Adaptation of a Participatory System-Modeling Method to the Constraints of Remote Working

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Abstract

The behavior of complex systems is intrinsically difficult to model and to predict. Agri-food chains can be considered as such. The problem considered in this paper comes from the commitment to anticipate the impacts of the implementation of innovations in such highly complex agri-food systems. The paper focuses on comparative methodological issues, when seeking to anticipate the possible evolutions of the system. Indeed, this article proposes adaptations in the classic “scenario method” because of constraints of remote working generalized during the pandemic, and discusses possible biases induced by these adaptations in the results obtained. The methodological and organizational differences are described, and show that the remote constraints do not prevent from delivering some “key variables” of the system. The adapted method is illustrated in a case study in the pork supply chain. Nevertheless, the face-to-face collaborative sessions generating a consensus among players in the classic method can not be replaced in the remote context. As a consequence, it is likely that some key variables that would have been selected thanks to consensus in the classical method are let aside in the adapted method, because the number of prospects quoting them spontaneously in individual interviews is not large enough. The following consequence is that the scenarios that would have been generated thanks to the various values of these likely key variables, are not taken into account. It is thus likely that less scenarios are depicted by the adapted method than by the classic one.

Keywords

Complex System, Social Complexity, Agri-Food Chain, Prospective, Multi-Actor, Scenario Method, Collective Modeling, Adaptation to Pandemic.

1. 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, 2009). Examples of complex systems can be found in various domains, from living organisms to communication systems or socio-economic organizations.

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. They are constrained by the pressure of production upstream and consumption downstream, be it climatic, regulatory, economic or social. Finally, their actions are not centralized but distributed, poorly coordinated and in constant evolution (Balmann et al., 2006).

In this context, the problem considered in this paper comes from the commitment of the authors to anticipate the impacts of the implementation of innovations in such highly complex agri-food systems. More specifically, the paper focuses on comparative methodological issues, when seeking to anticipate the possible evolutions of the system, which falls into the scope of prospective-building methods (de Jouvenel, 1964; Meadows et al., 1971; Godet, 1977; Lesourne, 1989; Cordobes and Durance, 2004). We will consider, as an illustrative application, a case study provided by the national SENTINEL project regarding the need for new screening technologies to ensure food chemical safety along agri-food chains. 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 and Soret, 2003). The pork sector is particularly illustrative of these concerns, with debates around health-nocive additives (Sindelar and Milkowski, 2012), salt (Campbell et al., 2011), and fat in traditional food products.

In the SENTINEL project, we must build prospective scenarios about the French pork supply chain in the next 3 to 5 years. Each actor 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 and of the impacts of an innovation on all the involved parties certainly helps reach solutions that are more thoughtful and acceptable. Moreover, one of the aims of the project is to raise awareness of stakeholders. Here are the reasons why we have chosen a certain prospective method based on participatory approaches, and especially including consensus building.

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: consensus building approaches (Susskind et al., 1999), argument-based modeling approaches (Bourguet et al., 2013; Thomopoulos et al., 2018), argument visualization (van Bruggen et al., 2003), system dynamics modeling and thinking (Stave et al., 2014), complex systems modeling (Perrot et al., 2011) and agent-based modeling (Taillandier et al., 2021). In this paper, we are concerned with prospective-oriented approaches including consensus building between the stakeholders of the supply chain. Therefore we focused on the so-called "method of scenarios" (Godet, 2001; Godet, 2008). 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 seems to fit in dealing with innovation at the supply chain scale, in the agro-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). Moreover, it is one among the most formal prospective methods.

However, the traditional face-to-face collaborative way has been proven inoperable in the current situation, during the COVID-19 pandemic. Consequently, we had to consider adaptations in the classic scenario method and jointly, possible biases induced by these adaptations in the results obtained. In the remainder of this paper, we call “classic method” the method of prospective by Godet that we ought to implement (if no pandemic), and the “adapted method” will mean the approaches that have been implemented in reality, because of the pandemic restrictions. In this paper, the general research questions dealt with are:

1) What are the adaptations of the classic method needed when face-to-face collaborative way is inoperable?

2) What are the biases and other impacts of implementing the adapted method instead of the classic one?

To answer these two questions is it first of all inevitable that we introduce in Section 2 the classic scenario method, its stages and its steps. We will then discuss in Section 3 the problems encountered due to the sanitary context as well as the organizational and methodological adaptations of the scenario method. Some of the results obtained from the adapted method are presented in Section 4 of this article.

2. 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 (2001, 2008). The data are gathered thanks to interviews of prospects, who are the stakeholders (in the broadest sense) of the supply chain under scrutiny. Citing this work, “The scenario method aims to construct possible representations of the future, as well as the means to achieve strategic objectives. The goal of these representations is to reveal the prevailing trends and the seeds of possible ruptures in the competitive business environment”. The method is composed of 3 main stages, namely:

(1) Constructing the base, which puts in relationships the variables of the system under scrutiny, identifies the key actors and the key variables, and builds numerous base scenarios, obtained by combining the values of the key variables.

