002), Kopp *et al.* (2021) and Chevalier et Meyer (2018):

- The interviewee has higher confidence in the interviewer.
- He interacts with the interviewer more easily.
- He gives more information and structures his views according to his own vision of the matter.
- He can elicit opinions (out of the mainstream) that he would not have dared to say as such in a collective session, especially if the topic is sensitive.

When treated separately individual long distance interviews do not suffice to determine the key variables. Indeed, it is possible that a variable cited just a few times can be deemed crucial if thoroughly discussed within the group of experts.

From a methodological viewpoint, this required some adaptations of the method. Those adaptations are presented in Table 2.

The tools used and the process followed are described more thoroughly in *Section 2.3. in Annex 1.* In the Annex 1, we detail the calculations followed so that the adapted method can be verified and reproduced.

After determining the key variables and their modalities, a questionnaire is sent to the prospects in order to confirm, complete or change the list of key variables selected from the first range of interviews. This idea is inspired by the Delphi method. Illustrations of the results are provided in the next section.

Table 2 - Tools used in each step of the "Constructing the base" stage of the adapted method. The main tools are highlighted in bold

Step	Tools implemented by researchers in the adapted method
1. Delimiting the system under study	Identification of the stakeholders by the **tool of Mitchell *et al.* (1997)**. Remote individual interviews. **Analysis of existing documents** (treated as interviews) on the matter.
2. Determining the key variables	List of the sub-concepts quoted by the sources (prospects and documents). Merging of the sub-concepts standing for the same concept. Conversion of each interview into a **cognitive map** to visualize influence relationships between the concepts identified. Grouping concepts into variables. Construction of **partial squared matrices** of variables. We can thus identify the partial influence and dependence of each variable. But we do not account for the indirect links, that is different from the classic method. Construction of the global set of variables by merging all partial sets of variables together. Merging of all partial **squared matrices** into a global one by summing partial influences and dependences of all variables. Identification of the key variables by two ways: whose influence and dependence are higher than the average, – and analysis of the **answers from the interviewees** following the submission of the list ofvariables and their modalities.
3. Elaborating the base scenarios	The preliminary scenarios are built by scientists as combinations of the possible modalities of all key variables. The scenarios presenting incompatible modalities are discarded.

3. Results: application to the French pork value-chain

The example taken is in the meat sector, which currently faces various challenging social demands, from reduced environmental impact to animal well-being, and tensions between vegetarian food trends and meat-based culinary traditions (Reijnders & Soret, 2003). The French pork sector is particularly illustrative of these concerns, with debates around health-nocive additives (Sindelar & Milkowski, 2012), salt (Campbell *et al.*, 2011), fat in traditional food products, and its environmental footprint (Basset-Mens, 2005), especially since the French value- chain is very strongly concentrated in the West of the country (more than 55% of French pigs come from the West (AGRESTE, 2021)).

The challenge is to build prospective scenarios about the likely evolution of the French pork value-chain in the next 5 years. The French pork value-chain actors are used to the cyclicality of selling prices (favorable and then unfavorable) that have punctuated its existence for 70 years. It has developed without the intervention of the State or the subsidies which other agricultural sectors have access to. It is a sector that seizes export opportunities (i.e. to

Russia and China in 2020)[1] and whose efficiency has grown steadily (Roguet, 2017; Roguet *et al.*, 2014; Teffène *et al.*, 1998), through a standard model of very intensive breeding, while the average number of animals raised per farm multiplied (Dourmad *et al.*, 2010; Roguet *et al.*, 2014). The shared values of the main players in the value-chain (slaughterers, farmers with large pig farms, specialized cooperatives, salters, IFIP[2]…) are efficiency, cost control, technicality. As a result, it is very difficult for them to think about alternative models (especially for the upstream part of the sector) because they would put in danger what they have built. On the other hand, because of the usual cyclicality, the surge in feed and energy prices is not perceived as a signal that a more sober model must be adopted. From the point of view of these stakeholders, the most important challenge is the attractiveness of the sector, which struggles to recruit young breeders or workers for the farm, slaughterhouse, cutting or processing. This was already their main concern 40 years ago (Chaib *et al.*, 2022). Another problem to which they are sensitive is the refusal by the local population of new pig farms, in connection with the societal rejection mentioned above.

In this section, we present the results obtained by applying the adapted method to the case study regarding the French pork value-chain. Our goal is to consider the plurality of the possible futures of the French pork industry. What are the factors that will determine its evolution?

3.1. *Results of the methodological adaptations of the scenario method*

3.1.1. Lists of concepts and concept-merging results

We realized a total of 21 interviews (including 12 prospects representing different professions in the pork value chain and 9 opinion papers). From them, 651 sub-concepts were defined. After merging similar sub-concepts as described in 2.3.1 and 2.3.2 in annex 1, we obtain a list of 169 concepts. In this list of concepts, we identify 12 variables (A to L). They are presented in Table 3 below:

1. Because of a surge in African Swine Fever in 2020, China's imports of meat of swine (fresh, frozen or chilled) from France almost doubled in volume according to the trade statistics for international business development. France also exported more than 780 tons of live pork to China whereas normally, such transactions do not take place. Exports of live pork to Russia until 2012 were around 500 tons. Those volumes drastically plummeted in 2014: Moscow had in fact decreed an embargo on European pork, officially motivated by the discovery of some cases of African swine fever in dead wild boars in Lithuania and Poland. In 2020 however, because of structural deficiencies, a few tons of live pork and pork grease and offals were exported to Russia (information from trademap.org).

