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SocLab: A Framework for the Modeling, Simulation and Analysis of Power in Social Organizations

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Abstract

This paper is a comprehensive presentation of a framework for the modeling, the simulation and the analysis of power relationships in social organizations, and more generally in systems of organized action. This framework relies on, and slightly extends, the Crozier and Friedberg's sociology of organized action, which supports a methodology for understanding why, in an organizational context, people behave as they do. SocLab intends to complement the discursive statement of sociological analyses with a formal formulation easing the objectivization of findings. It consists of a meta-model of organizations, a model of bounded-rational social actors and analytical tools for the study of the internal properties of organizations.

Keywords:

Organization Modeling, Meta-Model, Sociology of Organizations, Cooperative Behavior, Power Relationships



Introduction

1.1 The paper deals with organizations, and more generally social systems of organized action, viewed as social entities:

- established for some purpose, and thus aimed at achieving some objective(s),
- including individuals and resources,
- provided with rules intended to serve the achievement organization's objectives, about the handling of the resources by the individuals,

each of these elements being more or less precisely determined and recognized for some time. It does not focus on a specific social organization but presents a formal theoretical framework for the modeling and the study of such organizations. This framework is underpinned in the sociological theory of organization, namely the sociology of organized action (SOA), also called strategic analysis (Crozier 1964; Crozier and Friedberg 1980).

1.2 In any contexts of collective action featuring some duration, the occurrence of the regulation phenomenon is a well-established fact: every individual adopts a quite stable behavior as if he obeys precise rules, while these rules differ, to a more or less large extent, from the formal rules that codify the organization. This phenomenon is not contingent, since regulation is necessary for the proper working and the survival of any system of collective action. SOA postulates that the management of power relationships are the core of interactions between the actors of an organization and support the mechanisms that govern the occurrence of regulation: power relationships explain how behaviors are regularized and why individuals behave as they do. So, SOA is a generative approach (Fararo 1987; Hedström and Swedberg 1998) which focuses on the production of social phenomena. Through the study of organizational processes, it explains, at least partially, the phenomena at macro or meso level (the regulation of a system of organized action) by activities at the micro level (the interactions between the actors), while, in return, the actors of the system are constrained by the regulation that they have contributed to build.

1.3 However, SOA is hampered in this generative or analytical perspective by an almost exclusive use of qualitative methods. For the sake of the "irreducible contingency" of concrete systems of action, Friedberg does not believe in the possibility of producing general purpose knowledge. He limits the knowledge project of SOA to the perimeter of the idiosyncrasy and the accumulation of

monographs whose value is essentially pragmatic.

- 1.4 The concepts mobilized by SOA reveal to be sufficiently well defined to be amenable to formal definitions, which, although they are less expressive than the discursive approach, catch the essentials of this conception of organizations. The SocLab framework incorporates these concepts and enriches them thanks to the systematization induced by the formalization. This framework includes a formal model of the structure of social organization in terms of power relationships, in the form of a metamodel that will be instantiated by sociologists to structure their analysis of the constitutive elements of the organization under consideration. The simulation of a SocLab model makes it possible to consider under what conditions and in what form the regulation phenomenon can emerge from the processes by which every actor adjusts his behavior to that of others. In the reverse direction, simulation allows to consider to what extent the current regulation of an organization influences the evolution of its structure. Finally, the formal modeling of the structure of organizations opens the possibility to define tools allowing to study analytically their properties, to compare organizations and to produce theoretical knowledge whose assessment is not only a matter of subjectivity.
- 1.5 A computer-based platform enables to apply this theoretical framework to the analysis of concrete systems of organized action. The SocLab software platform^[1] allows the user to edit models of an organization, to study the properties of models with analytic tools, and to compute by simulation the behaviors that the organization's members could adopt the ones with respect to others. As far as one agrees with the fundamentals of SOA, this platform looks like a tool for organizational diagnoses and the analysis of scenarios regarding possible evolutions of an organization. It can be used also for the design of virtual organizations having no direct reference to reality, aimed at the study of theoretical properties of organizational configurations featuring particular characteristics.
- 1.6 In the line of Squazzoni (2012), the purpose of the paper is to provide a comprehensive view of the SocLab framework for the study of power relationships within social organizations, illustrated with a typical example of its use by means of the SocLab platform (Mailliard 2008, El Gemayel 2013). It is organized as follows. While the SOA conception of power is more or less endorsed by most theories in sociology of organization, section 2 recalls its main principles. Indeed, these postulates delineate the range of questions that may be addressed by this theory and in sociology, the agreement with the fundamentals conditions the confidence in the findings. Then, we present the scene of the case study, the question which motivated the elaboration of a SocLab model—i.e. the management policy of a river regularly provoking floods in SW France—and four hypotheses raised by the empirical study about power relationships in the concerned system of organized action. Detailed presentations of the case and the model are given in Sibertin-Blanc et al. (2013b).
- 1.7 Sections 3 to 5 are devoted to the meta-model and its use. Section 3 is a detailed presentation of the core of the meta-model enabling the sociologist analyst to design formal models of concrete (or fictive) organizations. We indicate how the main elements of a power relationships analysis are translated into a SocLab formal model and conversely how the SocLab concepts may be interpreted in sociological terms. This section defines the *social game* as the interplay between the processes carried out by social actors for the reciprocal adjustments of their behaviors that leads to the stabilization of these behaviors, i.e. the regulation of the organization. The elements of the model of the case study are presented along with the definition of the corresponding meta-model's concepts. Section 4 completes the presentation of the meta-model by the introduction of four mechanisms that extend its expressiveness in dealing with organizational arrangements. Section 5 addresses the use of the meta-model that, as any tool, needs a "user manual". Indeed, the building of a SocLab model requires quantitative data about individuals, which is not very common in sociology. So we present an investigation methodology that includes qualitative interviews whose results can be integrated in the formal model. Then, since a meta-model is also a language, we give—as elements of a (rudimentary!) pragmatics—some hints on the modeling of common organizational patterns.
- 1.8 Section 6 addresses simulation issues. Considering the model of an organization as a multi-agent system, we can endow the organization's actors with a suitable rationality to play the social game and so compute how the organization could be regulated. The plausibility of the results obtained in this way heavily depends on the rationality principles that are embedded into the simulation algorithm, so the main principles are presented at the detriment of the details of the algorithm and are given in a companion paper (Sibertin-Blanc et al. 2013b). Addressing the model of a concrete organization, the convergence between the observed actors' behaviors and the simulated regulation confirms (or not) the validity of the model. Addressing a virtual organization, e.g. an evolution of a concrete organization, simulations shed light on what could happen. Section 7 is devoted to analytic tools usable by the analyst to investigate underlying properties of an organization that can be inferred from its structure. The analytical results that can be obtained in this way complement the simulation results and improve their interpretation. The possibility to design such tools and to interpret their results in sociological terms relies upon the definition of the structure of an organization as an algebraic structure amenable to interpretation in organizational terms.
- 1.9 Section 8 presents simulation results of the model of our case study. Then, to the light of these results and a few analytical considerations, we analyze the four hypotheses whose study was the main motivation for the building of the model. The conclusion summarizes the main contributions of the paper.



The Sociology of Organized Action

- 2.1 Among the metaphors identified by Morgan (1997) in the vast literature about organizations, sociology of organized action (SOA)

falls within the "organization as a political system"^[2]. This sociology was initiated by Crozier (1964) and illustrated by the emblematic example of the "industrial monopoly". From the 1970s, it has been widely disseminated in the field of social science and beyond (Crozier and Friedberg 1980; Friedberg 1997; Dupuy 2001; Courpasson et al. 2012). This approach, also called "strategic analysis", conceives the organization in terms of power relations between its member actors. Echoing the Simon's conception of bounded rationality (Simon 1982) and the achievements of American sociologists criticizing the Weberian ideal-type of bureaucracy (Adler 2009), Crozier bases his method of sociological analysis of organizations on four postulates.

- 2.2 The first is to consider *the organization as a construct*, produced by the actions of its members, which is never fully determined neither by its environment, unlike the structural contingency theory (Aldrich and Pfeffer 1976), nor by the organization chart or the formal rules whose practical applications always require a contextual interpretation.
- 2.3 The second postulate concerns the actor of the organization who is never reducible to a mere instrument of the latter. Having goals, more or less conscious but still partially distinguishable from those assigned by the organization, the actor develops a *strategic behavior* aimed at achieving his objectives. This sociological approach is clearly different from the institutionalist theories which focus on the institutional and collective dimension of the organizational phenomena (see for example DiMaggio and Powell 1991). It also differs from theories which do not reduce the individual action to its strategic dimension, such as the justification theory which is interested in the compromises between "principles of justice" (Boltanski and Thévenot 1991).
- 2.4 The third considers that the strategy of each actor is characterized by the mobilization of resources to exert *power* over others. In any organized action context, we must obtain the contribution of others to take actions, and the power lies precisely in this ability to get from others the behaviors whose we need to act. The actor seeks to maintain or increase his power in order to get the means to achieve his objectives.
- 2.5 Finally, this sociology postulates that any organized action requires a minimum of collective order that can integrate individual behaviors of actors. This order results from the interdependence between the strategies of actors in the exercise of their power relations. It assumes the existence of a *regulation process*, even if it remains more or less precarious partly because of attempts by actors to make it evolve to their advantage.
- 2.6 The concern of SOA is social systems defined as "a complex set of intersected and interdependent games through which persons, often provided with very different assets, seek for maximize their gains, respecting the rules of the game which are not written and are imposed by the environment, taking systematically advantage of all their assets and seeking to minimize those of the others" (Crozier 1964: 8). These intersected and interdependent games take place in so-called "Concrete Systems of Action" which can be defined, in a given organizational context, as sets of actors, their alliances, their relations and the regularization of these ones. The scope of SAO is therefore not limited to organizations structured by formal rules, but extends to systems of actions regarding, for example, public policies, citizen associations, collaborations between (networks of) firms or institutions, partnered relationships or governance issues.
- 2.7 "The central question is to understand the social processes leading to the construction and organization of the competitive cooperation between a set of actors who are mutually dependent for the solution of a common problem, which they cannot solve by themselves and for the solution of which they have to secure the cooperation of partners who are also potential rivals" (Friedberg 1997: 122). Articulating the actor and the system, the SOA examines the forms of cooperation between actors in contexts of action structured by power relations and regulated by the strategic manipulation of these relations.
- 2.8 SOA emphasizes the concept of power because it underpins the regulation processes within organizations. In any system of collective action, everyone seeks to achieve his objectives and thus to gain access to needed resources, including resources he does not master because they are controlled by others. The access to such resources is that the SOA calls a "zone of uncertainty" (ZU), whose control enables an actor to behave in a way that is somehow unpredictable by other actors having a need for these resources^[3]. ZUs are the supports of the power relationships between the actors, and the power results from the mastering of ZUs: by setting the "exchange rules" in his relations with others, the actor intends to obtain from them a good access to the resources he needs himself^[4]. Thus, power is nothing but an indispensable instrument to obtain from others the means of achieving one's objectives. The regularization of the actors' behaviors results from an equilibrium between the steady pressures that they exercise the ones on the others, since each social actor both controls some ZUs and depends on some others.

A case study

- 2.9 As an illustrative case, we will consider the system of organized action in charge of the management of a river called Touch, which is accurately documented (Baldet 2012). Touch is a tributary of the Garonne in which it flows downstream of Toulouse, a city of one million inhabitants in the South-West of France. Its catchment area covers 60 municipalities and its 75 km long course crosses 29 municipalities. Upstream, three quarters of these municipalities are mainly agricultural villages weakly urbanized. On the contrary, the downstream quarter of municipalities form a dense urban area within the Toulouse built-up area. Downstream cities have been reached by several episodes of flooding during the past decades, and this raises the question of the prevention and management of flood risks.
- 2.10 Flood risk prevention supposes cooperation between municipalities, because of their interdependence within the same watershed. Downstream municipalities are concerned with important issues in terms of protecting people but also in terms of

urban development and therefore economic activity. Upstream, the main issue is the use of agricultural land and the preservation of village life. Each type of municipalities has specific issues but they are interdependent: excess water must go somewhere and the main way to limit the damage caused by flooding downstream is to let the upstream flow overflow onto agricultural land. Downstream municipalities consider that upstream ones do not cooperate enough and they have tried to protect themselves by building dikes that, even if expensive, are not sufficient to eliminate the flooding risk. On the contrary, upstream municipalities, strongly influenced by the farmers, consider that they have taken responsibility for preventing flooding by letting some land lying uncultivated to absorb the excess of water in case of flooding.