(2) Sweep the Field of Possibilities and Reduce Uncertainty, which identifies the strategies of the key actors and considers only the values of the key variables deemed plausible by the prospects, which reduces the possibilities of base scenarios.

(3) Elaborating the Detailed Scenarios. The task of this stage is to describe the pathways to reach the selected base scenarios, from all points of view (technical, organizational, economic, social etc.).

In this paper we will focus on Stage (1) only, constructing the base. Constructing the base consists of building a model which represents the current state of the system under study. This first stage is itself 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, and identifying the key actors.

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; then 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. The latter stage will be detailed below.

Step 3: Elaborating the general base scenarios.

The general base scenarios are all the scenarios built by combining the values of the key variables.

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

Table 1: Tools used in each step of the "Constructing the base" stage of the classic method, and who does what. Collective sessions are highlighted in bold.

Step	**Who does what?**	**Tools used in the classic method**
1. Delimiting the system under study	Researchers: identifying the prospects.	No specific method.
	Researchers: make individual and collective interviews with specialists. Prospects: provide variables influencing the system evolution.	**Brainstorming**, **workshops**, etc. to determine the main internal and external 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 the groups (e.g. 3 groups of 10 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 (which variable influences which other variables?) are built by consensus during **collective workshops, by small groups, then all together**. It is possible to use the MICMAC program (Matrix of Cross-Multiplication Impacts Applied to a Ranking) to determine the variables that most influence other ones, and are most influenced by other ones. '**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 the base scenarios	Prospects: build a consensus about the main values that can be taken by each key variable. Researchers: envision the different combinations of the values of the key variables.	Collective **workshops** These preliminary scenarios are built as combinations of the possible values of all key variables.

When searching for the key variables, one can classify the variables influencing the system evolution into 5 categories (Fig. 1): the input or entry variables are very influent and little dependent; at the contrary, the output variables are very dependent and little influent; the pack variables are moderately dependent and influent, while the excluded variables are neither dependent nor influent. Only the key variables are more influential and dependent than the average of all the variables. It means that they represent significant stakes, because, following quite small changes, they can make the situation evolve in very different directions.

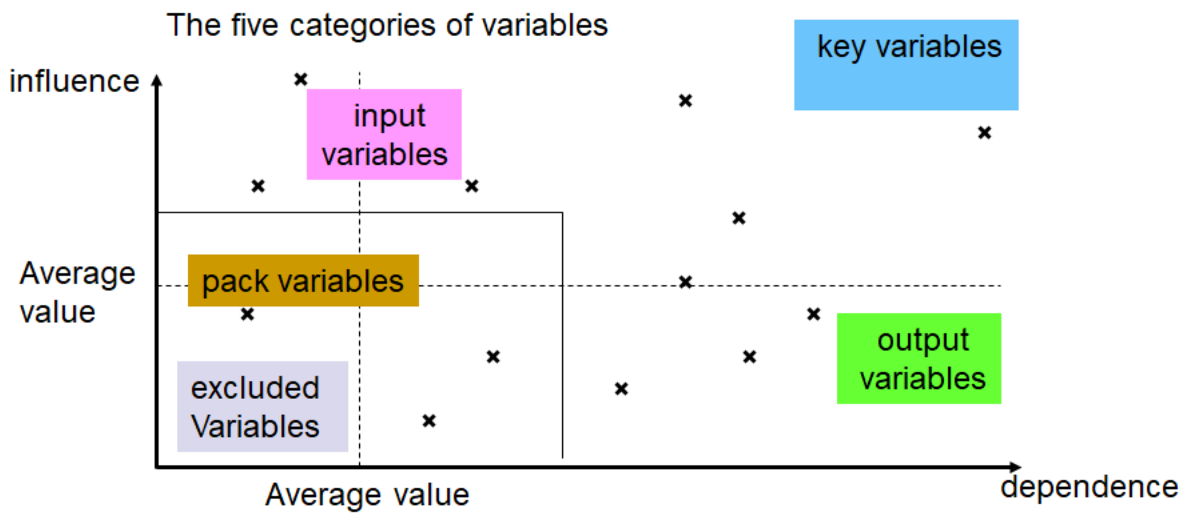

Fig. 1: Classification of variables at the end of step 2 of stage (1) in the classic method.