2. IFIP is the French pork technical institute.

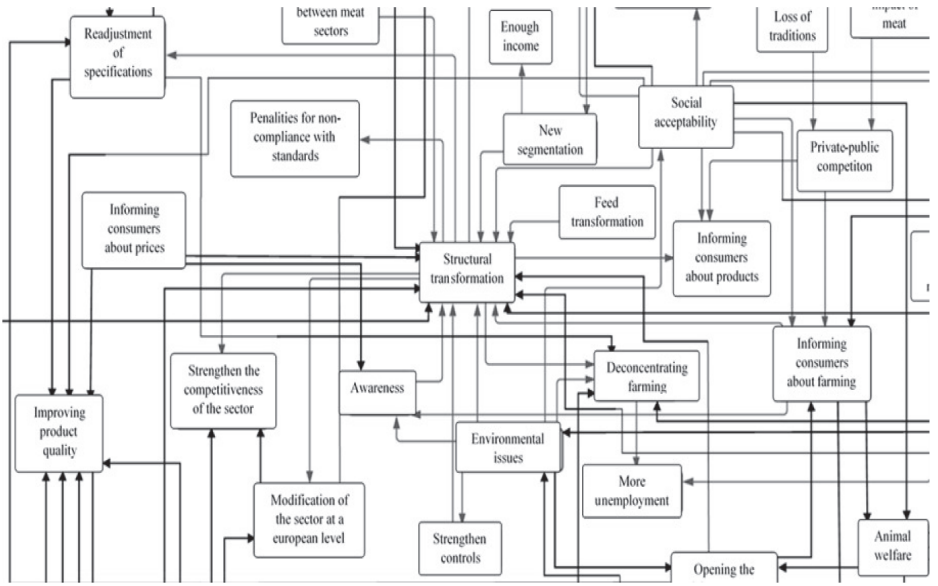
Table 3 - List of variables obtained after analysing interviews and documents

A	Social acceptability	**G**	Evolution of job attractiveness
B	Process of production and transformation	**H**	Institutional context
C	Consumption modes	**I**	Energy consumption
D	Production costs	**J**	Communication
E	Technical and technological progress	**K**	Value-chain structure
F	Market access	**L**	Product prices

3.1.2. Elaborating cognitive maps of the concepts identified per interview

Cognitive maps are drawn, based on the information gathered per prospect and per document. Figure 3 represents an extract of one of the 21 cognitive maps. They represent the influence and dependence links between two concepts identified in an interview.

Figure 3 - Extract of a cognitive map representing links between concepts identified in an interview



For example, the concept 'Structural transformation' in the center represents variable K (Value-chain structure). It influences the concept 'Informing consumers about products' (an arrow to the right) which represents variable J (Communication). This indicates that a readjustment of the value- chain structure can have an impact on the improvement of communication, according to the interviewee.

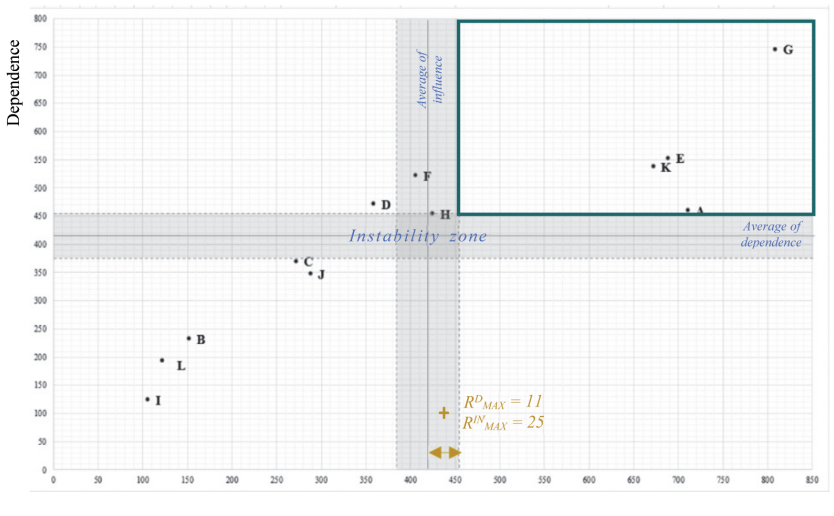
3.1.3. Creation of partial and global matrices to graphically determine the final key variables

The cognitive maps are translated into tables of concepts as described in definition 2 (2.3.3 in the annex 1).

Then the partial matrices are created (according to the processes described in definition 2, in annex 1). Figures 5, 6, and 7 in annex 1 are examples of the matrices obtained.

The final global squared matrix obtained (Figure 8 in annex 1) allows us to calculate influence and dependence values for each variable. The dot cloud corresponding to this matrix is below in Figure 4.

Figure 4 - Final graph allowing the identification of the key variables for all 21 interviews



Variables on the top right of the graph are the ones with the highest influences and dependences. They are key. Variables on the bottom right are entry variables, which means that they are also important when creating the reference scenarios. It is the same for the output variables on the top left. As for the variables at the bottom left of the graph, they are excluded: they are not considered when creating the scenarios.

The final stabilized key variables deduced from the adapted method are G (evolution of job attractiveness), A (social acceptability), E (technical and technological progress) and K (value-chain structure). Variable D (production costs) is a stabilized output variable. The variables located in the instability

zone are reallocated in the new category where they might fall in. Variables F (Market access) and H (Institutional context) for instance are more likely to be output variables.

Those results can be explained by the fact that considerable importance is granted to whether the pork sector is unattractive or if its professions are becoming attractive (variable G); it has always been the case (Chaib *et al.*, 2022). They also show that the number, the size and the location of farmsteads (variable K) heavily weighs on the evolution of the system. As for technical and technological progress in the value-chain (variable E), it is viewed by the prospects as a gateway to avoid negative consequences in the future – this of course can't always be the case. The social acceptability (variable A) of the pork value-chain is also an essential factor taken into account nowadays. It covers animal welfare, health and the socio-economic environment as well as the concerns around ecosystems, water and air pollution (Chaib *et al.*, 2022). We expected some of the variables to be key according to the interviews (notably variable I for energy supplies and use), especially considering the current world context. This however can be explained by the times at which the interviews were conducted (before the eruption of a war in Ukraine) and by the fact that it is indeed an underlying cause and not the first one that comes to mind when discussing issues of the French pork value-chain. However, this does not mean that we do not take those excluded variables into consideration: we do not use them when creating the different scenarios, however we cannot neglect them when describing the alternatives in detail.

3.1.4. Determining the modalities of the key variables

As mentioned in section 2.3.4 in annex 1, the modalities of the key variables are identified in the lists of concepts which make up said variable. In the following paragraphs and in Table 4, we illustrate through the example of variable A how we identify modalities.