- 2.11 The model has been designed on the occasion of enhancing the flood risk prevention plan of Touch (FRPP), an obligation of the French law since 1995 that was reinforced, among others, by the European directive 2007/60/CE relating to the evaluation and management of flood risks.
- 2.12 The study of actor's representations and their relationships shows that a "field flood risk " conception appeared in connection with a change in the orientation of the management of Touch (Baldet 2012). This management has become more global and environmental. The desire to "restore the river to its environment", which gradually prevailed, reflects the moving from a hydrological to a hydromorphological view of the river's management. SIAH, an inter-communal association for the management of the river, brought this evolution ^[5]. Extending his initial prerogatives, he managed to lead an innovation process corresponding to a cognitive change from hydrology (to ensure the flowing of water) to hydromorphology (to consider the river as an element of an ecosystem).
- 2.13 The sociology of translation (Callon 1986) was used for reporting the innovation process. This sociology allows to qualitatively describe the process of change by identifying the phases of formation and consolidation of all the (human and non-human) "actants"—or "actor-network"—bringing the change. In this context, SIAH is the actor that problematizes the hydromorphological orientation, makes other to be interested and enrolls them to get their mobilization in favour of change. The empirical study describes SIAH as the "obligatory passage point" of the actor-network, that is to say the legitimate actor that controls and directs the action of others towards the promotion of the environmental view of the river management.
- 2.14 Following the Lascoumes and Le Bourhis' approach (1998), SIAH is also identified as carrying the " Territorial Public Interest ". This sociology studies the process of building a shared conception of the general interest in a territory. It distinguishes, among the public policies conducted by the State, the "substantive" and the "procedural" policies. In the first case, the central authority specifically defines "the aims and means of achieving them" on behalf of the public interest previously established. In the second case, which marks a post-bureaucratic state action (Nonet and Selznick, 1978), the State simply produces "very general statements" and a "general framework" organizing the collective bargaining between local actors which are thus led to gradually build a " Territorial Public Interest " legitimizing the decisions.
- 2.15 If the "Actor-Network" and "Territorial Public Interest" analysis schemes catch properly the cognitive and axiological dimensions of change, they do not put power relationships at the heart of the analysis. We can even consider they ignore this aspect of change processes quite extensively. It is therefore interesting to compare the results obtained by these approaches with those produced by an analysis in terms of sociology of organized action, which provides an understanding of social affairs centred on power as the means necessary for action and thus for change. Therefore, one may wonder whether the analysis of power relationships between actors of the basin Touch confirms or complements the results described in (Baldet 2012). This leads to formulate four hypotheses (Baldet and Roggero 2011) that the SocLab model is intended to test:

Hypothesis 1: To be the obligatory passage point of the actor-network, is that SIAH has enough power to somehow constrain other actors?

Hypothesis 2: Purposing to play an important role and to introduce a change in the management of flood risk, is that SIAH has the means to do so?

Hypothesis 3: In the enrolment of other actors on the service of an hydromorphological management of the river, is that SIAH has powerful allies?

Hypothesis 4: Is that the agreement on the " Territorial Public Interest " is confirmed by the absence of major conflicts in the system of action?



The Meta-model of Systems of Organized Action

- 3.1 Purposing to enable SOA analysts to draw models of organizations, we propose a meta-model that catches the main concepts and properties of social organizations and can be instantiated on specific cases as models of (the structure of) real world social organizations. The model of an organization is composed of instances of the meta-model's classes, which correspond to the constitutive elements of the organization under consideration, and of links between these instances. A preliminary version of this meta-model was presented in (Sibertin-Blanc et al. 2006).

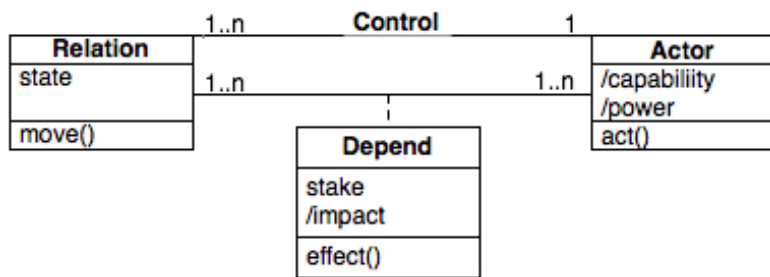


Figure 1. The meta-model of the structure of organizations

3.2 The meta-model is represented graphically in Figure 1 as a UML class diagram, and as an algebraic structure in Table 3. Accordingly, the structure of an organization includes a set of *Actors* and a set of social *Relations* that are linked by the *Control* and *Depend* associations. The actors are the active entities who handle the relations. When an actor *acts()*, he *moves()* the states of the relations he controls, and he is the only one to be able to do so. An actor also depends on some relations, usually including the ones he controls. He distributes *stakes* on each of these relations, and the impact of a relation upon an actor is the value of the *effect()* function applied to the state of the relation weighted by the stake. As a result, an actor gets some *capability*, or action capacity, as an aggregation of the impacts that he receives from the relations he depends on, and he exerts some *power*, as an aggregation of the impacts he grants to the actors who depend on the relations he controls. We now explain how these elements are interpreted in the terms of SOA.

Actors and their Stakes

3.3 According to SOA, a social actor is able to negotiate his collaboration, and this requires some autonomy with regard to the control of at least one relation. Therefore an actor is defined as someone who controls at least one relation. Actors and relations are defined in a dialogical way: something is a relation if and only if some actors depend on it, and someone is an actor if and only if he controls some relation. The actors of an organization are either individual actors, either collective actors, i.e. groups of individuals that interact with others like a single entity in the considered context of action, or plural actors, i.e. populations of individuals that interact each one on his own but in a similar way because they are in the same position, so that their behaviors may be averaged and aggregated as the behavior of a single population's representative actor.

3.4 SOA assumes that the actors are strategic and have an interested behavior, i.e. "motivated by some goals, without defining these goals in details" (Friedberg 1997: 214-215). To achieve his goals, a blend of his personal goals and the ones related to his interpretation of his role within the organization, each actor needs resources which entail his dependence on some relations. How much an actor depends on a relation is determined by the necessity of the resource for the achievement of his goals and the relative importance of this goal (see Figure 2). This level of dependency is depicted by the *stake* attribute of the depend association. More valuable is a relation for an actor, higher is his stake on this relation. Stakes are represented by numerical coefficients, on an arbitrary scale from 0 to 10:

null = 0, *negligible* = 1, ... , *significant* = 5, ... , *critical* = 10.

In order to provide every actor with the same degree of investment in the organization, he has a total amount of 10 stake marks to distribute on relations. As an actor cannot be indifferent to his own behavior, he should be dependent on the relations he controls.

3.5 The SOA analysis of an organization focuses on what the actors need to reach their goals rather than on the nature of these goals. SOA does not try to analyze the world of the goals, that are quite opaque, indistinct and most often incoherent; it only considers the actors' stakes, that are the projection of these goals in the phenomenological world of the observable behaviors. Under the rational behavior assumption, actors with different aims but similar stakes will have similar social behaviors^[6].

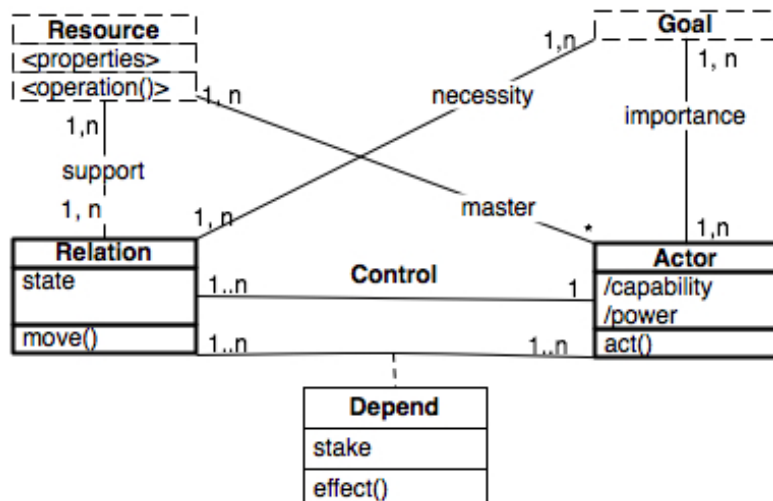


Figure 2. The Relations are supported by mastered Resources, stakes reveal their importance and necessity with regard to Goals

The case

3.6 Within the system of action regarding the Touch river, we encounter four categories of actors which are involved in the management of the river or have stakes in the elaboration or the results of the FRPP. First, the population and the local politicians of the 29 municipalities who have to cope with the constraints of the flood risks prevention and the damages caused by flooding. Second, State services and river basin authorities, which are responsible for the public good planning, namely the management of water, and third, the political authorities at the regional level, the two latter being responsible for the proper use of public funds. Forth, an engineering firm provides technical expertise. This leads to identify 10 actors:

- actor 1: *Departmental Territory Direction (DDT)* acts as the State representative. It investigates and will promulgate the new FRPP;
- actor 2: *National Office for Water and Aquatic Ecosystem (ONEMA)* is the reference agency for the knowledge and the monitoring of water and aquatic environment. It is also in charge, jointly with DDT, of the water police;
- actor 3: *Adour-Garonne Water Agency (AEAG)* is the operational authority in charge of strategic River Basin Management Plan. Accounting for the requirements of all water uses and in charge of the State policy for the protection of aquatic ecosystems, it defines, supervises and funds the water policy at the basin level;
- actor 4: a citizen organization of *riparian farmers* in the upstream area. They own floodplain lands and have an excellent empirical knowledge of issues related to the river;
- actor 5: the group of 25 *upstream towns* that have 21,000 inhabitants;
- actor 6: the group of 4 *downstream towns* (75,000 inhabitants) that are incriminated at each occurrence of a natural catastrophe. Due to flooding threats, they must prohibit any building on a portion of their territory;
- actor 7: the *inter-communal association for hydraulic civil engineering (SIAH)*, in charge of the management of the Touch, especially the maintenance of the river bed and banks. It is an arena both technical and political, which includes representatives of the 29 riparian municipalities. Its leader favors the cooperation among municipalities while worrying about the "good ecological status" of the river;
- actors 8 and 9: political actors, the *regional* and *departmental councils* respectively, which can bring additional financial support to civil engineering measures;
- actor 10: an *engineering consulting firm* specialized in water, energy and environment and entrusted with technical studies.

3.7 The actors who are the most engaged in the negotiation are actors 6, 4 and 5 from the population point of view, and actors 7, 3 and 9 from the institutional point of view. All these actors have a significant interest in the outcome of discussions, while actors 1, 2, 8 and 10 are more peripheral. There is no noticeable opposition between the politician actors due to differences in their political affiliations. Each actor has a variety of duties and goals of its own. The analysis of the debates, notably within the SIAH, allows to identify the actors' main objectives, which are all likely to be prioritized options for managing the Touch river. They are in the line of the scene as we presented:

- (O1) protecting the downstream towns against floods without hindering their planning and development (supported by actor 6)
- (O2) protecting the daily life of upstream villages, that requires to protect agricultural activities (supported by actors 4 and 5);
- (O3) ensuring a good ecological status of the river and the related aquatic environment (supported by actors 2 and 3 and also 7).

3.8 Upstream and downstream municipalities are tightly interdependent though their respective interests are different, if not conflicting. So the elaboration of the FRPP includes a fourth issue:

- (O4) finding a solution that is a compromise that is acceptable for the population and its representatives (supported by actors 7, 3, 1, 8 and 9 by order of importance, according to their respective status). The fulfillment of this objective is essential because, whatever the chosen solution, its effective implementation will be problematic if it is not agreed by most actors.

Resources, Relations and effect functions

- 3.9 Resources are whatever elements involved in actors' activities and whose availability is therefore necessary or somehow useful to achieve actions in the context of the organization. They look like concrete objects, cognitive entities such as factual or procedural information, expectation, know-how, services, attitudes and so on. Some resources are formal insofar as they are associated with a role of the organization, while others are just attached to an actor's specific way of doing.
- 3.10 Among the resources needed by an actor to achieve his objectives, some ones are at his free disposal, while others are under the control of another actor. There is a social relation between one actor who controls the relation and one or several others that are dependent when they repeatedly interact about the access to a resource (or a set of related resources, see Figure 2), and the relation is the persistent matter of these interactions. A relation is the playing of a role, be it an organizational role or a role that an actor takes by himself. As Friedberg wrote: "no power without relations, no relation without exchanges" (Friedberg 1997: 115). Power requires relations, relations imply exchange, and exchange requires goods to be exchanged: the resources.