Several reasons explain why we are focusing only on stage (1) of the Godet Method in this paper : on one hand, the steps followed in stage 1 are time consuming and are spread out over several months. On another hand, the complete Godet method is not necessarily used in its entirety as it is a very consequential process. Finally, it is essentially this stage that is centered on interactions with the prospects ; there are other interactions in the following stages but the initial steps are the ones who set the dynamics of the project. Plus, the difficulties faced during stages 2 and 3 are the same as the ones faced in stage 1. The problems encountered are detailed in the following section.

3. The Remote Context

3.1. 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 certain fields: in the scientific literature, from the latest decades, international collaboration has become increasingly frequent in nuclear science, where several papers have reported technical architectures and tools supporting remote participation (Krämer-Flecken et al., 2010; Stepanov et al., 2011; Sun et al., 2017). Nevertheless, other sectors are absent from the scene. Most importantly, feedback on the remote feasibility of participatory tasks and on the pros and cons of remote working to perform them is almost nonexistent. 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 is not only an option, it is 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 to the context even though it is obviously better and more efficient to have face-to-face interaction whether they be individual or collective. 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 between us researchers and the prospects.

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

3.2. 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. Given the sanitary context, the scenario method had to be adapted and several choices were available to us:

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's 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) 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. At the limit, if the researchers interview only persons with the same background, they likely deliver the same key variables, which is an impoverishment.

To mitigate this effect, we seek interviewing stakeholders (in the broadest sense) of the supply chain with background and opinions as diverse as possible. 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.

To improve the validity of the selection of interviewees (documents included), we checked the following. When split according to the partition of important stakeholders between 7 categories by Mitchell, Agle and Wood (1997), all the seven categories of stakeholders are addressed.

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. It had the advantages of individual interactions referred to in Suttrop et al. (2002) and Kopp et al. (2021):

- Higher confidence of the interviewee with the interviewer.
- Ease of interactions.
- More information per actor.

Even though we find individual long distance interviews more efficient, treated separately, they do not suffice to determine the key variables: it is essential to critically compare the interviews. From a methodological viewpoint, this required some adaptations of the method. To do so, we use the following tools:

- Cognitive maps.
- Individual matrices (see Table 1) of the variables cited by the prospects.
- Individual matrices of the variables identified by the researchers in the documents consulted.
- Combined matrices of all variables cited by all the sources (prospects and documents included).

The tools used and the process followed are described more thoroughly in 3.3.

3.3. Methodological Adaptations of the Scenario Method

In the classic scenario method, collective sessions serve 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 are summarized in a single matrix which is then discussed by all prospects, who have the final decision concerning the determination of the relationships. This whole process is called “structural analysis”.

Since 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. The semi-structured interview method is often used in sociology studies (Chevalier and Meyer, 2018). The main advantage of this type of interview is that it allows the interviewees to structure their view according to their vision of the matter. The concepts are thus defined by the interviewee and not the interviewer (Chevalier, F. and Meyer, 2018). 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 by the actors as the main determinants of the system evolution are not the same.

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 a consequence, variables are delivered by the sources -the prospects and the documents- with a given terminology, which differs from a source to another. Distinction has to be done between the variable and its denomination(s). Given a variable v, let us denote by *name(v)* the denomination of v in a given source. Denominations identified for each source differ from each other, however the underlying variables can be common to two or more sources. Hence, equivalent denominations, considered as synonyms, have to be merged together. We follow the below process.

Definition 1: Variable-merging process.

- Following the interviews, and the perusing of the found documents, a set **V** of all the variables v associated with their corresponding denominations *name(v)* cited by all sources is created. Initially, all variables v are considered as distinct.
- Given two equivalent denominations *name(x)* and *name(y)*, we deduce $x = y$ which allows us to merge both variables and thus reduce the cardinality of the set of variables **V**.

In the rest of the paper we will focus on the set of variables and will not further comment denomination issues. Deeper details on vocabulary building based on equivalence, specialization relations and functional dependencies can be found in Thomopoulos et al. (2007, 2013). In the latter, merging as well as other operations on variables are considered.

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.

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

- In the classic method, the set of variables of the system, which we denote by **V**, is built by collective consensus between the prospects. For each variable of **V**, its influence and its dependence are 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, the same process is followed, but it has to be performed for each source (prospects and documents included) separately, then merged to obtain the global results. Hence, a partial source-by-source phase is followed by a global merging phase.

  Partial source-by-source phase. For each source i, we define:

  - A *partial* set of variables, which we will denote by $\mathbf{V_i}$ and valid for source i.
  - For each couple of variables (x, y) belonging to $\mathbf{V_i}$ the existence of an influence relationship from x to y is defined for each source i independently. Individual cognitive maps are used to formalize relationships between variables cited spontaneously by each source.
  - The cognitive maps are then converted into individual squared matrices: a *partial* squared matrix of variables is created for each source i. A *partial* influence $I_i(v)$ and a *partial* dependence $D_i(v)$ of each variable $v \in \mathbf{V_i}$ are computed as in the classic method, but for each source i independently.
  - *Partial* key variables can be determined as in the standard method.