- The modality gathering all the characteristics described in the first column of the table 4 is:

> Society demands a major change in the production model in the name of animal welfare, respect for the environment and public health. It is no longer possible to establish a new pig farm somewhere, and short circuits are developing at the expense of long circuits.

We give it the name "**rejection of the current model of pig production**"

Table 4 - Determination of the modalities of the variable A "social acceptability", through concepts and opposite concepts

Some of those concepts (the ones in bold and italic in Table 4) are rather explicated by us, according to what was said during the interviews.

A: Social Acceptability	
Concepts identified in the interviews	**Opposite concepts found in the interviews or elicited**
Refusing all types of productions near houses	***Accepting nearby pig farming***
Desire to develop local circuits	Accepting current long circuits
Consumer awareness (criticism) Criticism of the environmental impact of livestock farming Strengthening environmental requirements Increasingly recurring environmental problems	Improving the image of the (current) pig sector
Animal welfare requirements Improving animal health Reducing the use of inputs for human health Meeting consumer demands	***Status-quo***
Criticism of the nutritional impact of processed meat Concerns about traceability	***Recognition of the current quality of meat***

- The modality gathering the characteristics described in the second column is:

> At the price of some adjustments (increase in the surface area devoted to spreading, methanisation of surpluses, etc.) a consensus is reached with society.

We give it the name "**consensus about an improved model**"

At the end of the process for all the variables, we handle a list of stabilized key variables with their modalities presented in Table 5 below.

Table 5 - List of stabilized key variables and their modalities

Variable	Modality 1	Modality 2
A: social acceptability	Rejection of the current model of pig production	Consensus about an improved model
G: evolution of the job attractiveness	Unattractive sector, professions less and less practiced	Making the sector attractive
E: technical and technological progress	Improvement of techniques and technologies used	Stagnation in the use of techniques and technologies
K: value-chain structure	Restructuring and improving the sector	No structural changes

Even though we 'stabilized' the variables we obtained, we still wanted to make sure that those variables are indeed key to the prospects, plus, it is possible that some likely "real" key variables (that would have been selected thanks to long discussions and consensus building in the classic method) are let aside in the adapted method. That is why we submitted the list of variables with their modalities as discussed below.

3.2. *Submitting the list of variables and modalities to interviewees*

We assume that the "real" key variables are all included in the list of variables elicited thanks to the individual interviews. Indeed, it is highly unlikely that variables representing key issues in the food chain are not cited by anyone. This could happen if we only chose respondents from the same group of stakeholders, but this is not the case (see 2.2.2).

We decided to merge the list of the selected key variables graphically identified with the rest of the variables identified by all former interviewees: prospects are thus in a way 'forced' to see and think of **all** the variables together. Indeed, each reader can think that "if this variable is in the list, it means that someone quoted it as being key, is it true?". Our idea is to replace the impossible face-to-face consensus building by a second step of a Delphi consultation.

We thus contacted the interviewees and sent them an email with the questionnaire. For those who preferred filling it directly, we did it with them, by phone, since most prospects are geographically far from our locals.

Table 6 is an extract of the questionnaire we sent. The experts were asked to choose 5 variables at most to which they accord a high or very high importance. The variables are classified according to the French alphabetical order.

Table 6 - Extract of the Delphi questionnaire sent to the prospects

Below are the results of the analysis of 21 interviews with experts like you. Filling this questionnaire allows you to confirm and explicit your choices.
The objective of our working group is to gather different and contrasting points of view on the sector and its trends. The purpose of this questionnaire is therefore to identify the key variables in order to be able to develop reference scenarios for the future of the pig sector over the next 3-5 years. Below you will find all the variables and their modalities (values that can be taken by the variable) noted during the interviews about the evolution of the pig sector.
Please choose no more than 5 variables with a "High" or "Very high" importance.

Variables cited by the experts interviewed (and the 2 or 3 modalities that this variable can take)	**Importance of the variable**				
	Very low	**Low**	**Average**	**High**	**Very high**
Acceptability of the current production model (Requirement for change concerning the sector OR acceptance of the current porkvalue-chain)					
Market access (Facilitation of international trade OR difficulty of international trade)					
Inter- and intra-link communication (Improved communication OR same level of communication)					

By displaying the contrasted modalities of each variable, we expect to raise reflection about the role of the variable itself, especially to prospects who did not quote this variable spontaneously. In addition, to push the prospects to sort out the more important variables, we limit the number of variables to which a "very high" or "high" importance is attributed to 5.

We do not ask the prospects to classify the variables as either, key, output, input or excluded for several reasons: first of all, most of them are not familiar with those terms which could lead them into confusion. Secondly, our aim is only to confirm the results we already have: ideally we would like the results of all questionnaires to be that the five variables A, E, G, K and D are highly important.

After gathering all the responses, the results were the following (Table 7):

Table 7 - Results obtained after receiving 10 responses from prospects

Variables	Very high	High	Total
A: Acceptability of the current production model	6	3	9
G: Evolution of the attractiveness of professions	2	5	7
L: Final product price	3	4	7
D: Production costs	2	4	6
J: Inter- and intra-link communication	1	4	5
C: Pork meat consumption	4	1	5
F: Market access	2	1	3
H: Institutional context	0	3	3
B: Production and transformation processes	2	1	3
I: Costs and sources of energies	2	0	2
K: Value-chain structure	1	1	2
E: Technical and technological progress	0	0	0

The variables obtained are not quite the same as those that were identified as key according to the interviews. This however does not discredit our work. In fact, the questionnaires were sent almost a year after the interviews were conducted, and a lot has happened since then (numerous other waves of Covid, war between Ukraine and Russia, increase in feed prices, etc. …); this shows how much prospects opinions is highly influenced by current events (Cossette, 2004). In addition, some variables such as K (value-chain structure) are undoubtedly key, but prospects do not consider that the value-chain's structure can change, at least not in the next 3 to 5 years. That is why most of them did not mark it as high or very high importance for the following years. As for the variables that were excluded according to the adapted Godet method but are of high importance according to the Delphi results (L, J and C), particular attention is paid to them when describing in detail the scenarios chosen.