- 3.11 A relation refers to a type of exchange involving the resource on which it is based, and this exchange is unbalanced: an actor—who master, at least partially, the resource—controls this relation, whereas some other actors—who need the resources for achieving their goals—are dependent on this relation. Thus, the actor who controls a relation is in a position to define how the resource is available to the dependent actors, and thereby he controls to what extent they will have the means to reach their goals. A key idea of SOA is that every relation is an unbalanced power relationship. But the actors within an organization are mutually dependent: an actor *a* dominated by an actor *b* in a relation can dominate *b* in another relation, possibly via a third actor *c*.
- 3.12 The state attribute of a relation stands for the behavior of the actor who controls the relation, i.e. his policy with regard to the access to the underlying resource. Its value ranges over a space of behaviors, representing the set of all the behaviors that the actor can adopt in the management of the relation on a scale of cooperativity. In order to keep it simple, the space of behaviors of each relation is formalized as an arbitrary interval $SB = [-10; 10]$, where the bounds stand for the technical or practical feasibility limits, according to the very nature of the underlying resource. This interval is oriented: the lower bound represents the least cooperative behaviors, the upper bound represents the most cooperative behaviors, while the zero value stands for neutral behaviors that comply with the norms and may be qualified neither as cooperative nor as uncooperative.
- 3.13 Friedberg defines the power as "the capacity to structure the negotiated behavior exchange in one's favor" (Friedberg 1997: 113), i.e. to obtain favorable behaviors. The actor who controls a relation may change his behavior by using the function $move()$, that modifies the value of the state of the relation. The SOA does not consider how actors adjust their behaviors one to another within an organization, it just spots the current behaviors. We made the assumption that an actor adjusts his behavior by a greater or lower cooperation with regard to his actual behavior.
- 3.14 The state of a relation—that is the behavior of its controller actor—has an effect upon each actor who depends on this relation: for each depending actor, the state determines the availability of the underlying resource and to what extent the actor is granted to use the resource according to his goals. The effects take values on a bipolar arbitrary^[7] scale from -10 to 10 measuring a capacity of action:

worst access = -10, strongly prevented = -8, ..., neutral = 0, ..., good = 6, ..., optimal = 10.

Higher is the effect of a relation on an actor, more usable is the resource for his desires, and therefore larger is his capability to realize his aims. Depending on the very nature of a relation and the specific needs of an actor, the link between the state and the effect is given by an $effect()$ function. When the controller of a relation *r* chooses a state value *s* in the space of behaviors of the relation, the effect on a dependent actor *a* is given by $effect_r(a, s)$. More formally, the $effect_r()$ function of a relation *r* is defined as:

$effect_r : A \times SB_r \rightarrow [-10, 10]$,

where *A* is the set of actors, SB_r the space of behaviors of relation *r* and $[-10, 10]$ the range of the capability to use a resource.

The case

- 3.15 The model is designed in such a way that each actor controls a single relation that summarizes his means to influence or carry out the management policy of the river. (For space limitation, we can not bring all the empirical arguments in favour of this model, but see Sibertin-Blanc et al. (2013b) for details).
- *Validation* (between -10 and 10) is the more or less harsh regard of actor 1 on the prevention plan proposed by actor 7. This validation is made on the basis of technical and ecological criteria;
 - *Expertise* (between -8 and 8) is the outcome of a study of which actor 2 is in charge. Actor 2 gives a positive or negative appraisal on the construction work, based mostly on ecological criteria;
 - *Funding* (between -8 and 8) is a funding coming from actor 3 who can pay for up to 75% of the total cost of a construction work if the project is considered as ecological;
 - *Lobbying* (between -10 and 10) is the more or less dynamic and efficient activity of actor 4 who owns the floodplain lands. As this actor is not much concerned by ecological issues, he is frequently arguing against actors 2 and 3;
 - *Control of flow* (between -8 and 8) is the capability of upstream villages (actor 5) to keep (positive values of the state) in their territory a part of the water that floods the downstream towns;
 - *Self funding* (between -8 and 8) is the propensity of downstream towns (actor 6) to realize civil engineering works and engage in SIAH; negative values correspond to focusing on protection of the town against flood and denigrating the efficiency of SIAH; positive values correspond to engaging in SIAH while denouncing the selfishness of upstream towns.
 - *River management* (between -8 and 8) is the activity of actor 7 on the river management: low values of the state mean that the association limits his involvement to legal competence, *i.e.* river maintenance, and high values mean that the association engages in the prevention of threats coming from the river;
 - *Additional funding RC* (between -8 and 8) is the financial involvement of actor 8 in the project;
 - *Additional funding DC* (between -8 and 8) is the financial involvement of actor 9 in the project: actor 9 has his own rules to give a project financial assistance. A high level for this relation means stronger (mainly ecological) constraints to grant the project;
 - *Studies* (between -8 and 8) is a study conducted by actor 10: a positive value means an *hydromorphological* outcome for this study (ecological approach that uses the shape of the river to prevent flooding) and a negative value means an

hydraulic outcome for this study (e.g. dikes and dams, without consideration for the natural course of the river).

- 3.16 Table 1 shows the stakes that actors (in column) put on the relations. Actors disperse their stakes in very different ways, from 5 relations (actors 6 and 10) to 8 relations (actors 2 and 3). Each actor put about one third of his stakes on the relation he controls. The River management is clearly the most relevant relation since it collects 21 stake points, while relations Expertise, Additional funding and Studies gather about 5 stake points each.
- 3.17 As an example, we comment the SIAH's stakes. His capacity for action depends on the behavior of the water agency (actor 3) that finances its operation and most of the works of the river development. Its capacity also depends on the behaviors of the upstream and downstream municipalities and citizen associations (actors 5, 6 and 4) since their cooperation is necessary for a management of the river that is efficient and in accordance with the SIAH's convictions. To a lesser extent, SIAH also depends on the interpretation of legal constraints by the State services, i.e. the DDT.

Table 1: The stakes of the actors on the relations

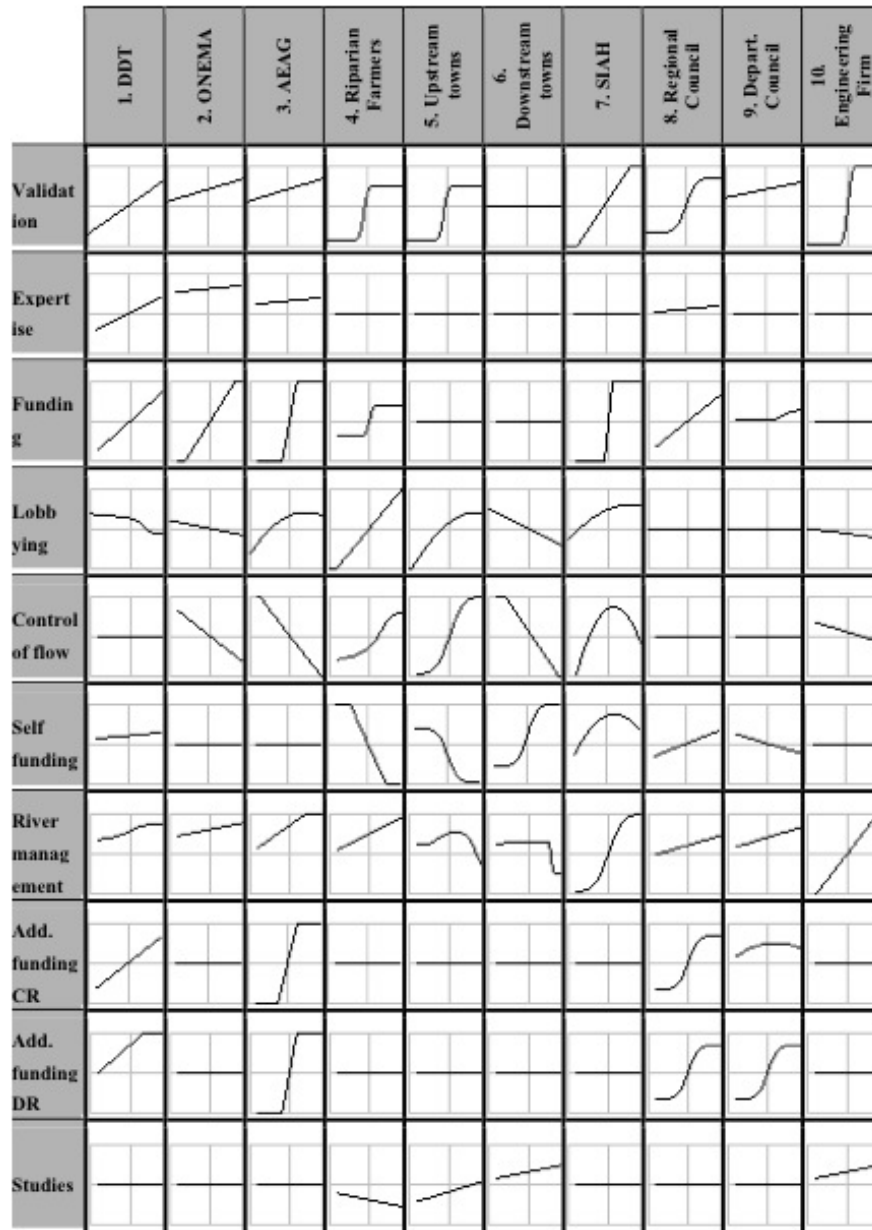
	1. DDT	2. ONEMA	3. AEAG	4. Riparian Farmers	5. Upstream towns	6. Downstr. towns	7. SIAH	8. Regional Council	9. Depart. Council	10. Engineering Firm
Validation	4.0	2.0	1.0	0.5	0.5	0.0	0.5	1.0	2.0	1.5
Expertise	1.0	3.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Funding	1.0	1.5	4.0	0.5	0.0	0.0	2.0	2.0	1.5	0.0
Lobbying	0.5	0.0	1.0	4.0	1.0	1.0	0.5	0.0	0.0	1.0
Control of flow	0.0	1.5	1.0	2.0	4.0	2.0	2.0	0.0	0.0	1.5
Self funding	0.5	0.0	0.0	1.0	1.5	4.0	2.0	0.5	0.5	0.0
River management	2.0	1.5	1.5	1.5	2.5	2.5	3.0	2.5	2.5	2.0
Add. funding CR	0.5	0.0	0.5	0.0	0.0	0.0	0.0	3.0	0.5	0.0
Add. funding DR	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.5	3.0	0.0
Studies	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.0	0.0	4.0

- 3.18 Table 2 shows the shape of the effect functions. These functions are linear, quadratic or sigmoid. Each row in the table shows the effect of the state of the relation on each actor (in columns). Since each actor controls one relation, the diagonal contains the effect function of each relation on its controller actor. This function is particularly significant firstly because it is generally subject to an important stake and secondly because it is indicative of the actor's wishes and how much he feels pleased by the achievement of his aims. We only comment the functions of the relation River management controlled by SIAH.
- 3.19 The range of the state is reduced to [-8, +8] to take account of institutional constraints on SIAH because of his status. (Enlarging this range would generate another model enabling SIAH to override these constraints). SIAH is legally responsible for the maintenance of the river, but his activist technical manager aspires to play a role in the management of flood risks based on a hydromorphological conception of the river. The shape of the effect function on SIAH expresses this orientation. Negative values of the state (along the x-axis) correspond to situations where SIAH remains within the narrow framework of its mandated role and the hydrologic conception associated with it. They provide SIAH with a negative satisfaction (along the y-axis). More SIAH implements his hydromorphological conception and participates in the management of flood risk, more he becomes satisfied. The inflection points of the curve correspond to thresholds. Above -4, the statutory role of SIAH begins to be enough overcome to have an increasing effect. Similarly, the value +4 is the threshold where the excess of his assigned role begins to cause difficulties with other actors.
- 3.20 The effect functions of the River management relation on upstream and downstream towns have profiles partially opposed to that of SIAH. When SIAH keeps the role of maintenance manager, the former are quite satisfied, but moderately as the SIAH imposes maintenance constraints. When SIAH gets out of this role, initially they are more satisfied but they become less satisfied when SIAH begins to exert an influence limiting their prerogatives in the planning of their territory. Downstream municipalities have more resources than the upstream ones to perform the required work. Their satisfaction will be positive until SIAH takes too much power on their territory.
- 3.21 The effect functions on other actors operate in the same direction as SIAH. They are therefore rather favorable to an extension of the role of the inter-communal association. DDT is in favor that SIAH takes better care of risk management, which would facilitate the work of investigating the case. ONEMA sees a convergence with his own environmental orientations. For AEAG, the convergence is even more accentuated because a greater role SIAH is consistent both with his environmental preferences and an increase in his own influence through SIAH's policy. The Riparian Farmers are also pleased by an expanded role for SIAH.

This enhances their ability to influence, due to the good relationships of the leaders of the association with the technical team of SIAH (they share a concrete empirical knowledge of the river).

- 3.22 Funders such as CR and CG are also in favor of increasing the role of SIAH in the field of flood risk management. For these institutions, to have a single contact would be a facilitation of their work. Finally, the Engineering Firm prefers a risk manager, because he could therefore be asked for more studies.

Table 2. The effect functions of the relations on the actors. The x-axis corresponds to the state of the relation, the y-axis corresponds to the resulting capability for the actor.



States of an Organization, Action Capacity and Power of Actors

- 3.23 We define a *state of the organization*, or one of its possible *configurations*, as a vector of all the relations' states. For each actor and each relation he depends on, we define the relation's *impact* as its effect weighted by the actor's stake. To the extent that relations' impacts are commensurable, the aggregation of the impacts received by an actor depicts his overall ability to access the resources he needs to reach his goals, weighted by the relative importance of these resources. It measures the actor's capability to reach his goals, by having the means required to this end. Under the hypothesis that there are no interferences between resource uses (Cf. 4.12 below), it is possible to sum the impacts and to define the *capability* of an actor *a*, when the organization is in the state *s*, as:

$$capability(a, s) = \sum_{r \in R} stake(a, r) * effect_r(a, s_r) = \sum_{r \in R} impact(r, a, s_r), \tag{1}$$

where *stake(a, r)* is the stake of *a* on relation *r* and *effect_r(a, s_r)* is the effect on *a* of relation *r* being in the state *s_r*.