  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:

$$\mathbf{V} = \bigcup_{\mathbf{i}} \mathbf{V_i}$$

  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 dependences, for all sources which considered the variable v:

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

  The results are represented in a final *global* square matrix. Finally, the *global* key variables are then determined using the standard method, as shown in Fig. 1. The results are presented in dot clouds.

Illustrations of the results are provided in the next section. Table 2 resumes the tools used in the adapted method.

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 Mitchel et al. (1997)**.
	Remote individual interviews. **Analysis of existing documents** (treated as interviews) on the matter.
2. Determining the key variables	List of the variables quoted by the sources (prospects and documents). Merging of the variables standing for the same concept. Conversion of each interview into a **cognitive map** to visualise influence relationships between the variables identified. Construction of **partial square matrices** of variables. We can thus identify the partial influence and dependence of each variable. Construction of the global set of variables by merging all partial sets of variables together. Merging of all partial **square matrices** into a global one by summing partial influences and dependences of all variables. Identification of the key variables which have the highest influence and dependance values.
3. Elaborating the base scenarios	**Individual remote discussions** with the same specialists. These preliminary scenarios are built as combinations of the possible values of all key variables.

4. Application to the Analysis of an Agri-Food Chain

In this section we present some of the results obtained by applying the adapted method presented previously to the SENTINEL case study regarding the pork supply chain. The results obtained are temporary and are limited to the first two steps of stage one in the method of scenarios.

After extracting all variables from the interviews conducted and the documents read, a total of 204 variables was defined for 5 interviews and 2 official documents for now. After the first variable-merging process (see Definition 1), a list of 78 variables was left. Then cognitive maps were drawn, based on the information gathered per prospect and per document. Below are two examples of cognitive maps, one resulting from an interview with an expert (Fig. 2) and the other resulting from the analysis of a document on the pork industry in France (Fig. 3).