3.3. *Scenarios obtained using the adapted Godet method*

The scenarios are created by combining the modalities of the key variables obtained using the adapted Godet method (A, E, G and K). Each of those variables has 2 modalities. We thus have 2^4=16 scenarios possible. However, certain incompatibilities between the modalities were detected, and so the scenarios including them were eliminated. We were left with 8 possible framework scenarios, two pairs of which were compatible; we ended up merging them together. We obtain 6 final framework scenarios, called "framework-scenarios" as they are quite roughly described. They are presented in the following order: from the one that requires the least inflections in the current trends to the one that would require the largest inflections. On the other hand, they describe a trend that could emerge in 5 years, rather than a stabilized situation in 5 years.

Business as usual

The pork value-chain does not change its model, it remains unattractive because of the continuous expansion of farms (which are becoming too expensive to be taken over), the low selling prices of carcasses and finished products (because of competition with imports) and its poor image in society. Some efforts are made by the stakeholders of the value-chain when it comes to animal welfare, health and the environment. Advances in the technologies actually adopted do not change the situation. The sector remains concentrated in the Great West. Production costs remain volatile and continue to rise in trend, while selling prices remain affordable for consumers. The quantities produced in France are gradually eroding.

Technologies to the rescue

The jobs offered by the value-chain remain unattractive, and the image of the sector in society remains mediocre. Major efforts are being made to reduce pollution (methanization, etc.) and reduce additives in cold cuts, in order to ease social demands. Techniques and technologies (robotics, digital) are more and more efficient, and lead to the automation of many tasks (in breeding, slaughter, cutting…) to increase hourly productivity. Their introduction requires expensive investments. Many workstations are robotic. Intensification and concentration of production continues. Costs are rising, but the increase is modulated by productivity gains linked to the use of technology. Prices for the consumer remain reasonable, and the quantities produced are stable or slightly increasing as export markets open.

A more attractive value-chain

The sector has managed to make its professions more attractive, among other things through inter- and intra-link communication. Some aspects

of animal welfare and other environmental and health aspects are being improved, making it easier for consumers to accept pig farming as it is. The techniques and technologies used greatly improve the working conditions of all the actors in the value-chain, at the cost of rather heavy investments. The sector remains intensive and concentrated in the West region. Costs are increasing while prices for the consumer remain reasonable. This puts the most fragile stakeholders in difficulty, but the succession is nevertheless assured. Quantities produced remain stable.

Regional magnet/Compromise

Communication with consumers and potential future breeders and actors in the sector has succeeded in making the sector attractive, which improves the transmission and survival of very large pig farms. It is easier to find workers trained in the meat sector. Following a strengthening of standards and regulations (environment, animal welfare and health) at national and European level, the pork value-chain has managed to forge a new compromise with society. Consumers are willing to pay more for pork, which allows for higher selling prices and better remuneration for all players. Without significant technological progress, the value-chain remains concentrated in the major areas of current pig production, with a stabilization of the quantities produced. Production costs continue to rise in trend, but selling prices follow.

A two-faced value-chain

The strong demands of society towards the pork value-chain (organic, animal welfare, less pollution…) lead to a new distribution on the territory: large structures towards the West develop little, while small to medium farms are deployed throughout the territory, using multi-species slaughterhouses and local processing workshops. The professions in this short livestock sector are becoming more attractive, which encourages future breeders and processors to set up. The West invests in digital and robotization technologies and continues to export when opportunities arise. Direct sales in short supply chains are developing, with high prices, while prices remain moderate for products from intensive structures in the West. Overall, the quantities produced are stable. Production costs remain reasonable. On average, the consumer consumes less pork, and pays more for it. Consumer markets continue internationally.

Stop in the West

The current sector is becoming less and less attractive: large pig farms do not find buyers, especially since institutional support is unsuited to the problem. It becomes impossible to install a new building in the great West.

Society totally rejects pig farming as it is today, demanding different farming techniques in the name of animal welfare, and the end of "green algae". As a result, the sector is undergoing drastic regulations, and a profound transformation (new distribution of livestock throughout the French territory, growth in the number of small/medium farms, short circuits etc. …) without significantly modifying the techniques and technologies used. The quantities produced fall very sharply and rapidly. Pork and deli meats are becoming scarce and expensive commodities, and consumers are reducing their purchases. There is no longer any "basic" commodity for major international markets. Some niche markets for renowned artisanal processing (Bayonne ham, rillettes, etc.) continue to develop for export.

Those are the six framework-scenarios developed thanks to the adapted Godet method. Normally, in the Godet method, the scenarios would have been presented to the stakeholders of the French pork value-chain so that they could choose two of them as desirable. However, in the adapted Godet method, considering the situation, they are rather presented to project Sentinel partners (including IFIP representatives). During a general assembly of the partners of the SENTINEL project, two scenarios were unanimously chosen, on the grounds that they were the only bearers of hope. In particular, in these two scenarios, the sector's professions have become attractive again. The scenarios chosen are ***"Regional magnet/ Compromise"*** and ***"A two-faced value-chain"***. In the rest of the project (not covered in this paper), these two framework scenarios will be studied in detail, in order to explain the conditions and actions to be taken for their realization.

4. Discussion

4.1. *About scientific issues*

From the adapted method proposed, results are obtained in the case study regarding the future of the French pork supply chain, showing that the remote constraints do not prevent from delivering some "key variables" of the system.

4.1.1. Limits

The time granted to the process is considerably expanded. The approach allows highlighting possible biases induced by these adaptations in the results obtained.

Even though it is possible to conduct the adapted method by using virtual individual reunions and including new tools, it is possible that some key variables that would have been selected thanks to consensus in the classic method are left aside in the adapted method for two reasons: 1) because the number of prospects quoting them spontaneously in individual interviews is not large enough, and 2) because Delphi consultation is less efficient to raise awareness than peer-to-peer discussions. The fact that prospects cannot meet with each other influences the final choice of the key variables.

In addition, there is a risk of misusing subjectivity, which nonetheless is essential in the participatory approach. In the adapted method, a subjectivist perspective is adopted (Cossette, 2008; Lundberg *et al.*, 2020; Nissen, 2012). Citing Cossette (2008), "the individual cannot disregard his own cognitive structure when he approaches reality". Therefore, the cognitive maps, which serve as foundations to our analysis, are biased by the perception and interpretation of events specific to each individual (Cossette, 2004; Nissen, 2012). It is however what interests us and what allows us to collect as many variables as possible in order to create different scenarios.