- 3.24 By his control on some relations, each actor contributes to the capability of actors who depend on these relations. The whole

influence of an actor on the capability of others, i.e. to what extent his behavior contributes to their ability to reach their goals, fits the concept of *power*, a core concept in SOA. The power exerted by an actor *a* upon an actor *b* when the organization is in the state *s* is thus defined by:

$$power(a, b, s) = \sum_{r \in R; a \text{ controls } r} stake(a, r) * |effect_r(a, s_r)|^{[8]} \quad (2)$$

3.25 The definition of the meta-model of organizations as a UML class diagram as in Figure 1 provides a graphical representation that is easy to understand. However, we may also define the model of an organization as an algebraic structure, as given in Table 3.

Table 3. The algebraic definition of organizations' models

The *model of an organization* is a finite structure including:

- *A* the set of *actors*;
- *R* the set of *relations*;
- *control* : $R \rightarrow A$; *control*(*r*) is said to be the *controller actor* of relation *r*;
- *state* : $R \rightarrow SB_r$, where SB_r is the additive *Space of Behaviors* of relation *r*; *state*(*r*) evaluates the cooperativity of the actor *control*(*r*) and we put $SB_r = [-10, 10]$ for any relation *r* without loss of generality;
- *stake* : $A \times R \rightarrow [0, 10]$ such as $\forall a \in A \sum_{r \in R} stake(a, r) = 10$; an actor *a* is said to be *dependent* on relation *r* iff $stake(a, r) \neq 0$;
- *effect* : $R \rightarrow (A \times SB_r \rightarrow AC)$, where *AC* is the range of value of *action capacities*; we put $AC = [-10, 10]$ without loss of generality and assume that actions capacities may be added and multiplied by coefficients (stakes and solidarities).

The Social Game

3.26 Such an interaction setting defines a *social game*. According to SOA, the regula(riza)tion of an organization results from the intentionality of actors' behaviors. Actors are strategic; each one seeks, as a meta-objective, to obtain from others a satisfying level of capability and to this end adjusts the state of the relations he controls. Doing so, he modifies the capability of every actor depending on the relations he controls, including himself. More precisely, at each step of the game, every actor moves the values of the states of the relations he controls, and this change of the game's state modifies the capability of other actors. Let (s_{r1}, \dots, s_{rm}) be a state of the organization and (c_{r1}, \dots, c_{rm}) be moves such that $(c_r + s_r) \in SB_r$ and c_r is chosen by actor *a* = *control*(*r*). Once each actor has chosen such an action, the game goes to a new state defined by:

$$\begin{aligned} & \text{Transition: } [-10; 10]^m \times [-10; 10]^m \rightarrow [-10; 10]^m \\ & \text{such as} \\ & \text{Transition}((s_{r1}, \dots, s_{rm}), (c_{r1}, \dots, c_{rm})) \Rightarrow (s_{r1} + c_{r1}, \dots, s_{rm} + c_{rm}). \end{aligned} \quad (3)$$

3.27 The game ends when a stationary state is reached. In such a state, each actor no longer modifies his behavior because he is satisfied by the level of capability he actually obtains. Therefore, the organization is regulated and can operate in this way.

3.28 The social game is a game in the sense of Morgenstern et al. (1953), where the capability of an actor serves as utility function. However, it differs from games that are considered in economics: the social game does not worry about the amount of capability gained by the actors, but about the possibility for the game to exist thanks to the persistency of the organization's concrete existence. In the section 6, we will consider the implementation of the model of an organization as a multi-agents system that makes the organization's actors to play the social game and so compute how it could be regulated.



Some Extensions of the Meta-model of Organizations

4.1 The elements presented in the previous section catch the underpinning concepts of SOA. We now introduce complementary elements which extend its somehow simplistic view. They allow to develop more accurate models and lead to the meta-model of organizations shown in Figure 3.

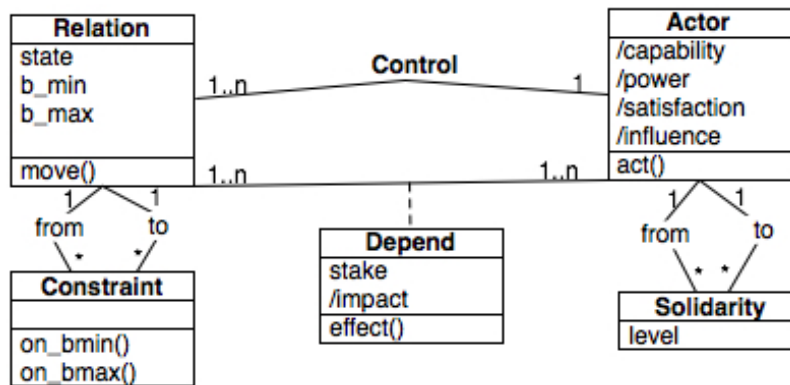


Figure 3. The extended meta-model of organizations' structure

Solidarities between Actors: Satisfaction and Influence

4.2 The interactions among the actors of an organization are not totally shaped by relations underpinned on the need and the control of resources. There are links tied inside the organization such as esteem or the recognition of shared (or opposite) interests that would be artificially represented by resources of the organization, while they clearly affect the actors' behaviors. The same holds for the charismatic and traditional types of authority as opposed to rational-legal authority (Weber 1958). There are also links outside the organization that influence the way actors consider each other such as kinship links, common social condition or scholarship, common membership to another organization and so on.

4.3 That led us to introduce the *solidarities* that actors maintain between them to model how they account each other. Solidarities are represented by a function which measures the degree of solidarity $solidarity(a, b)$ that an actor a puts on an actor b :

$$solidarity: A \times A \rightarrow [-1, 1] \text{ such that } \forall a \in A \text{ } solidarity(a, a) = 1^{[9]}, \tag{4}$$

where negative values represent hostility, zero represents lack of concern, and positive values represents real solidarity.

The case

4.4 Table 4 shows how much each actor (in line) is solidary with some others (in columns). One may notice that hostilities mainly concern Riparian Farmers, Upstream and Downstream towns, that is the field actors that are directly concerned by floods. We will explain in the following section how actors' solidarities are measured, but one may also notice that AEAG and SIAH are the target of high solidarities (1.7 and 1.5), as a sign of the expectations from the other actors about them.

Table 4: Solidarities between the actors of the Touch's system of organized action

	DDT	ONEMA	AEAG	Riparian Farmers	Upstream towns	Downstr. towns	SIAH	Regional Council	Dept. Council	Engineering Firm
DDT	0.6	0.05	0.05	0.1	0.1	0.0	0.1	0.0	0.0	0.0
ONEMA	0.05	0.6	0.15	-0.05	0.05	0.0	0.2	0.0	0.0	0.0
AEAG	0.05	0.1	0.7	-0.05	0.0	0.0	0.2	0.0	0.0	0.0
Riparian Farmers	0.05	0.0	0.0	0.8	0.2	-0.1	0.05	0.0	0.0	0.0
Upstream towns	0.2	0.0	0.0	0.3	0.7	-0.1	0.0	0.0	0.0	-0.1
Downstream towns	0.1	0.15	0.3	-0.2	-0.1	0.7	0.0	0.0	0.0	0.05
SIAH	0.1	0.0	0.05	0.0	0.1	0.1	0.65	0.0	0.0	0.0
Regional Council	0.0	0.05	0.1	0.0	0.0	0.05	0.1	0.7	0.0	0.0
Departmental Council	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.6	0.0
Engineering Firm	0.0	0.1	0.15	-0.1	-0.05	0.0	0.2	0.0	0.0	0.7

4.5 The introduction of solidarities leads to consider two quantities, in addition to the capability and power, to characterize a social configuration: *Satisfaction* and *Influence*. When an organization is in a state s , the *satisfaction* perceived by an actor a is the sum of the capabilities of all the actors weighted by his solidarities for them:

$$\begin{aligned} \text{satisfaction}(a, s) &= \sum_{b \in A} \text{solidarity}(a, b) * \\ \text{capability}(b, s). \end{aligned} \quad (5)$$

- 4.6 The capability of an actor evaluates his effective freedom of action, while his satisfaction corresponds to the representation that guides his behavior. In the reverse way, we redefine the *power* exerted by an actor *a* on another actor *b* as the sum of the impacts of the relations controlled by *a* weighted by the solidarities of *b*:

$$\text{power}(a, b, s) = \sum_{c \in A} \text{solidarity}(b, c) * \text{influence}(a, c, s), \quad (6)$$

where $\text{influence}(a, c, s) = \sum_{r \in R, a \text{ controls } r} \text{stake}(a, r) * |\text{effect}_r(a, s_r)|$.

Bounds of the Spaces of Behaviors of Relations

- 4.7 The actor who controls a relation can not assign whatever value to the state of this relation, due to the cultural dimension of the organization (Schein 1985), social norms or rules imposed by a legitimate authority that set boundaries whose crossing can not be the subject of negotiations. He has to abide norms of the social game and they restrict the set of behaviors that he is allowed to adopt. These social constraints may be represented by associating to each relation two attributes

$$\begin{aligned} b_min_r \text{ and } b_max_r, \text{ where } -10 \leq b_min_r \leq b_max_r \leq \\ 10^{[10]}. \end{aligned} \quad (7)$$

- 4.8 Therefore, the $[b_min_r, b_max_r]$ interval models the real room to manoeuvre of the actor who controls the relation *r* and quantity $(b_max_r - b_min_r)$ measures the extent of his leeway. Distinguishing the social limitations from the ones imposed by the nature of resources will allow to examine what happens when social norms are overpassed, one of the tricks of organizational change. It also allows to consider constraints among relations.

Constraints among Relations

- 4.9 The paradigmatic case of SOA, *i.e.* the "industrial monopoly" (Crozier 1964: 67-174 and 186-214), includes a relation concerning the "maintenance of the machines" that is controlled by the "maintenance workers" and another relation concerning the "contribution to the production" controlled by the "production workers". It is clear that the proper working of the machines determines to what extent they can be used by the production workers and thus their possibility to put a lot into their work. Thus, the model must account the fact that a bad maintenance of the machines prevents a high contribution by the production workers and thus decreases the b_max bound of the contribution to the production.
- 4.10 This can be expressed by constraints that the state of a relation imposes on the bounds of the space of behaviors of another relation by the two following functions $on_bmin_{r, r'} : SB_r \rightarrow SB_{r'}$ and $on_bmax_{r, r'} : SB_r \rightarrow SB_{r'}$ such that

$$on_bmin_{r, r'}(s_r) \leq on_bmax_{r, r'}(s_r), \quad (8)$$

and for any configuration where relations *r* and *r'* are in states s_r and $s_{r'}$

$$max_{r'; r \text{ constraint } r'} \{on_bmin_{r, r'}(s_r)\} \leq s_{r'} \leq min_{r'; r \text{ constraint } r'} \{on_bmax_{r, r'}(s_r)\}^{[11]}. \quad (9)$$

The case

- 4.11 Our case includes no constraints between relations, each actor being relatively autonomous in the conduct of his policy. Certainly, the behavior of Upstream towns can prevent Downstream towns to intensify his development strategy, but this aspect is not included in the Self funding relation.

Interactions among the Effects of Relations

- 4.12 The capability of an actor is computed by summing the impacts of the relations he depends on. This way of aggregating impacts of relations assumes that their effects are independent and it makes impossible to express, for example, that two relations are redundant (a good effect from only one of the two relations is sufficient) or complementary (a good effect from one of them is useless without a good effect from the other). This is a matter of *preference aggregation*, a well-known issue in the field of decision-making (Labreuche and Grabisch 2007).
- 4.13 Instead of looking for a complex aggregation function such as the Choquet or Sugeno integrals (Dubois et al. 2001; Labreuche and Grabisch 2006), we propose to consider, in addition to the *elementary relations* whose state is controlled by an actor, *compound relations* whose state is defined by a function that aggregates the states of its component relations according to the nature of the interaction (cf. Figure 4). For example, if two relations r_1 and r_2 are redundant for an actor, he will not put stakes on

the r_1 and r_2 relations but upon a new compound relation r such that $r.state = \max\{r_1.state, r_2.state\}$.