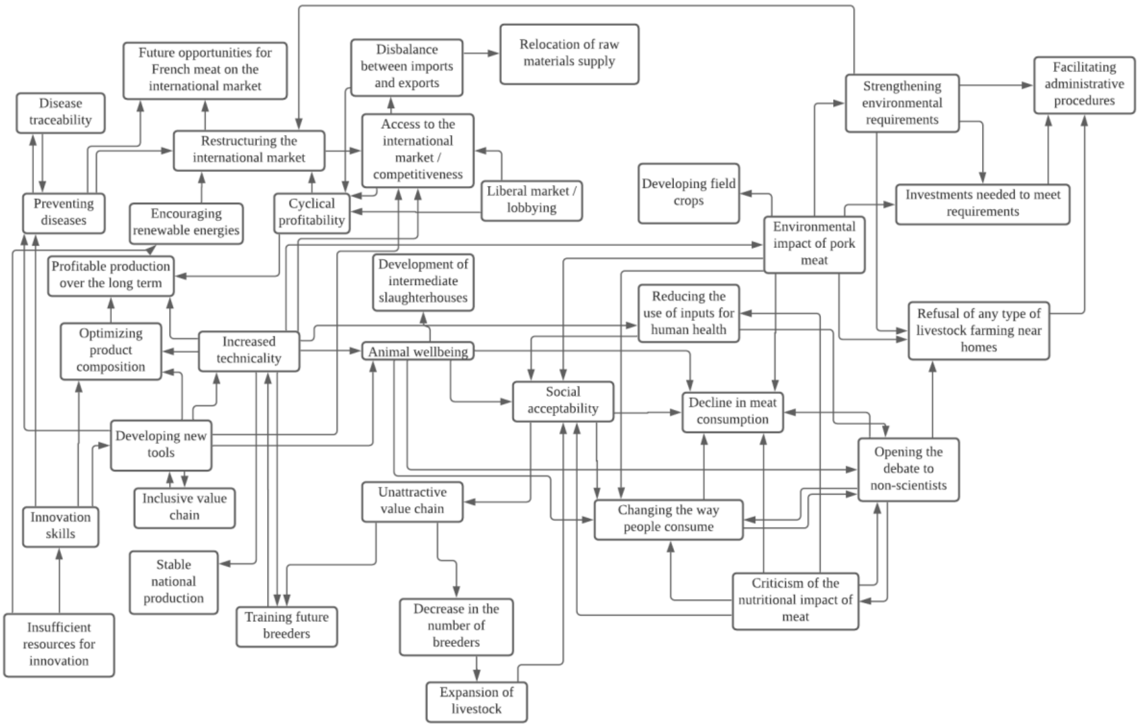

Fig. 2: Cognitive map resulting from an interview with an expert

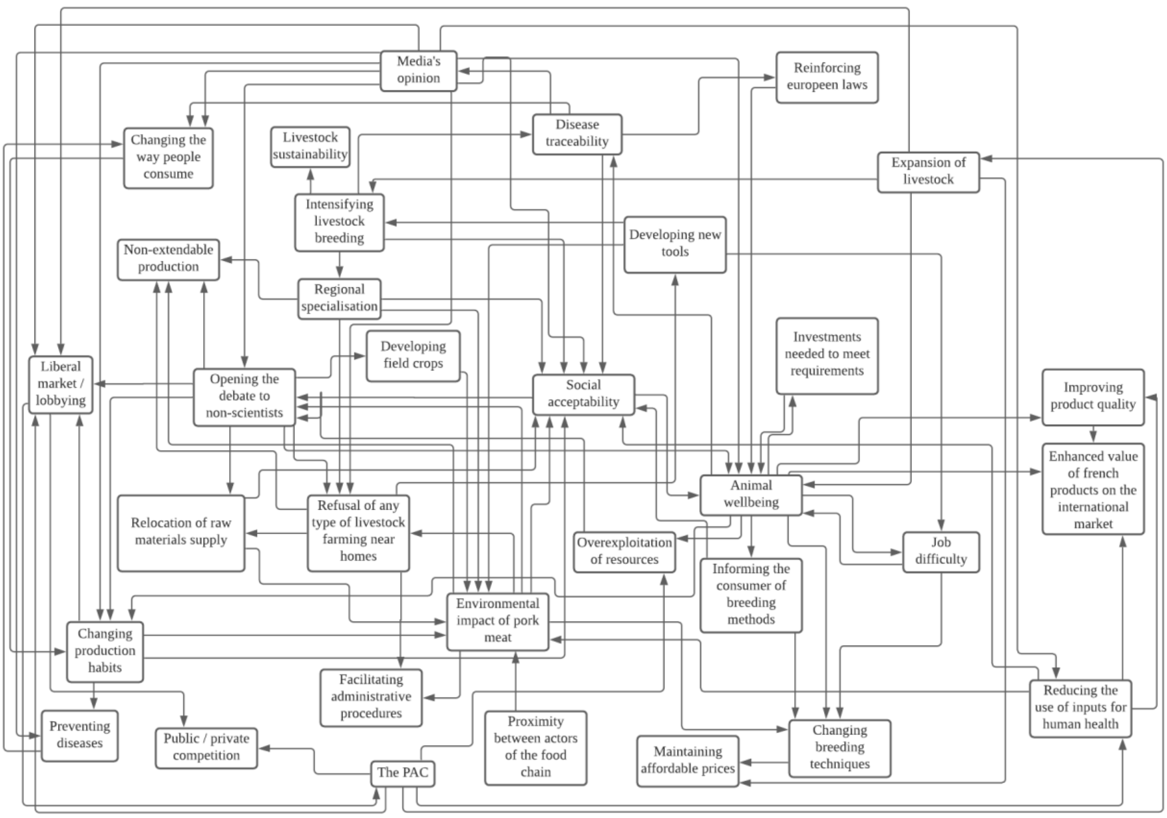

Fig. 3: Cognitive map obtained after analyzing a document on the French pork industry

Then the partial matrices were created (see Definition 2). Several series of variable-merging processes led us from the initial large set of variables to an intermediate and then a final small one. The results are shown in Table 3 of Appendix 1. Following the variable-merging processes, updated partial matrices are created. The partial matrix in Fig. 4 is an example of what the final result looks like. Fig. 4 as well as the graph in Fig. 5 correspond to the cognitive map of Fig. 3. Note that variables with zero influence and zero dependence are not taken into account.

		Dependence Σcolumns											
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**Σinfluences**	**Σdependences**
Influence Σlines	**A**	23	4	12	0	8	7	6	4	0	1	**65**	**65**
	B	9	1	6	0	1	2	0	0	0	0	**19**	**8**
	C	19	1	7	0	3	3	2	0	0	0	**35**	**30**
	D	0	0	0	0	0	0	0	0	0	0	**0**	**2**
	E	9	2	5	2	3	2	1	1	0	0	**25**	**19**
	F	0	0	0	0	0	0	0	2	0	0	**2**	**15**
	G	1	0	0	0	1	0	0	0	0	0	**2**	**9**
	H	3	0	0	0	2	1	0	1	0	0	**7**	**8**
	I	0	0	0	0	0	0	0	0	0	0	**0**	**0**
	J	1	0	0	0	1	0	0	0	0	0	**2**	**1**
		Average										**17,4**	**17,4**

Fig. 4: Partial squared matrix obtained from the cognitive map of Fig. 3 after the variable-merging process