Before the pandemic, we had chosen to implement the scenario method because of two particularly interesting features of it.

The first is that it generates by consensus building a shared vision of the future, stemming from actors bearing in mind different visions before this process. It would be an asset for the supply chain, especially when the time comes to develop a new collective vision (French EGALIM law n. 2018_938 30th of October 2018[3]). The second feature is that this scenario method builds scenarios that nobody, among the prospects, predicted before nor thinked of. Indeed, by combining systematically different characteristics – the modalities of the key variables –, Godet's method generates totally unexpected scenarios. In a nutshell, the classic method presents "emerging" properties, including ruptures.

Unfortunately, meeting with prospects individually and virtually sweeps away a strength of participatory methods which is to collectively involve a wide range of actors. They allow us to get a global view of the supply chain in its current and future state, but do not provide the expected consensus building process. So, by using the adapted Godet method, we do not benefit from the first feature, but we do benefit from the second one, especially since we tried to make the process of identifying the key variables sufficiently robust.

3. EGALIM (2018), *Loi pour l'équilibre des relations commerciales dans le secteur agricole et une alimentation saine et durable*, Ministère de l'Agriculture et de l'Alimentation. Available via www.legifrance.gouv.fr/loda/id/JORFTEXT000037547946.

4.1.2. Scientific interest

Overall, probably less scenarios are depicted by the adapted method than by the classic one. However, it is clear that notwithstanding the sanitary crisis we faced, reuniting prospects (as was usually done in the classic Godet method) is becoming more complicated and will be less and less frequent, because of both work intensification and the difficulties to travel. Consequently, the adapted method can offer a contribution to scientists to replace the classic method, when it is not practicable.

4.2. *About business issues*

It is important we note that none of the interviewees described any of the scenarios. It is the combination of factors considered major for the evolution of the sector that birthed them.

From the stakeholders' points of view, the six framework scenarios obtained may seem frightening at first. Indeed, they depict either a sector that is moving more or less quickly towards its defeat, or a complete reversal of the trends at work for 50 years.

4.2.1. Scenarios of defeat

- In the ***"business as usual"*** scenario, French production is eroding because "Production costs remain volatile and continue to rise in trend, while selling prices remain affordable for consumers". Farmers give up, eventually defeated by the "price scissor" that ruthlessly shrinks their margins as charges rise (input prices rise) while products decline (through lower pork and consumer prices).
- ***"Stop to the West"*** is even scarier because of its realism[4]. For some stakeholders, it describes the situation that is taking hold: drastic regulations and a rapid fall in the takeover of farms and installations. The industry is shrinking, defeated by societal attacks to which it has not been able to respond.
- The scenario ***"a more attractive value-chain"*** has solved the question of the attractiveness of the sector, but it is slowly fading, eliminating the most fragile breeders, and without great prospects for the future.
- ***"Technologies to the rescue"*** forms the bet that robotization and digitalisation will be the "deus ex-machina" of the sector. They should

4. See in this regard the recent demands of the Dutch government towards breeders (June 2022).

compensate for its weaknesses: lack of manpower and attractiveness in general, pollution of all types, lack of acceptability by society, performance cap… but nothing is less certain in reality.

4.2.2. Trend reversing scenarios

Both the ***"Regional magnet/Compromise"*** scenario and ***"a two-faced value-chain"*** describe a stagnation or even a decline in production, slaughter and processing in the West of France. Similarly, both scenarios foresee an increase in pork prices, which would cope with rising input costs and the trend erosion of consumption. Finally, they plan to comply with societal expectations, which would help make the sector's professions more attractive.

These three characteristics describe developments diametrically opposed to the trends of the last 50 years. It is therefore psychologically difficult for the actors of the sector to confront it.

Moreover, favoring these scenarios would profoundly affect the French agricultural policy in at least three areas.

- From a macroeconomic point of view, pork meat would become much more expensive at the retailer's stall. It is nevertheless currently a "cheap" meat, a factor of social peace because it makes it possible to preserve the purchasing power of households when the price of other meats soars.
- From a regional planning point of view, a new distribution of slaughtering and processing of meat on the territory would lead – among other things – to a geographical rebalancing of structures (methanizers, slaughterhouses, cutting plants, roads, etc.), often subsidised by local authorities. The same applies to intangible structures. For example, training in pig farming and the pork sector should be redeployed throughout the country, and no longer reserved for the West and the surroundings of Rodez. Instead of advocating the generalization of digital technology and robotics, we should train breeders and workers in their basic profession.
- From a micro-economic point of view, at the level of farms, these 2 scenarios call for practices (straw farming, freedom of movement of animals, access to the open air, daylight etc.) that are impossible to achieve in large intensive pig barns. The fact is, this is the scheduled end of intensive pig farming in the West.

4.2.3. Novelties

From a business perspective, the advantage of this approach is to generate scenarios that no one had considered before. It is a way of avoiding hyper-

sensitive themes (pollution of waterways, hyper-intensification, animal welfare…) without provoking a sterile confrontation of stakeholders. It is also a positive way of dealing with sensitive themes (for example, the excess pollution, linked to the concentration of livestock in the Great West is automatically "managed" in the hypothesis of a more balanced distribution of farms throughout the national territory). Finally, the problems are considered actively (what scenario will we put in place?) and no longer defensive.

The main limitation for business is that it is necessary to force oneself to gather (virtually) actors of the sector whose opinions differ profoundly on "what to do". It is tempting to consult only those with whom the profession is used to working, and whose "business" values are common. In the latter case, the approach would probably be very disappointing, and the scenarios not very innovative.

5. Conclusion

In this paper, we proposed adaptations in the classic participatory "scenario method" to the constraints of remote working generalized during the pandemic. These adaptations concern, on the one hand, organizational aspects such as the replacement of collective face-to-face sessions by recorded individual remote interviews complemented by literature reviews. On another hand, we dealt with methodological aspects characterized by numerous additional steps required in comparison with the classic method, and with the biases induced by implementing the adapted method instead of the classic one.