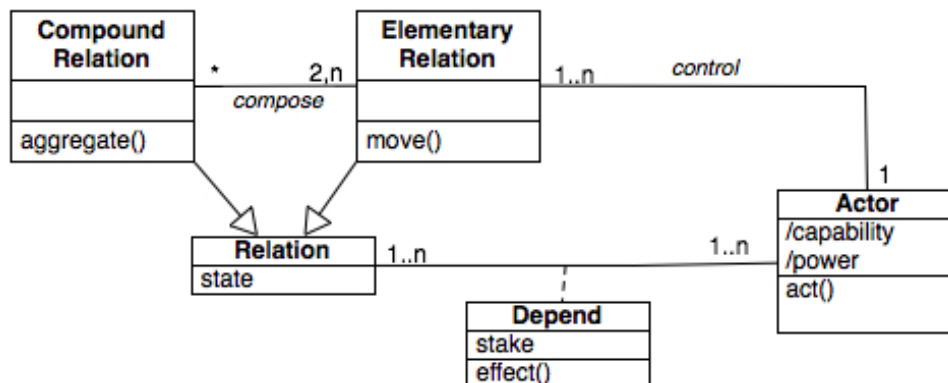


Figure 4. Dealing with dependencies among the effects of relations for an actor

- 4.14 In some case, it is irrelevant to aggregate the relations' impacts because they are not commensurable, for instance whether positive impacts do not compensate negative ones due to the actor's risk aversion. In such cases, the actors' capabilities and satisfactions are defined as vectors of impacts, each component corresponding to the capability to reach one of the actor's goals.
- 4.15 Many other extensions of the meta-model could be defined, such that the shared control of a relation by several actors or the fact that the control of a relation can be exerted only in particular configurations.

Modeling a System of Organized Action

- 5.1 The meta-model presented in the previous sections is a tool that shapes models of organizations, so it needs a "user manual" to guide the production of the pieces of models. After an overview of a methodology for the design of such model, we provide pragmatic hints for dealing with common organizational patterns.

A Methodology for the Design of SocLab Models

- 5.2 The pieces of the model of an action system are the following:

1. the list of actors;
2. the list of relations with their controller actor;
3. the stake of actors on relations;
4. the interpretation of states of each relation in terms of behaviours of its controller actor,
5. the effect functions;
6. the constraints between relations;
7. the solidarity between actors.

- 5.3 The sociologist may elaborate a model in a purely analytical way, on the basis of his own understanding of the phenomena in play. However, most sociologists enjoin to underpin models on qualitative interviews purposing to catch the subjective representation of the actors and stakeholders of the phenomena under consideration. In that regard, the peculiarity of our meta-model is to require an amount of quantitative data on individuals. It falls neither within quantitative approaches, which are mainly based on the collection of statistics nor within qualitative approaches that produces discursive analysis of phenomena under consideration. Therefore it requires an appropriate methodology that ensures the practical feasibility of the integration between qualitative interviews and formal modelling and so the design of faithful models. So we will provide hints on a methodology to produce the above mentioned pieces of a model.
- 5.4 The first step is the identification of the relevant actors (1), that is the persons, individuals or collectives who take part to the system's activity and whose behaviour has a significant effect on the relevant properties of the system's functioning. The identification of actors goes hand in hand with the identification of resources mobilized in collective action, material and cognitive entities (data, knowledge, expertise, expectations, attitude, ...) which are handled by the actors in their actions and interactions; this provides the basis for (2). This exploratory step is common to all sociological review in the field and it has nothing specific.
- 5.5 Table 5 shows the form that can be used to collect the data needed for the characterisation of each relation (3), (4) and (5). Experiments tend to show that organization's members have no difficulty to provide answers that are clear and reliable enough to fill these forms (Adreit et al. 2011).
- 5.6 For each relation, the consistency of the answers on the one hand of the controller actor and on the other hand the dependent actors must be carefully checked, to ensure that there is no ambiguity on the substance of the relation. For the actors corresponding to a collective or population, a few individuals will be interviewed, as representative as possible of this group or population and their answers should be summarized into a single form. The construction of a consistent model most often leads

to a second interview with some people to clarify certain points. Notably, it can be necessary to come back to the controller of a relation after the interviews of the persons who depend on him. In the course of the investigation process, it can happen that an actor is not so influential as expected and can be put away from the model, while a person seemingly marginal reveals to play a significant role and must be considered as an actor in the model.

- 5.7 Questions 1 and 2 in Table 5 purpose to set the list of relations, who controls and who depends on each relation and thus to finalise (2). (Note that, to remain in the domain of the facts, it can be better to speak of 'resource' rather than 'relation' with the interviewee). Thanks to the knowledge of the organization acquired during the initialisation step and the previous interviews, the sociologist can help the interviewed person to clearly delineate the relation in question. The interviewer and the interviewee must be as clear as possible on what they are talking about.
- 5.8 Question 3 enables to determine the stakes of the interviewee on the relations he depends on (3). People are used to quantify the importance of something on a scale of 0 to 10 and this question is not difficult to answer. The values given are normalized so that their sum is equal to 10. This process ensures that the model reflects the relative importance of each relation for the actor (remember that the range of value of stakes is arbitrary, only the proportion between stakes matters).
- 5.9 Questions 4, 6 and 8 are intended to characterize the range of possible behaviors of the actor who controls the relation and therefore to calibrate the range of its state (4). According to SOA, actors exchange behaviours and the range of the controller actor's behaviors is what characterizes a relation. Therefore, the answers of all actors who depend on a relation (including the controller actor) need to be reconciled into a careful description of these behaviors.
- 5.10 The answers to questions 4, 6 and 8 describe respectively the behaviors associated with the values -10 (worst case), 10 (best case) and 0 (neutral case) of the relation's state. It may happen that good behaviors for some dependent actors are bad for others and conversely, because the actions of the controller actor have opposite effects on them. Then, the sociologist must align the good / bad appraisals into the most relevant orientation of the -10 ... 10 range of value. It will be up to the sociologist to make interpolations to associate a negative value of the state with an intermediate behavior between responses to questions 4 and 8 and a positive value with a behavior between responses to questions 4 and 8.
- 5.11 As for the answer to question 10, it is intended to position the actual configuration of the action system within this scale of value. Once again, for each relation a single (approximate) value is needed and the very nature of the relation should be reconsidered if the actors' answers are not compatible, unless specific explanations justify to dismiss divergent views. It is expected that this configuration will be compatible with the simulation results.
- 5.12 Questions 5, 7 and 9 are used to shape the effect functions (5) of the interviewed actor. They gives the y-coordinate value of the points of abscissa -10, 10 and 0 respectively. Thus, the sociologist has three points to define the effect function, and it is up to his understanding of the nature of the relation and the actor's sensitivity to complete the shape of the curve. The question 11 is intended to provide a fourth point on the curve, as an auxiliary data.
- 5.13 There is no systematic question about possible constraints between relations (6), because there is a huge variety of cases depending on the peculiarities of each concrete relation. Thus, generic questions would be quite abstract and difficult to understand by interviewees. Thanks to his knowledge of the whole system of action, the sociologist should be able to analyze the interferences between relations, to infer constraints to introduce into the model and to ask questions allowing to confirm his hypotheses.
- 5.14 The last question 12 is about the interviewed actor's solidarities, *i.e.* the other actors who matter to him whether he wants or he fears their success. Processing in the same way as for stakes, data can be collected by asking the person to quantify his degrees of commitment on a scale 0 to 10 for positive solidarity and a scale 0 to -10 for hostilities. Then these values are normalized by giving the actor a solidarity of 10 or 15 with himself.

Table 5: Form for the collection of the data needed to quantify a SocLab model

Interviewee: as model's actor:	Resources		
	A	B	C
1. What are the resources do you need to perform your tasks, to achieve your objectives ? What does matter for you?			
2. On who do you depend to access the resource, to use it according to your own need? Who controls the resource?	<actor name>	<actor name>	<actor name>
3. How much important is that resource for your own work (on a scale 0 ... 10)? What is the behavior of the person who controls the resource that would be:			
4. a- the worst case for you? describe this behavior			
5. assess the effect of this behavior on your capability to achieve your objectives (on a scale -10 ... 0)			

6. b- the best case for you? describe this behavior
 7. assess the effect (on a scale 0 ... 10)
 8. c- the neutral case, neither favourable or unfavourable? describe this behavior
 9. assess the effect (on a scale -10 ... +10)
 10. d- the behavior that you experience usually? describe this behavior
 11. assess the effect (on a scale -10 ... +10)
 12. Who does matter for you? actor XX:
 favorably (on a scale 0 ... 10) actor YY:
 adversely (on a scale -10 ... 0) . . .
-

Dealing with some organizational patterns

- 5.15 The metamodel SocLab as it is shown in Figure 3 is quite simple. This simplicity warrants the practical feasibility of designing understandable models but it could hamper the analyst to describe aspects of the organization that he wants to account and study. In fact, the primitive elements of this metamodel may be combined into higher level elements allowing to account for more specific organizational patterns. Let us give some examples.
- 5.16 One can have to deal with an actor who either is rather *marginal*, because he does not take an active part to the operating of the organization, or is less engaged in the game, because his social capital provides him valuable alternatives to being member of the organization so that he can limit his participation to the game. To express such a position of an actor in the model of an organization, one may introduce a relation whose he is the controller and the only one dependent actor, with an amount of stake in proportion with his level of retirement. Then, this actor will be less sensitive than others to variations in the organization's state, and thus less reactive. Another way to model this position, whether it is (explained as) due to the actor's temperament, is to provide him with a low level of *tenacity*, a psycho-cognitive trait of actors that will be introduced in the following section.
- 5.17 This issue is related to the *boundaries* of the system, which may be more or less fuzzy. This phenomenon is also taken into account by the relevance (*i.e.* the total amount of stakes) of the relations controlled by an actor: more the relevance of the relations controlled by an actor is low, more this actor is peripheral.
- 5.18 There exist alliances or actors' *coalitions* that play a significant role in the functioning of an organization and thus must be accounted. A 2-actors coalition is well described by a reciprocal solidarity between these actors. For a broader coalition, a first solution is to personify the coalition as a collective actor having his own means of action (the relations it controls) and objectives (the relations it depends on), while making the coalition members solidary with the coalition-actor in proportion to their dependency on the coalition success. This modelling assumes a tight coordination between the coalition members. Another solution is to model the coalition as a virtual actor who controls no relation, where each member is solidary with the coalition-actor in proportion to his involvement. This latter solution models a *de facto* coalition: the members share interests and behave accordingly, but they do not explicitly coordinate their behaviors. In both solutions, the cohesion of the coalition will be expressed by solidarity links from the coalition towards its members. Adjusting the levels of stakes and solidarities allows to model a wide variety of cases.
- 5.19 The SocLab model of an organization focuses on relationships inside the organization, not on the interactions between the organization and its *environment*. To take into account dependences of the organization with respect to its environment, the model can include relations that are not controlled by an organization's actor. These relations correspond to resources which are needed by the organization and provided by the environment. The state of these external relations is fixed since it is not under the control of the organization. The analyst determines their value and may vary them to test different hypotheses about the environment's behavior. Another possibility is to introduce the environment as an actor which controls and depends on relations but whose behavior is fixed (that is, $b_{min_r} = b_{max_r}$ for the relations it controls) Many social games may be viewed as *multi-scale nested games*, or systems of systems. At each level, the game involves its own actors, resources and stakes, and these games interact first by the fact that some actors take part to games staying at different levels second, by the fact that rules of the game at a given level are framed by the outcomes of the encompassing game and third, the outcomes of a game can have a retro-effect on the upper level. In the model of an organization, it is possible for any actor to correspond to a collective, in fact a sub-organization that can be "opened" and in turn modelled as an organization. So, it is possible to define a network of organizations that interact through actors that belong to several (sub-)organization and through relations that constraint another one or are controlled by an actor of one organization while the depending actors belong to one or several other organizations. The possibility to refine the description of an actor in the form of an organization, that is to recursively apply the modelling process, enables to catch a significant part of the complexity of the interplays between systems of organized action.



Simulation: Playing the Social Game

- 6.1 As we have seen in section 3.26, an organization defines a *social game*, where each actor adjusts the state of the relations he controls in order to obtain from others an acceptable level of "satisfaction". Doing so, he modifies the satisfaction of actors depending on the relations he controls, who in turn ... Actors are mutually dependent . When the game reaches a stationary state, the organization is in a regulated configuration: every actor gets an acceptable satisfaction and no longer needs to modify his behavior. The social game is nothing but a model of the regulation process by which the actors of social organizations stabilize, at least partly, their behaviors^[12].
- 6.2 To compute how an organization could be regularized, its socially plausible regulated configurations, we may conduct simulations of the social game. We just have to implement the model of the organization as a Multi-Agent System, where each actor is represented by an agent endowed with a rationality which enables him to play the social game in search of an acceptable satisfaction. We outline here the principles of the social game player algorithm implemented in the SocLab platform, many more details are presented in (El Gemayel et al. 2011, El Gemayel 2013 and Sibertin- Blanc et al. 2013a) ^[13].