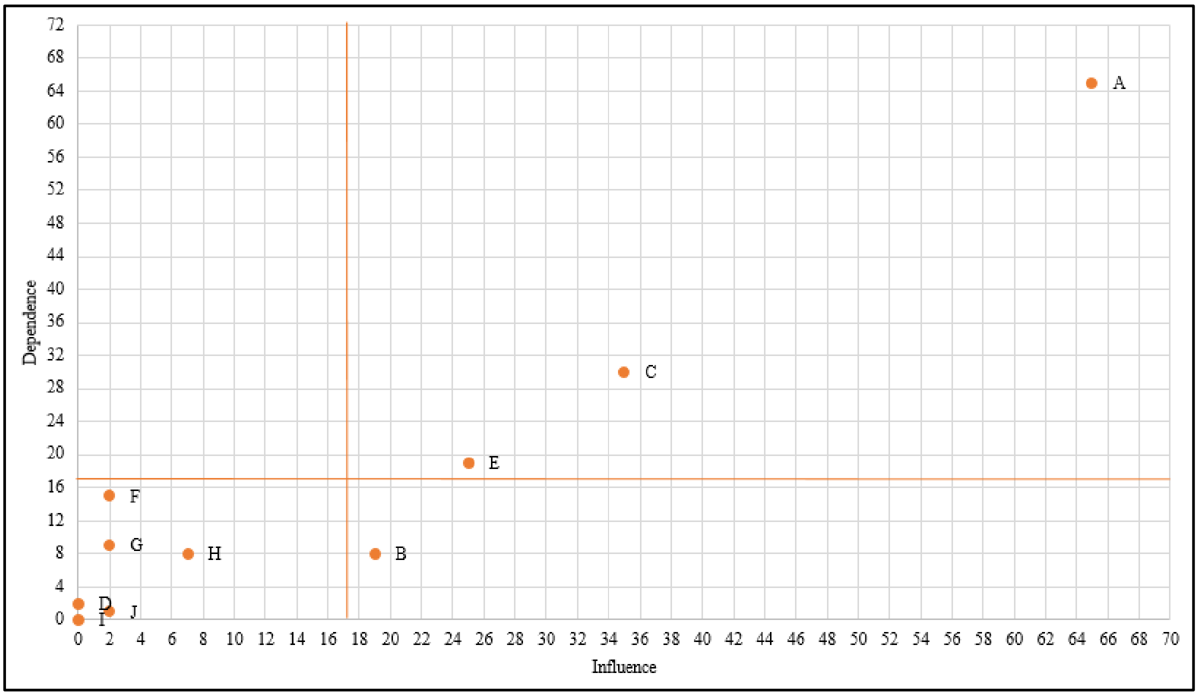

Fig. 5: Dot cloud of the partial matrix depicted on Fig. 4

These steps allow us to determine partial key variables, according to each prospect and document read. For example, based on the method shown in Fig. 1, we find that according to Fig. 5, the key variables are A (social acceptability), C (the way of consuming products) and E (technical and technological progress).

Those same steps are repeated for all of the interviews and documents. Then partial influences and dependences of each couple of variables and of each prospect are summed, which results in a global squared matrix presented in Fig. 6.

		Dependence Σcolumns											
		A	B	C	D	E	F	G	H	I	J	Σinfluences	Σdependences
Influence Σ lines	A	56	10	33	2	13	14	17	10	0	7	**162**	**146**
	B	14	2	14	0	2	4	1	2	0	1	**40**	**30**
	C	29	5	16	0	5	6	6	4	1	2	**74**	**81**
	D	3	1	0	2	2	2	0	0	0	0	**10**	**12**
	E	27	3	8	4	24	14	8	4	0	4	**96**	**67**
	F	1	1	4	0	2	32	6	5	0	2	**53**	**86**
	G	1	1	1	0	9	2	6	1	0	0	**21**	**47**
	H	4	2	2	3	7	9	3	4	1	1	**36**	**31**
	I	1	0	0	0	0	1	0	0	0	0	**2**	**2**
	J	10	5	3	1	3	2	0	1	0	6	**31**	**23**
		Average										**52,5**	**52,5**

Fig. 6: Final global square matrix obtained by summing partial influences per couple of variables.

The dot cloud corresponding to this matrix is depicted on Fig. 7.