The application to the case of foresight of the French pork sector, within a scope of 5 years, has given 6 possible scenarios, of which we discussed the main characteristics and implications in terms of public policies. In the upcoming phases of project Sentinel, we anticipate and evaluate the impacts of changes in two of the presented scenarios using multicriteria argumentation.

The prospective approach followed in the SENTINEL project has a main merit. It familiarizes influential players in the French pork industry with new ideas, which are very difficult to make them hear in any other way, but which may need to be adopted quickly in the years to come.

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Annex 1

2.3. *Methodological Adaptations of the Scenario Method*

In this section, we will be detailing the calculations followed so that the adapted method can be verified and reproduced.

In the classic scenario method, collective sessions serve to identify the variables and to build consensus about relationships between variables, first of all by small groups then by joining all prospects together. From these group discussions about the relationships between each pair of variables, matrices of relationships are built for each group. From the consensus built between the different groups, all the relationships (direct and indirect) are summarized in a single matrix which is then discussed by all prospects, who have the final decision concerning the determination of the meaningful relationships. This whole process is called "structural analysis". Since this part of the classic method is based essentially on social interactions, skipping from collective to individual sessions had methodological repercussions.

In the adapted method, structural analysis is based on individual semi-directive discussions as we said previously in 2.2. As explained before, the interviews are carried on with experts who presumably have different views on the sector (political, social, economic, technological, environmental, etc.). It is therefore expected that the variables quoted as the main determinants of the system evolution differ from one actor to another.

In the following section, we discuss the different approaches used to determine the variables after extracting concepts from the interviews done with experts of the studied value chain.

2.3.1. Linguistic and mathematical approaches

In the classic as well as in the adapted method, we access and identify variables through interviews, discussions or document readings, that is to say, through natural language.

As we have said before, in the classic method, the variables – with their final denominations – are given directly by the prospects after establishing consensus. However, in the adapted method, variables are delivered by the sources – the prospects and the documents – with a given terminology, which differs from a source to another. That is why we distinguish concepts (linguistic approach) from variables (mathematical approach) and we combine the use of both.

- The notion of concepts belongs to the lexical domain. A concept $\mathbf{c} \in \mathbf{C}$ (a set of concepts) can be extensively described by the set of sub-

concepts denoted by $\mathbf{C_c}$ composed of the various denominations (synonymous or more specific) of said concept: in other words, a sub-concept (or a denomination) is a word or a phrase extracted as is from the verbatim of the interviews or the documents. Thus, a concept is made up of one or more sub-concepts. So, for a concept **c**, $\mathbf{C_c} = \{\mathbf{c'} \in \mathbf{C} \mid \mathbf{c'} \preccurlyeq \mathbf{c}\}$ (Thomopoulos *et al.*, 2013). All concepts together make up what Thomopoulos *et al.* (2013) call an ontology Ω defined as a tuple $\Omega = \{\mathbf{C},\mathbf{R}\}$ where **C** is the set of concepts and **R** is a set of relations between concepts. **R** is here composed of the synonymy and specialization relations.

- Variables on another hand are used in mathematical approaches and are handled in the "scenario method". Given a set of variables **V**, each variable $\mathbf{v} \in \mathbf{V}$ is associated with a concept $\mathbf{c} \in \mathbf{C}$ in the ontology Ω. Each variable can take several values which are called modalities.

The process followed below (Definitions 1, 2 and 3) is not automated, it is therefore a delicate and time consuming task. It is of course a subjective analysis of the interviews and the documents. Nevertheless, by involving several researchers and experts in the merging process and validating it at each step, the vocabulary defined becomes more relevant, and the process more efficient (Thomopoulos *et al.*, 2013).

2.3.2. Definition 1: Concept-merging process to obtain the variables

After doing the interviews and perusing the documents found on the matter studied, the set of concepts **C** is extracted, and considered as distinct, for each interview or document. The experts – which have different opinions and different domains of expertise – can adopt different ontologies to describe similar things, however the underlying concepts can be common to two or more sources. That is why an ontology matching procedure is followed in order to limit the heterogeneity of the concepts used (Todorov *et al.*, 2010). The ontology is built manually by merging concepts which have synonym denominations (Thomopoulos *et al.*, 2007, 2013). Given two equivalent concept denominations name(c1) and name(c2), we deduce c1 = c2 which allows us to merge both concepts and thus reduce the cardinality of the set of concepts **C**.

Then, concepts which refer to the same global notion are grouped into a variable. We will denote by var(c) the variable which concept c is associated with. So a variable **v** is a global notion made up of similar concepts which are explanations and descriptions of what it could be.

Example: In our case study, the concepts expressed as "Informing consumers about products" and "Informing consumers about farming" could be merged

and associated with the variable labelled "Communication". Similarly, the concepts "Refusing all types of breedings near houses" and "Criticism of the negative environmental impact of livestock farming" were both identified as concepts belonging to the variable "Social acceptability".

Let us now define the elements handled respectively in the classic and in the adapted method in order to identify the key variables of the system studied.

2.3.3. Definition 2: Partial versus global sets of variables, matrices, influences, dependences and key variables

- **In the classic method**, the global set of variables of the system, which we denote by **V**, is built by collective consensus between the prospects. The influence and the dependence of each variable of **V** is determined as follows. For each couple of variables (x, y) belonging to **V**, we will denote by $n_{xy} \in \{0; 1\}$ the existence of an influence relationship from x to y, built by collective consensus between the prospects. There are two cases:
  – $n_{xy} = 1$ if the prospects agree on the existence of an influence relationship from x to y;
  – $n_{xy} = 0$ otherwise.
  These influence relationships are represented as a squared matrix which resumes the influence relationships between each couple of variables.
  The influence of a variable $v \in \mathbf{V}$ is then computed as $I(v) = \sum_y n_{vy}$.
  Similarly, the dependence of $v \in \mathbf{V}$ is computed as $D(v) = \sum_x n_{xv}$.
- **In the adapted method**, a partial source-by-source phase is followed by a global merging phase.
  Partial source-by-source phase. For each source i, the following process is performed:
  – A *partial* set of concepts is defined, which we will denote by $\mathbf{C_i}$ valid for source i.
  – Individual cognitive maps are created to formalize relationships between concepts cited spontaneously by each source.
  – Cognitive maps are then converted into tables of concepts for each source i. For each couple of concepts (c, c') belonging to $\mathbf{C_i}$, we will denote by $n_{cc'i} \in \{0; 1\}$ the existence of an influence relationship from c to c' according to source i.
  $n_{cc'i} = 1$ if c influences c' (and equivalently c' depends on c) according to source i;
  $n_{cc'i} = 0$ otherwise.