The social actors' rationality

- 6.3 According to SOA, the behavior of social actors is strategic: each one seeks to get from others the highest level of satisfaction and to this end, he uses the resources he masters as action levers to influence the behavior of others. The relative stability of actors' behaviors stems from this characteristic. However, this behavior is exercised within the framework of a bounded rationality (Simon 1982): social actors are poorly aware of the structure and the current state of the game, have limited cognitive capacity, can not spend the time and energy required to find the best solution, have only a vague idea of the outcomes of each action, and look only for a "satisficing" level of satisfaction, which is not predetermined.
- 6.4 We do not rely actors' behaviors on an hypothetical formal theory of social games and assume that most social competences are acquired by experience. So, the algorithm is grounded upon the classic self-learning paradigm by trial-error and reinforcement (Sutton and Barto 1998). Under this approach, an individual experiences the reactions of the environment to the actions he undertakes in order to gradually learn what is the best behavior to reach the objective. To this end, each agent builds and updates a rule base that associate actions to situations (or cases). Each rule is of the form (situation, action, strength) where:
- *situation* is the vector of impacts perceived by the agent from each of the relations he depends on;
 - *action* is a vector of changes in the state of the relations controlled by the agent;
 - *force* is an evaluation of the effectiveness of the rule.
- 6.5 A rule is applicable when its component situation is "close", according to an Euclidean distance, to the agent's current situation. When no rule is applicable, for example at the beginning of the simulation, a new rule (current situation, random action, default force) is generated.
- 6.6 The game stabilizes when every actor-agent gains an acceptable level of satisfaction. To determine the acceptability threshold, each agent maintains an *ambition* variable (Selten 1998): a state of the organization is acceptable for an agent if its current level of satisfaction is greater than its ambition. The initial value of an agent's ambition is set to its highest possible satisfaction and, according to the reality principle, ambition decreases toward the actual level of satisfaction obtained by the agent.

The psycho-cognitive parameters of the algorithm

- 6.7 Three psycho-cognitive parameters are associated with each agent to account the actor's individual dispositions:
- The *tenacity* (between 1 and 10) determines his propensity to focus on the exploration of new configurations or on the exploitation of knowledge already acquired (March 1991);
 - The *discriminability* (between 1 and 5) determines his ability to discriminate situations, as the distance between the current situation and the situation component of a rule that makes it applicable or not; if it is set to 1, each rule is applicable in any case;
 - The *reactivity* (between 1 and 10) determines the relative weight of what the agent has already learned with regard to the information gained at the current step of the simulation.

The algorithm

- 6.8 The main variables of the algorithm are the ambition and the *exploration/exploitation rate* of each agent. The explore/exploit rate of an agent determines whether it searches to acquire knowledge about states of the organization which are quite remote from the current state or whether he rather intends to improve the knowledge he has already acquired.
- 6.9 A simulation runs until the satisfaction of every agent passes above its ambition. The main steps of the algorithm executed by each agent to select an action are as follows:
1. the agent perceives its situation and the resulting level of satisfaction;
 2. it updates its explore/exploit rate according to its tenacity, its reactivity and the gap between ambition and satisfaction^[14];
 3. it updates its ambition according to the explore/exploit rate and the gap between its satisfaction and ambition to bring

closer the two;

4. it updates the force of the last and penultimate rules applied, according to the gap between its current and previous satisfactions and the explore/exploit rate;
5. it searches in its rule base for applicable rules according to its discriminability. If any, it selects one of the stronger ones; else it creates a new rule according to the explore/exploit rate (more the agent explores, more the changes in the states of controlled relations are important).

Once every agent has made its choice (step 5), the selected actions are applied.

- 6.10 An essential property of this algorithm is that agents have very few knowledge neither about the structure nor the state of the game. They perceive the game just by the level of satisfaction that they obtain at each step and, if their discriminability is not too low, they distinguish whether two situations are equivalent or not. Doing so, this algorithm respects the opacity that prevails in relationships between social actors (David et al. 2002).
- 6.11 The configurations computed by this algorithm feature expected properties. Compared with the set of all configurations that an organization's structure makes possible, they appear to be close to Pareto optima, while the configurations featuring the biggest gaps between the agents' levels of satisfaction are discarded. To the extent that cooperation has not a too much detrimental effect on their own satisfaction, agents adopt a cooperative behavior. This corresponds to a common property of social organizations, whose efficiency and steadiness require the members' cooperation. In particular, more the cooperation is beneficial, i.e. more the gap between the best and the worst configurations is great, more the actors cooperate, i.e. more the computed configuration is close, in proportion, to the best ones. On the contrary, zero-sum organizations, where the sum of the actors' satisfactions is null for any configuration, do not motivate the cooperation. Since any gain of an agent is lost by another agent, such organization model do not ensure the convergence of the algorithm^[15].
- 6.12 The data analysis of simulation outputs are means to improve the interpretation of simulation results. For instance, the standard deviation and the number of steps of simulations are significant: a low standard deviation over a number of simulations indicates that the actors' behaviors are firmly constrained by the organization structure; the length of simulations indicates whether it is easy or difficult for the actors to discover collectively how to cooperate. The correlations between relations' states and between actors' satisfactions are also very instructive, as well as the shape of clusters among computed configurations (Villa-Vialaneix et al. 2014).
- 6.13 Another powerful means to get knowledge from simulation results is to compare the set of the configurations computed by simulation with the set of all the configurations that the structure of the organization makes possible. The relative position of the computed configurations within other noteworthy configurations is very meaningful.



The Analytical Study of an Organization

- 7.1 From the moment that the model of an organization includes more than four or five actors, it becomes difficult to understand the origin of the regulation that emerges from simulations, due to the complexity of the interactions among the actors that are framed by the stakes, the shape of effect functions, the solidarities and the constraints between relations.
- 7.2 The formal definition of organizations' models as algebraic structures (see Table 3) in 3.25 allows us to define tools for the analytical study of their internal properties (Axelrod 1997) and so to shed light on deep structural features.

The indexes

- 7.3 The algebraic structure of (the model of) an organization enables to define and compute the value of many mathematical expressions, called indexes, that turns out to be meaningful for the sociologist. Some of these indexes are *contextual*—their value is a function of the considered state of the organization—while other are *structural*—they are state-independent and bring information about the very structure of the organization. Moreover, one may consider *dyadic indexes* which relate two actors, one relation and one actor or two relations, and *monadic indexes* which bear on one actor, one relation or the whole organization. The scales of value of these indexes are arbitrary, so only comparisons make sense and they must be carefully interpreted in sociological terms. Most of them may also be computed in proportion within their range of value, typically as $(\text{value} - \text{minimum_value}) / (\text{maximum_value} - \text{minimum_value})$; such ratings are also informative and allow to compare indexes having different scales of value.
- 7.4 We give examples of such indexes regarding the actors' capability and power:
- 7.5 Dyadic contextual indexes associated with a state of the organization:
 - $\text{gap}(a, b, s) = \text{capability}(a, s) - \text{capability}(b, s)$;
 - $\text{relative_dependency}(a, b, s) = \text{power}(a, b, s) - \text{power}(b, a, s)$;
 - $\text{link}(a, b, s) = |\text{power}(a, b, s)| + |\text{power}(b, a, s)|$, how much the two actors are tied;
 - $\text{concession}(a, b, s) = \sum_r ; a \text{ controls } r \text{ AND } b \text{ depends on } r \text{ Max}_s \{ \text{impact}(r, a, s) \} - \text{impact}(r, a, s)$, the amount of capability that actor a abandons in his relations with actor b ;

- $benevolence(a, b, s) = \sum_r$, a controls r AND b depends on r $impact(r, b, s) - \text{Min}_s\{impact(r, b, s')\}$, the amount of capability that actor *a* freely gives to actor *b*;
- $transactional\ benefit(a, b, s) = benevolence(b, a, s) - concession(a, b, s)$, the capability balance of a's behavior with regard to *b* (Mailliard and Sibertin-Blanc 2010);
- $constraint(r, r', s) = 20 - (on_bmax_{r, r'}(s_r) - on_bmin_{r, r'}(s_r))$.

- 7.6 Dyadic structural indexes: each dyadic contextual index provides a structural index defined as the average (or any aggregate of the values), minimum or maximum values, the standard deviation or the amplitude of values over the state variable. The *strength* of a relation on an actor, defined as $strength(r, a) = \max_s\{impact(r, a, s)\} - \min_s\{impact(r, a, s)\}$, provides also a structural version of most contextual indexes, by substituting the impact of a relation on an actor by its strength. Solidarities between actors and constraints between relations are other indexes.
- 7.7 Monadic contextual indexes: every dyadic contextual index provides a monadic index associated with one of the terms by averaging, summing^[16] or aggregating in any way, maximizing or minimizing the values over the other term. The $autonomy(a, s) = power(a, a, s)$ is the amount of capability of an actor that depends on himself; $dependency(a, s) = capability(a, s) - autonomy(a, s)$ is the complement of autonomy.
- 7.8 Monadic structural indexes: monadic indexes may be deduced from the dyadic structural ones, in the same way that monadic contextual indexes are deduced from dyadic contextual ones. The *relevance* of a relation, is the sum of the stakes put on this relation.
- 7.9 Finally, *Global contextual or structural indexes*, bearing on the whole organization, can be derived from monadic indexes by averaging or aggregating the values over all the actors or relations^[17]. We do not elaborate on the sociological interpretation of this number of indexes, this would require a quite long discussion (Roggero 2008). The questions that arise when one investigate a specific aspect of a concrete organization are also very numerous and diverse, and each of these indexes is susceptible of shedding light on a facet of a specific question.

The Configuration Space of an Organization

- 7.11 Each configuration of the organization supplies a distribution of capabilities among the actors (and the same holds for power, satisfaction and influence). Since the relations' effects are continuous functions and the impacts on actors are aggregated by means of a continuous operator, the capability of an actor features the properties of a *scalar field* defined over the spaces of behaviors of the relations, and it may be represented as a "landscape" like in Figure 5 (Chapron 2012). The same holds for the aggregation by a continuous operator of the landscapes of a group or of all the actors of the organization.

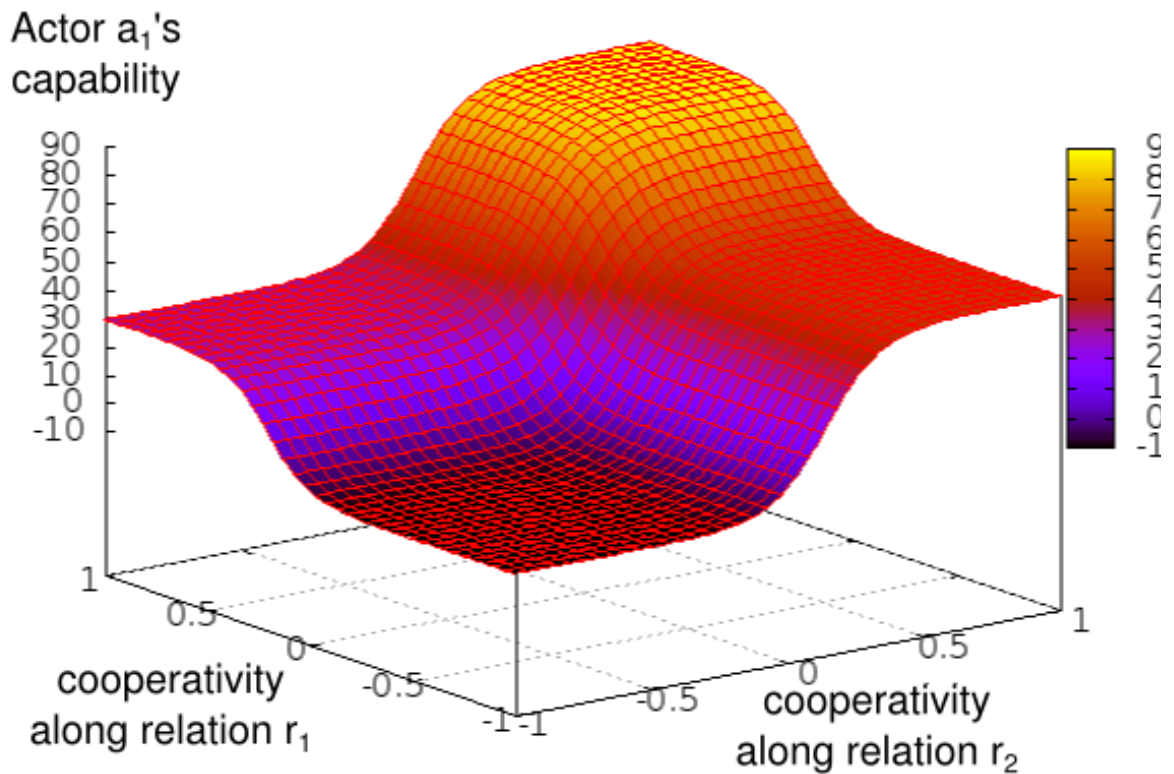


Figure 5. Projection of the landscape of actor a1's capability on relations r1 and r2