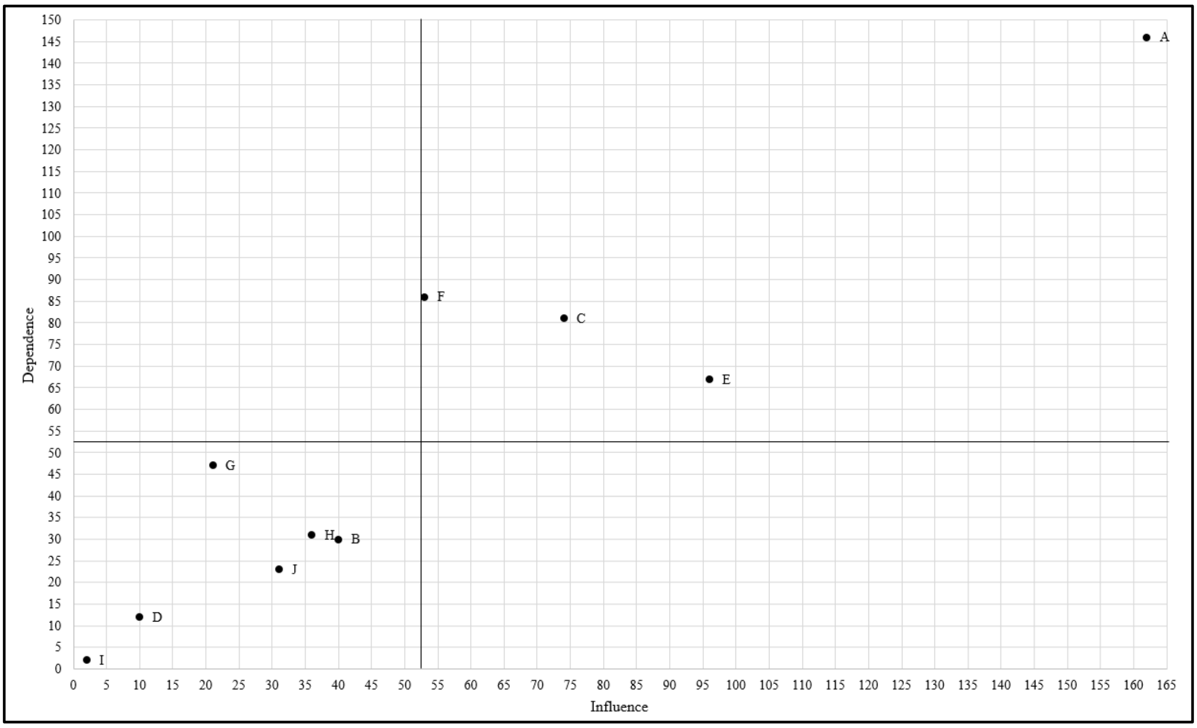

Fig. 7: Dot cloud of the global matrix depicted on Fig. 6

The global key variables deduced from the adapted method are A (social acceptability), C (the way of consuming products), E (technical and technological progress) and F (Access to the international market). Even though it may seem that variables A, C and E were retained because they were partial key variables according to one of the prospects, this is not always the case: a variable could be a partial key variable for one source without being retained as a global key variable in the final result.

The results presented above are temporary because more interviews should be conducted in the near future with other prospects who could have different opinions concerning the evolution of the French pork supply chain.

When comparing the classic and the adapted methods, it is possible that some likely key variables (that would have been selected thanks to consensus in the classical method) are let aside, or aren't even mentioned, in the adapted method. For instance, regarding the pork supply chain, no actor quotes the issue of energy prices (oil) to date. Nevertheless, 60% of the cost of a pig is the price of its feed (of which 70 to 80 % are cereals and their price is linked to oil prices). Despite the importance of this issue for the future cost of the pig production, no scenario can be generated regarding the oil price stability, decrease or increase, because no prospect has quoted it to date. As a result, it is likely that less scenarios are depicted by the adapted method than by the classic one, based on consensus building. To fix this problem, we can try to question more supply chain actors who could be particularly aware of the impacts of oil price fluctuations on the future pork supply chain. Nevertheless, this would introduce another bias, which is selecting the respondents according to the variables that the researchers carrying the study deem to be important !

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 individual remote interviews complemented by literature reviews; on the other hand, methodological aspects characterized by numerous additional analysis steps required in comparison with the classic method: use of cognitive maps, merging of redundant variables, distinction between partial results stemming from one source and global results obtained by combining all sources.

From the adapted method proposed, results are obtained in the SENTINEL case study regarding the future of the pork supply chain, showing that the remote constraints do not prevent from delivering some "key variables" of the system. Future research and interviews will either confirm or rebute the current choice of key variables. Other tools and methods, such as questionaries or the Delphi method, could be used in order to ratify the final list of key variables. Nevertheless, the time granted to the process is considerably expanded. Moreover, the approach allows highlighting possible biases induced by these adaptations in the results obtained.

Indeed, even though it is possible to conduct the adapted method by using virtual individual reunions and including new tools, 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. In the SENTINEL case study, we chose to implement the scenario method because one particularly interesting feature of this method is the following: it builds scenarios that nobody, among the prospects, predicted before nor thinked of. Indeed, by combining systematically different characteristics -the values of the key variables-, the classic Godet's method generates totally new scenarios. In a nutshell, the classic method presents "emerging" properties, including ruptures.