From these pairwise relationships, the *partial* influence of concept c according to source i can be defined by $I_i(c) = \sum_{c'} n_{cc'i}$, while the *partial* dependence of concept c according to source i can be defined by $Di(c) = \sum_{c'} n_{c'ci}$.

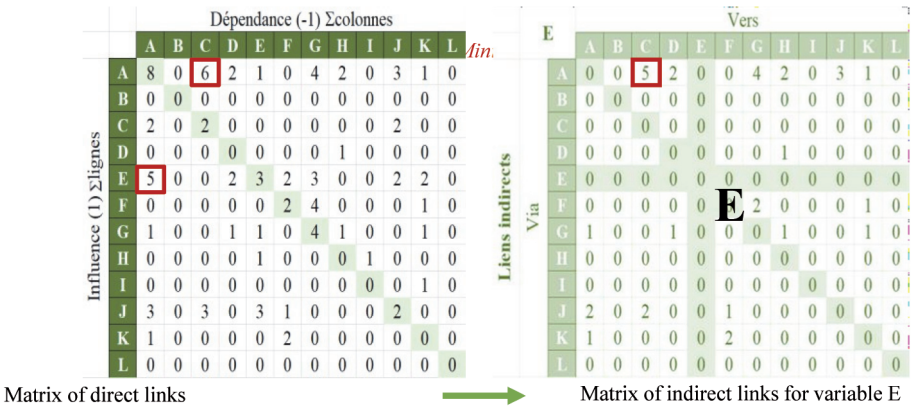
- After merging the concepts into variables (Definition 1), a *partial* set of variables $\mathbf{V_i}$ is defined for source i. The number of direct influence links $n_{vv'i}$ between two variables v and v' according to source I can be computed by summing the direct influence links between the concepts composing them: $n_{vv'i} = \sum_{c,c'|var(c)=v,\ var(c')=v'} n_{cc'i}$.
- A *partial* squared matrix representing the **direct links** between variables is created for each source i.
  A *partial direct* influence $I_i^d(v)$ and a *partial direct* dependence $D_i^d(v)$ of each variable $v \in \mathbf{V_i}$ are calculated for each source i independently.
  $I_i^d(v) = \sum_{c|var(c)=v} I_i(c)$
  $D_i^d(v) = \sum_{c|var(c)=v} D_i(c)$
  This squared matrix thus represents direct pairwise influences and dependences in the set of variables $\mathbf{V_i}$. Figure 5 is an example of the result obtained.

Figure 5 - Squared matrix of direct links identified in an interview between 12 variables

Influence (1) Σlignes \ Dépendance (-1) Σcolonnes	A	B	C	D	E	F	G	H	I	J	K	L
A	8	0	6	2	1	0	4	2	0	3	1	0
B	0	0	0	0	0	0	0	0	0	0	0	0
C	2	0	2	0	0	0	0	0	0	2	0	0
D	0	0	0	0	0	0	0	1	0	0	0	0
E	5	0	0	2	3	2	3	0	0	2	2	0
F	0	0	0	0	0	2	4	0	0	0	1	0
G	1	0	0	1	1	0	4	1	0	0	1	0
H	0	0	0	0	1	0	0	0	1	0	0	0
I	0	0	0	0	0	0	0	0	0	0	1	0
J	3	0	3	0	3	1	0	0	0	2	0	0
K	1	0	0	0	0	2	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0	0	0

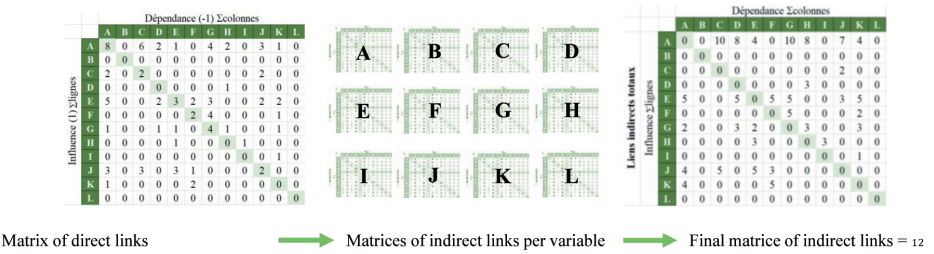
- We also need to calculate indirect **links of first order** between the variables. In fact, the number of indirect links between two variables is higher than the number of direct links between them. This could change the final results of which variables are key.
  Those indirect links of first order are calculated based on the partial matrix of direct links. The results are also squared matrices. For each variable, we obtain a specific squared matrix of first-order indirect links. Those squared matrices are then summed to obtain the final squared matrix of first-order indirect links for all variables on an interview. Figure 6 and 7 illustrate how we obtain the matrices of indirect links from the matrix of Figure 5.

Figure 6 - How indirect links of first order are calculated for each variable



Variable E is taken as an example here. To compute the number of indirect links from E to C through A, we retain the minimum between the number of direct links from E to A (5 direct links) and the number of direct links from A to C (6 direct links). The minimum is 5, there are thus 5 first-order indirect links from E to C through A. The same computation has to be performed taking all other ways from E to C (through B, D, etc.), then from E to all other variables than C.

Figure 7 - How we obtain the final squared matrix of indirect links of first order based of the squared matrix of direct links identified in an interview



More generally, to obtain the number of indirect links between two variables v and v' according to source i, denoted by $I_i^{in}(vv')$, we proceed as follows: $I_i^{in}(vv') = \sum_z \min(n_{vzi}; n_{zv'i})$ where $z \in \mathbf{V_i}$ is the intermediate variable between v and v'.