7.12 Standard mathematical tools may be used to compute properties of landscapes such as (Chapron 2012):

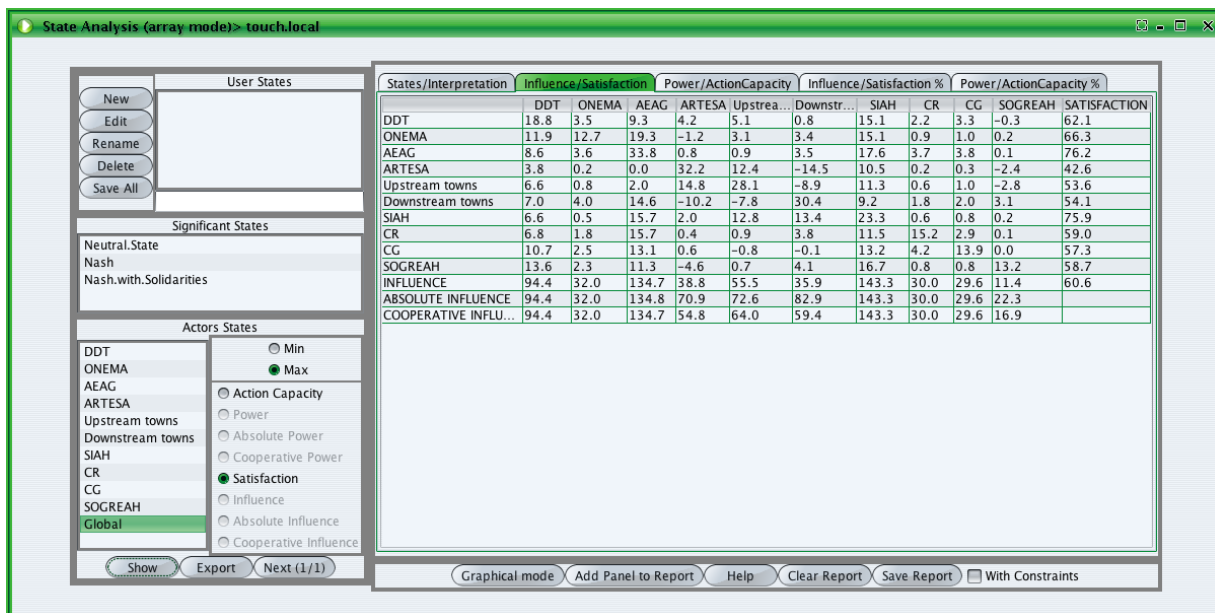
- the gradient of a landscape, and thus its optima, minima and saddle points;
- the scalar product of the gradient vectors of two landscapes (of two actors, two groups of actors or one actor versus a group), considering or not the components corresponding to controlled relations;
- the topography of a landscape, that is the shape, the size and the distribution of hills and depressions (the area providing a capability that is higher or lower than a given threshold);
- a measure of the (dis)similarity between two landscapes, either at some configuration or considering the whole landscapes.

7.13 The systematic exploration of the (finite) state space of an organization also allows to identify configurations that feature noteworthy properties as well as the fulfillment of structural properties of the organization as a whole:

- the configurations that *maximize* or *minimize* the capability of a given actor or of a group of actors, and the configurations that are favorable (or not) to the whole organization;
- the configurations that correspond to *Pareto optima* or to *Nash equilibria*, that maximize or minimize the standard deviation, the median, highest or lowest capability;
- *structural conflicts* between actors having opposite landscapes or in local conflict at a configuration where the scalar product of their gradients is negative: what is good for one of them is bad for the other and reciprocally;
- conversely, *similarity of interests* between actors, and actors that could, for various reasons, take advantage to constitute a *coalition* (by an additional coordination of their behaviors);
- *instability* of a configuration if components of the gradient of a landscape have a high value: any accidental change in the state of the corresponding relations can give rise to a significant reaction of the actor and then provoke the change of all actors' behaviors in a chain reaction;
- *cooperativeness* of the organization in the case there is at least one quite large and central (*i.e.* easy to find) area of the space of configurations that provides to most of the influential actors a substantial benefit to cooperate;
- *variety* of the organization, in the case there are several such areas or smaller areas which are close to each other.

7.14 Another way to investigate the structure of an organization is to consider networks of actors, or of actors and relations, whose node are labelled monadic indexes and edge by dyadic indexes. They can be studied thanks to the numerous tools developed in the framework of the social networks analysis (Jackson 2008), for example to reveal the centrality or the specificity of an actor (Chapron et al. 2011).

- 7.15 The results of such studies shed light on macro properties of the structure of an organization that could on the one hand formally explain why an actor is empirically observed to behave as he does and improve the understanding of the regulated configuration computed by simulation. On the other hand, since the organization is a social construct, actors try to make it to evolve, as much as they hope to get some advantage from this evolution. These structural properties give insights into the direction of the macro-level changes that an actor could be tempted to undertake in order to improve or strengthen his position.
- 7.16 The *SocLab* platform allows the user to get the value of many of the above-mentioned indexes. It also allows to know which are configurations featuring a noteworthy property and to interactively explore the organization's space of configurations; each configuration is detailed by giving the states of the relations and the amount (in value and in proportion) of capability and satisfaction given by each actor to each other by means of the controlled relations or the solidarities. As an example, Figure 6 displays data about the configuration that maximizes the sum of all actors' satisfactions (in the case of this model, there is only one such configuration, and it is nearly the same which maximizes the sum of actors' capabilities).



(a) the array mode



(b) the graphical mode

Figure 6. The window of the SocLab platform that allows the user, in the left hand part, to select a configuration of the organization model while the right part displays data about that configuration. The array mode (a) shows the detail of the values of actors' satisfaction (in row) and influence (in column) in value or in proportion; the graphical mode (b) uses histograms to represent the values.

Analysis of the Case

- 8.1 We present the results of 100 simulation runs of the model of the basin Touch action system with the same medium values of psycho-cognitive parameters for all actors: 2 for discriminability, 5 for tenacity and reactivity. A sensitivity analysis of the tenacity

and reactivity parameters provides similar results.

Simulation results

- 8.2 In average, simulations converge, *i.e.* a stationary state is reached, in 5434 steps. Table 6 shows that standard deviations are quite low in comparison with other organizations, regarding the fact that the range of the actors' satisfactions—that is the difference between the maximum and the minimum satisfactions of each actor, as shown in table 8—is 130 in average. This may be interpreted as a strong regulation of the system of action, actors being quite firm in their respective positions.
- 8.3 Table 7 shows the distribution of capability at the convergence state. In columns, the impact of each actor on all others due to the relation he controls with, at the last row, his power as the sum of his impacts on others. In rows, the amount of capability gained by each actor from others, accounting for his stakes and solidarities. The two last columns show the resulting satisfaction in value and in proportion with regard to his maximum satisfaction. The mean value of actors' satisfaction is 53.
- 8.4 Table 8 is a view of a structural property of the action system. It allows to compare the configurations of the system that are the best and the worst for each actor and for the whole system. For instance, among the maximum satisfactions, one corresponding to downstream town (providing him satisfaction 110) is the lowest for the whole system (providing a global satisfaction 405), while the best configuration for SIAH (providing him satisfaction 71) is the highest for the whole system (providing a global satisfaction 560). Regarding the configurations of minimum satisfactions, they are the same for AEAG and Regional council, as for SIAH and the whole system.

Table 6: The *convergence state*, defined as the average values of the relations states at the ends of 100 runs, with the standard deviation of relations and of the satisfaction of the actor that controls this relation

	average value	standard deviation	standard deviation of the controller actor's satisfaction
Validation	9.98	0.1	1.6
Expertise	4.7	4.0	1.7
Funding	6.79	1.5	1.1
Lobbying	9.33	0.6	0.7
Control of flow	7.7	0.5	3.0
Self funding	6.36	1.6	4.0
River management	4.94	1.1	2.5
Add. funding CR	6.53	1.6	2.1
Add. funding DR	6.66	1.5	1.3
Studies	5.29	3.7	3.0

Table 7: The impact of each actor (in column) on others (in rows) at the convergence state with, in the last column and rows, the resulting satisfactions and powers; the *cooperative power* (last line) considers only positive impacts.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Satisfaction	Percentage of maximum satisfaction
	DDT	ONEMA	AEAG	Riparian Farmers	Upstream towns	Downstr. towns	SIAH	Regional Council	Depart. Council	Engin. Firm		
DDT	18.8	2.5	8.6	4.3	3.9	-0.6	14.7	1.8	3.3	-0.3	57.0	94.0%
ONEMA	11.9	12.0	19.2	-1.5	-6.1	2.0	14.6	0.9	1.0	0.1	54.1	84.6%
AEAG	8.6	3.3	33.7	0.2	-8.9	2.7	17.1	3.6	3.8	0.1	64.2	86.8%
Riparian Farmers	4.1	0.1	2.9	33.3	19.1	-14.3	12.2	0.1	0.3	-2.3	55.7	82.6%
Upstream towns	6.6	0.5	1.8	15.2	33.2	-17.1	11.0	0.5	1.0	-2.7	49.9	81.6%
Downstream towns	7.0	3.7	14.5	-11.2	-24.8	31.3	9.7	1.8	2.0	2.8	36.8	60.5%
SIAH	6.6	0.3	15.6	1.8	0.1	9.7	21.4	0.5	0.8	0.2	57.0	89.6%
Regional Council	6.8	1.7	14.4	0.3	-2.7	4.0	11.1	15.0	2.9	0.1	53.6	93.1%
Departmental	10.7	2.4	12.8	0.4	-2.9	-0.4	13.1	4.4	13.8	0.0	54.2	89.2%

Council																			
Engineering Firm	13.6	2.2	11.3	-5.0	-7.3	3.9	16.0	0.8	0.8	11.6	47.8	76.3%							
Power	94.7	28.6	134.8	73.0	109.0	86.2	141.0	29.4	29.5	20.2									
Coop. power	94.7	28.6	134.8	55.4	56.4	53.7	141.0	29.4	29.5	14.9									

Table 8. In columns, the configurations corresponding to the maximum and the minimum satisfaction of each actor and of the whole (i.e. the sum of actors' satisfactions); in the rows, the state of relations and the satisfactions of actors.

	Maximum satisfaction states										Minimum satisfaction states								
	Global satisfaction	1. DDT	2. ONEMA	3. AEAG	4. Riparian farmers	5. Upstream towns	6. Downstream towns	7. SIAH	8. Regional Council	9. Depart. Council	10. Engineering Firm	Global satisfaction	1. DDT	2. ONEMA	3. AEAG	4. Riparian farmers	5. Upstream towns	6. Downstream towns	7. SIAH
Validation	10	10	10	10	10	10	10	10	10	10	-10	-10	-10	-10	-10	-10	-10	-10	-10
Expertise	8	8	8	8	8	8	8	8	8	8	-8	-8	-8	-8	-8	-8	-8	-8	-8
Funding	8	8	8	8	8	8	8	8	8	7	-8	-8	-8	-8	-8	-8	-8	-8	-8
Lobbying	8	9	-6	1	9	9	-10	3	2	4	-10	-10	10	-10	-10	-10	-10	10	-10
Control flow	3	5	-2	-5	8	8	-8	2	-3	-8	-8	-8	8	8	-8	-8	8	8	-8
Self funding	2	-4	2	3	-5	-8	8	3	6	-8	-8	8	-8	-8	8	8	8	-8	-8
River management funding CR	5	5	6	8	6	2	4	5	8	8	-8	-8	-8	-8	-8	8	7	-8	
funding DR	8	8	8	8	8	8	8	8	5	3	-8	-8	-8	-8	-8	-8	-8	-8	
Studies	8	4	4	4	4	4	4	4	8	8	-8	-8	-8	-8	-8	-8	-8	-8	
DDT	60	63	48	48	62	59	40	57	50	48	41	-39	-41	-20	-29	-41	-29	-8	-39
ONEMA	63	59	68	67	53	48	64	66	67	61	68	-12	-10	-23	-21	-9	7	-7	-12
AEAG	74	68	80	83	62	56	74	77	82	76	78	-43	-39	-54	-57	-39	-18	-33	-43
Rip. farmers	51	77	-24	-5	84	81	-52	24	-1	26	-45	-54	-80	54	-14	-81	-68	66	-54
Up. towns	43	72	-25	-32	76	80	-49	27	-26	-5	-53	-51	-78	50	16	-78	-83	49	-51
Down towns	44	-4	71	77	-27	-16	110	60	73	29	87	5	56	-68	-45	58	51	-75	5
SIAH	70	59	62	56	47	34	37	71	59	26	55	-62	-49	-45	-49	-49	-12	-8	-62
CR	58	52	58	60	49	45	57	59	61	52	56	-44	-37	-46	-47	-37	-22	-32	-44
CG	57	56	58	61	55	53	57	56	61	64	55	-18	-19	-22	-24	-19	-7	-11	-18
Eng. firm	58	51	73	75	38	26	68	62	74	56	79	-31	-25	-52	-44	-16	26	-12	-31
GLOBAL	579	554	468	490	500	466	405	560	499	434	420	-347	-322	-227	-312	-311	-157	-72	-347

Interpretation of results

8.5 The analysis of the simulation results allows us to examine, in terms of power relationships, the hypotheses about the action system of basin Touch derived from the results gained by the Actor-Network and Territorial Public Interest theories (Cf. 2.15). The first three hypotheses are clearly confirmed, while the fourth is not. The convergence state is interpreted as a regularized configuration and, on the whole, it matches the one observed by the field investigation^[18].