In addition, there is a risk of misusing subjectivity, which nonetheless is essential in the participatory approach. In the adapted method, a subjectivist perspective as presented by Cosette (2008) is adopted.

Citing Cosette (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). It is indeed what interests us and what allows us to collect as many variables as possible in order to create different scenarios. Nevertheless, the fact that prospects can’t meet with each other influences the final choice of the key variables. In other words, a key variable evoked by one prospect could not be in the final list of key variables determined by the adapted method; however if the classic method was applied, prospects would have discussed this variable and could have decided to include it in the list.

It is thus likely that some key variables that would have been selected thanks to consensus in the classical method are let aside in the adapted method. Consequently, the scenarios that would have been generated thanks to the various values of these likely key variables, are not taken into account. Overall, probably less scenarios are depicted by the adapted method than by the classic one.

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Appendix 1

Table 3: Initial, intermediate and final variables

ID	Final variables	Intermediate variables	Initial variables
A	Social acceptability	Rejection of pig farming as it is today	Animal well being
			Environmental impact of pork meat
			Reinforcement of environmental requirements
			Opening the debate to non-scientists
			Changing production habits (organic farming)
			Reassurance of the concerned consumer
			Negative media gaze
			Willingness to develop local circuits
			Non-scalable production / need to stabilize or reduce pig numbers
			Traceability of diseases
			Refusal of any type of production near homes
		Tolerance towards breeding	Reduce the use of inputs for human health
			Reduction in the use of antibiotics for animal health
B	Ultra-processed product	Change in processing practices	Consumer distrust of ultra-processed products
			Opening the debate to non-scientists
			Negative media gaze
			Change in feed formulation
			Prohibit the use of nitrites
		Maintenance of industrial practices	Industrial problems that influence the image of the sector
C	Way of consuming	Maintain current consumption	Specialization by region
			Segmentation of national consumption, preservation of traditions
		Decrease in consumption	Decrease in consumption
			Opening the debate to non-scientists
			Negative media gaze
			Reinforcement of environmental requirements

			Critique of the nutritional impact of meat
			Environmental impact of pork meat
		Improved consumption	Willingness to develop local circuits
			Changing production habits (organic farming)
			Relocation of raw material supply
D	Food prices	Maintaining affordable prices	Control of production costs
			Change in feed formulation
			Economic accessibility of foreign labor
E	Technical and technological progress	Improvement of techniques and technologies and their use	Feed optimization
			Ability to innovate
			Change in breeding techniques
			Disease prevention
			Increased technicality within the sector
			Traceability of diseases
			Development of new tools to improve the image of the sector
			Connected and collective future
			Development of field crops reduces environmental pollution
			Mastery of tools
			Diversification of product lines
			Proximity between actors of the supply chain
			Rehabilitation of the transformation sector to meet the needs of the supply chain
			Development of intermediate slaughterhouses
			Improving product quality
		Excessive use of technology	Intensification of livestock farming
			Expansion of farms
			Expansion of processing companies
			Overexploitation of resources, impact of technical choices on the availability of raw material
			Destruction of jobs by robotization of the process

F	Access to the international market	Facilitation of access to the international market	Future opportunities for French meat on the world market
			Export of French know-how and French gastronomy
			Promotion of French production abroad in terms of health
			Restructuring of the international market
			Increase in global consumption
			Facilitation of administrative procedures
			Diversification of product lines
			Strengthening national health measures
		Difficulty of access	Competitiveness
			Imbalance between imports and exports
			Health problems when trading raw materials
			Liberal market / lobbying
			Logistics issues
G	Profession	Making the sector attractive	Training in the profession of pig farmer
			Training in processing techniques
			Facilitation of administrative procedures
			Stability of production
			Profitable long-term production
		Impossibility of making the sector attractive	Non-scalable production / need to stabilize or reduce pig numbers
			Difficulty of the profession
			Sector not very attractive
			Decrease in the number of breeders
			Cyclical farm profitability / farm viability
			Decrease in production
H	Institutional support	Strong institutional support	Support from public authorities
			Facilitation of administrative procedures
			General support
			Strengthening of European rules

		Weak institutional support	Economic accessibility of foreign labor
			Insufficient resources for innovations
			Private / public competition and lobbying pressures
			Investments required to meet requirements
			The PAC
I	Methanization	Develop methanization	Promoting renewable energies promotes methanization
J	Communication inter and intra actor groups	Insufficient communication inter and intra actor groups	Insufficient communication inter and intra actor groups
		Improving communication inter and intra actor groups	Reassurance of the concerned consumer
			Connected and collective future
			Communication on product quality to consumers
			Inform the consumer about the products
			Inform the consumer about breeding and its techniques