After identifying the number of indirect links between each pair of variables, we obtain as many matrices as we have variables (as shown in Figure 7). All those matrices are summed to obtain the final squared

matrix of all indirect links. We denote by $I_i^{in}(v) = \sum_{v' \in \mathbf{V_i}} I_i^{in}(vv')$ and $D_i^{in}(v) = \sum_{v' \in \mathbf{V_i}} I_i^{in}(v'v)$ the number of *partial* indirect influence and dependence links for each variable $v \in V_i$.

- Total influence and dependence values for each variable can be then calculated for each source i independently:

$$I_i(v) = I^d(v) + I_i^{in}(v)$$
$$D_i(v) = D_i^{in}(v) + D_i^{in}(v) \text{ with } v \in V_i$$

Partial key variables can be determined as in the classic method. They are the ones with $I_i(v)$ and $D_i(v)$ higher than the averages.

Global merging phase. From the partial sets of variables of all the sources i, we define the *global* set of variables **V** by merging all the partial sets together:

$$\mathbf{V} = \bigcup_i \mathbf{V_i}$$

If one variable appears several times in one partial set, it is counted once in the global set.

From the partial influences stemming from all sources, we compute the *global* influence of variable v as the sum of its partial influences, for all sources which considered the variable v:

$$I(v) = \sum_i I_i(v) \text{ with } v \in V_i$$

Similarly, we compute the *global* dependence of variable v as the sum of its partial dependencies, for all sources which considered the variable v:

$$Dv = \sum_i D_i(v) \text{ with } v \in V_i$$

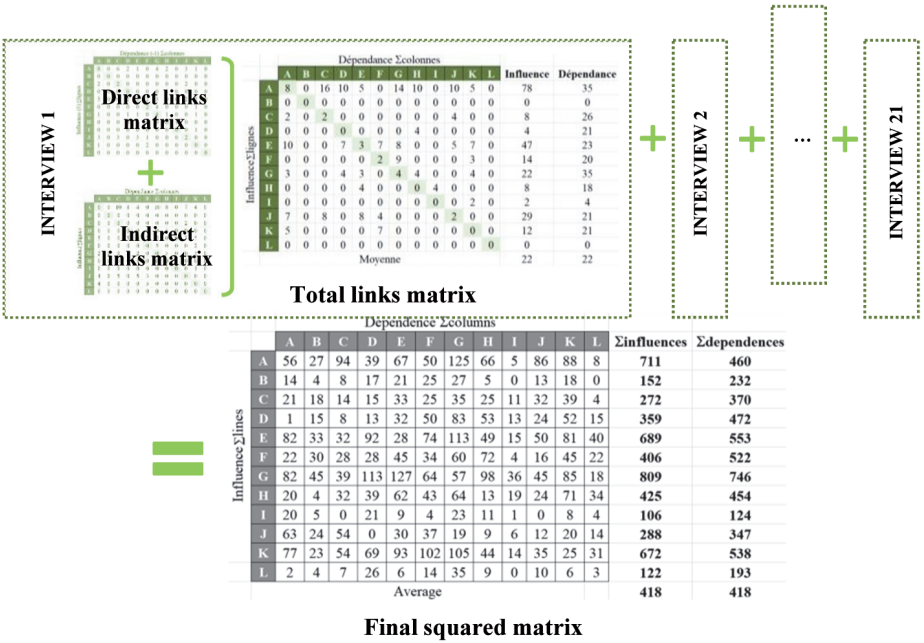
The results are represented in a final *global* square matrix. Figure 8 resumes all the process followed.

Finally, the *global* key variables are determined using the final squared matrix. The results obtained resemble those that would have been obtained using the classic Godet method (Figure 1). The key variables are those that are more dependent and more influential than the average.

However, the robustness of the identification of the key variables is a specific issue, especially in the adapted method because the prospects do not spontaneously agree about the determinants of the future. If we can perform hundreds of interviews, we could reasonably expect that the addition of one new interview to the former pool of results would not change the identification of the key variables. They would be "stabilized". We are however committed to stabilizing the key variables without necessarily doing a huge number of interviews.

The rule we chose is therefore the following: in this foresight exercise, the key variables are those which are graphically determined and which are not

Figure 8 - Summary of how we obtain a final squared matrix using the adapted Godet method



threatened to become output, input or excluded variables by the addition of one new interview. For that reason, we calculate instability zones of influence and dependence:

$Z_{influence}$ = average of influence ± (R^{D}_{MAX} + R^{IN}_{MAX})

$Z_{dependence}$ = average of dependence ± (R^{D}_{MAX}+ R^{IN}_{MAX})

With R^{D}_{MAX} the maximum number of direct relations;

R^{D}_{MAX} = Max(I^{d}_{i}(v);

D^{d}_{i}(v)) and R^{IN}_{MAX} the maximum number of indirect relations;

R^{IN}_{MAX} = Max(I^{in}_{i}(v);

D^{in}_{i}(v)) with v ∈ V_i

The process for determining the values of R^{D}_{MAX} and R^{IN}_{MAX} is iterative: it's done after each interview as the values may change. We then decide to exclude from their status of key variables, those which could change their status (by becoming either output, input or excluded variables) by the addition of (R^{D}_{MAX} + R^{IN}_{MAX}) links or less. Graphically speaking, it means that the key variables positioned too close to one or the other of the average lines are not "stabilized" key variables. The rule is valid whatever the status of the variable is.

After determining the stabilized key variables, their modalities must be considered as defined in the next section of the main text.

2.3.4. Definition 3: Defining the **modalities** of the variables

The modalities of one given variable are the values that can be taken by this variable, according to the analysis of the interviews and documents included.

- **In the classic method**, the modalities of each key variable are chosen by consensus whilst choosing the key variables. It should be noted that it is necessary to limit the number of modalities (while 2 are the minimum), or it will generate an extremely high number of scenarios!
- **In the adapted method**, the modalities of variable v are extracted from the set of concepts **C**, **c** being the concept associated with variable **v** (see Section 2.3.1 in this Annex). The modalities of v are the concepts strictly more specific than **c** – synonyms are thus excluded. More precisely, we look at the list of concepts and keep the ones which describe some characteristics of the variable v. Some of those concepts can either be explicit modalities of the variable, or they can be "rebuilt" in a simpler brief manner – implied by the interviewee or the document – so that they are modalities of the variable. The number of modalities for each variable is also at best limited to two.

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