8.6 *Hypothesis 1: To be the "obligatory passage point" of the Actor-Network, is that SIAH has enough power to somehow constrain other actors?*

The results in table 7 show that SIAH is the actor having the highest level of power (141) at the convergence configuration, with a significant gap - except with AEAG (the Water Agency). Moreover, this high level of power is purely cooperative: SIAH is in conflict with no actor in the system. SIAH is the one who gives others the more capability for action. It therefore appears to be the "obligatory passage point" for the proper functioning of the system, since he is the one who gives them the means to cooperate. Another element, structural, tends to confirm this central position of SIAH: the configurations that maximize and minimize the system's whole satisfaction, i.e. the sum of all actors' satisfactions (see table 8). The configuration that provides SIAH with the highest satisfaction (71) is very close to the one that maximizes the system's whole satisfaction (579). In other words, the more SIAH has the means to achieve his goals, the more all actors do. The same holds in the opposite: the configuration that minimizes the SIAH's satisfaction (-62) also minimizes the system's whole satisfaction (-347). The SIAH appears as embodying the "Territorial public interest" of basin Touch—the action system works properly if and only if the SIAH has the means to be

active.

8.7 *Hypothesis 2: Purposing to play an important role and to introduce a change in the management of flood risk, is that SIAH has the means to do so?*

This is to examine the state of the relationship controlled by SIAH, which is 4.9 in average. Recall that negative values represent situations where SIAH does not act as he wishes with respect to flood risk management. They produce a negative capability for himself. In contrast, positive values are associated with positive and increasing capability and reflect situations where SIAH may more and more act in the way he wants, that is to say promote an hydromorphology which includes risk prevention. Value 4.9 corresponds to a situation where SIAH exerts his action in the direction he wants and, being an "obligatory passage point", he incites the whole system of action to go in this direction. However, not as much as it could be possible. He is limited by the interplay of actors and regulatory constraints, particularly because it is the DDT which investigates and appraises cases of FRPP and continues to apply a rigid regulatory framework taking little account of local actors. This limitation is the price to pay for his strategy whose consensual nature is necessary for the enrolment of other actors. The resulting configuration of the action system provides SIAH with a satisfaction of 57, corresponding to 89 % of his maximum satisfaction, which is quite convenient.

8.8 *Hypothesis 3: In the enrolment of other actors on the service of an hydromorphological management of the river, is that SIAH has powerful allies?*

One can answer in the affirmative: SIAH has a powerful ally in AEAG. On the one hand, AEAG is the most powerful actor after SIAH (134.8). On the other hand, the strong contribution of AEAG to the satisfaction of SIAH (15.6), and, conversely, the important contribution of SIAH to the satisfaction of AEAG (17.1) demonstrate the existence of an alliance between the two organizations. Moreover, the study of correlations over the 100 runs shows that the satisfactions of SIAH and AEAG are highly correlated at 0.814. This alliance is certainly important for SIAH, since he is funded by AEAG. But it is also fully convenient for AEAG: the high state of the relation he controls (6.8) shows that he pursues the action he wishes; the resulting configuration provides him with the highest level of satisfaction of the action system, 64.2. Undoubtedly, AEAG firmly contributes to the enrolment of others led by SIAH.

8.9 *Hypothesis 4: Is that the agreement on the " Territorial Public Interest " is confirmed by the absence of major conflict in the system of action?*

The results show the persistence of a conflict between the upstream and downstream towns. The relative agreement on an hydromorphological management of the river fails to resolve the conflict between their respective interests. This conflict is reflected by the negative contribution that the first offers to the satisfaction of the seconds (-24.8) and vice versa (-17.1). The two types of communes adopt strategies that remain antagonistic despite the action of SIAH. This conflict is to the detriment of downstream towns. He is the less satisfied actor (36.8) at a level that is significantly below average. He is also the actor that exploits the less his possibilities (60.8%) while all others manage to gain more than 80% of their maximum satisfaction. One explanation of this failure could be that, in fact, downstream towns is in structural conflict with the whole system of action: table 8 shows that his highest satisfaction (110) is the lowest (among the maximum satisfactions) for the whole system (405) and his lowest satisfaction (-75) is the highest for the whole system (-72). He should change his strategy to succeeds in negotiating the value of his financial support. However, the configuration corresponding to the maximal global satisfaction shows that there exists a compromise, but it is not accepted by Riparian farmers and upstream towns, whose satisfactions would decrease from 55.7 to 51 and 49.9 to 43 respectively.



Conclusion

9.1 This paper does not primarily present an agent-based model and simulation results about a particular case or phenomenon. According to the taxonomy of Boero and Squazzoni (2005: 3), the metamodel presented in section 3 and 4 falls in the scope of "typification", that is researches which "are intended to investigate some theoretical properties" of "a specific class of empirical phenomena that share some idealised properties" and are the object domain of a social science theory. So, we have presented a class of models which is defined, by intention, by the constitutive elements and relationships of these models, as shown in table 1. Staying at a higher level of abstraction than the level of particular models, it is then possible to develop mathematical tools, like the ones introduced in section 7, whose definition relies on the common structure of models and which may be applied to each model. These tools allow to significantly improve the interpretation of the simulation results and, quite often, as for the case studied in section 8, they bring a deeper explanation for the phenomena that emerge from simulations. Moreover, they allow to compare results and so to produce knowledge that are not just restricted to a particular case but are generalizable to the entire class of models (Boero and Squazzoni 2005).

9.2 The SocLab framework is a matter for sociology, not for management sciences. It does not address issues related to the performance of an organization, its operational efficiency or effectiveness, or the contingent relevance of its structure with regard to its environment and goals. In this, it differs, among many others, from management-oriented models such as PCANS (Krackhardt and Carley 1998), ORA (Carley et al. 2011) and the 28 models examined by Ashworth and Carley (2007), from organization-based models for multi-agents systems such as MOISE (Hubner et al. 2002; Gâteau et al. 2005), OPERA (Dignum and Weigand 2003; Penserini et al. 2009), ISLANDER (Esteva et al. 2001) and DEPINT (Sichman 1998), or from logic-based models of power relationships (Castelfranchi 2003; 2011). All these models reduce more or less the members of an organization to the strict fulfillment of roles assigned to them by the rules of the organization. They do not pay much attention to the nature of human beings which, as stressed by (Ashworth and Carley 2007), are the core of organizations while their behaviors feature "a

seeming defiance of theoretical conformity".

- 9.3 This framework just addresses the social dimension of organizations, assuming that it deserves to be considered for itself and that it is an essential (if not the main) determinant of the proper functioning of any organization. To this end, it considers the instrumental use of roles, whether defined by the organization or introduced by the actor who seizes it, which are handled by actors as both opportunities and constraints for the achievement of their own aims and the recognition of themselves by others. So, SocLab models are focused on power relationships which stay at the heart of the dynamics of collective action systems^[19]. This framework includes analytical tools enabling to objectivize the relative position of each actor in the current configuration of the organization and to unveil the potentialities of other possible configurations. Thanks to a model of the social actor's rationality, mostly interested by the achievement of his aims but suffering from cognitive and awareness limitations, the simulation enables to compute how an organization could be regulated.
- 9.4 We have presented a model of an actor system concerned by the definition and the implementation of the management policy of a small river in SW France. In the context of first an increase within the whole society of concerns for ecological issues and perspectives and second the socio-economic problems raised by the frequent floods of the river, the research question for the sociologist is whether there is an evolution in the principles of the river's management policy, who could promote this evolution and whether there is a shared agreement on these new principles. These interrogations led to state four hypotheses which are translated into technical questions for the model. To the extent that, at the building of the model, the translation from the sociological analysis of the organization into the SocLab model is well documented and substantiated, the findings resulting from the analysis of simulation results and properties of the model are easily translated back in the terms of the organization under consideration. For space limitation, it was not possible to document the proposed SocLab model, *i.e.* to document the relations between the field observations and the model constituents. However, we have shown how to argue that the first three hypotheses to be checked are clearly confirmed, while the fourth is not.
- 9.5 The main domain of application of the SocLab framework could be the assessment of the social dimension of public policies. There is a growing demand for regulatory impact assessment, see e.g. (European Commission 2005), including the social dimension which, in practice, is coped with great difficulty. Indeed, the discursive statement of the results provided by most sociological analyses does not feature the properties of quantitative scientific knowledge, so that they are difficult to compare and integrate with results provided by economics and environmental sciences. The quantitative results provided by SocLab makes this integration possible, as experienced in the Life European project *Concert'Eau* (Adreit et al. 2011).
- 9.6 We believe that this framework is also relevant for integrated assessment (Toth and Hizsnyik 1998) and companion modeling processes (Becu et al. 2003), where scientists and/or stakeholders have a collective interest in establishing a shared representation of the state of affairs. In this context, each actor will have the possibility to express his own view in a formal way, which includes no ambiguity and can be discussed by others; the agreed and problematic points can be clearly identified. Then, SocLab can be used to shed light on the causes of dysfunctions and to investigate the impact of new distributions of resources among the actors. The SocLab environment may also be used to undertake practical experiments in a teaching or theoretical context (Roggero 2008). As for well-circumscribed concrete organizations, their formal study entails an exposure of the power relationships, what enterprises, associations or institution do wish only in specific circumstances.



Notes

¹ <http://soclabproject.wordpress.com>

² Morgan addresses different aspects of the organization through the eight following images: organizations as organisms, as machines, as political systems, as psychic prison, as flux and transformation, as culture, as brain and as instruments of domination.

³ According to SOA, ZUs are grounded upon: specific competence or expertise; the control of interactions with the environment of the organization; the control of the internal communication; and the knowledge and proper use of the organization formal rules.

⁴ The power of an individual or a group, a social actor, is "a function of the size of the zone of uncertainty that the unpredictability of the actor's conduct enables him to control vis-a-vis his partners" (Crozier and Friedberg 1980: 34).

⁵ Literally "Syndicat Intercommunal d'Aménagement Hydraulique" of the Touch river. It is entrusted by the State with the maintenance of the river for the sake of the riparian proprietors, which own the bank and the bed of the river. It is funded by the Water Agency. See <http://www.siah-du-touch.org> for more details.

⁶ Actors are endowed with a *situated rationality*, as Friedberg qualified it (Friedberg 1997). This was to highlight the limitations raised by Simon, and to link the rationality to the context of action.

⁷ This scale is also arbitrary; but this is not an issue, since results of analysis and simulation only make sense in comparison one to another or as a rate (the position of its actual value within its range).

⁸ It is also relevant to consider the *cooperative_power* (i.e. the sum of the positive impacts) and the *uncooperative_power* (i.e. the sum of the negative impacts) of an actor.

⁹ One can also impose the constraint $\sum_{b \in A} \text{solidarity}(a, b) = 1$ to keep the same range of value for all actors' satisfactions, or other constraints such as $\sum_{b \in A} |\text{solidarity}(a, b)| = 1$. To clarify the sociological interpretation of each case would require a long discussion. The default value is $\text{solidarity}(a, b) = 1$ if $a = b$, 0 else.

¹⁰ The default values are $b_{min_r} = -10$ and $b_{max_r} = 10$.

¹¹ The default values are $on_bmin_r_r(s_r) = -10$ and $on_bmax_r_r(s_r) = 10$.

¹² This stability is required for the anticipation of others' actions, and thus for coordination.

¹³(Sandri and Sibertin-Blanc 2007) also shows how the rationality of social actors can be modeled within a fuzzy framework.

¹⁴ When the gap between the ambition and the satisfaction of the agent decreases, the explore/exploit rate moves toward more exploitation, in order to improve the possibility for the satisfaction to overtake the ambition. This bias favors the convergence of simulations, i.e. the fact that the satisfaction of each agent becomes greater than his ambition. This property of the algorithm models the fact that each actor who is a member of an organization has some interest in the prolongation of his membership, therefore the prolongation of the organization, and thus its regulation.

¹⁵ Concrete social organizations are not zero-sum games: the *raison d'être* of any organization is to improve the collective capability of its members.

¹⁶ Concerning the power of an actor, one may include or not the power he exerts on himself.

¹⁷ Once again, there are many ways to aggregate monadic or diadic indexes, according to the conception of social or organizational welfare (Arrow et al. 2002).

¹⁸ In case the convergence states of simulation runs are quite dispersed, we will consider that the organization is weakly regulated and seems feature some anomy. In case the convergence states of simulation runs feature several modes, or clusters which can be highlighted by a Hierarchical Ascending Classification or a Principal Component Analysis, one could be expected that one of these modes corresponds to the observed configuration, while the others are potentialities of the organization that are not actualized but could become so (Villa-Vialaneix et al. 2014).

¹⁹ This paper is not the place to discuss the concept of power, which is the subject of a considerable literature; we just notice that, despite appearances, the contemporary evolution of the forms of authority does not decrease its importance (Courpasson et al. 2012).



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