BOUNDARY ORGANIZATIONS: AN EFFICIENT STRUCTURE FOR MANAGING KNOWLEDGE IN DECISION-MAKING UNDER UNCERTAINTY

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Abstract

Modern environmental issues imply that decision-makers take into account opinions from experts of different spheres. Boundary organizations are institutions able to cross the gap between different areas of expertise and to act beyond the boundaries while remaining accountable to each side: by encouraging a flow of useful information, they permit an exchange to take place while maintaining the authority of each side, in order to provide a better knowledge and understanding of a situation characterized by uncertainty. Though never formally proved, this hypothesis is widely accepted based on the observation of existing boundary organizations. Through a multi-agent simulation, it is possible to assess their impact on the diffusion of opinions among experts. This virtual interaction of heterogeneous agents based on a model of continuous opinion dynamics over two dimensions, shows that boundary organizations have a significant quantitative impact on the diversity of opinions expressed and the number of experts agreeing to each emerging position.

Key words: boundary organization, opinion, knowledge diffusion, multi-agent system

Modern environmental issues, characterized by uncertainty and complexity, imply that decision-makers consider information from various disciplines as the necessary knowledge is held by experts from different spheres. Traditional decision-making processes provide independent advice from experts of each field, but opinions may be difficult to put in perspective together, or even conflicting. Yet, decision-makers rely on their capacity to realize this confrontation. In order to ease and improve this aspect of the decision-making process, boundary organizations have been designed to manage the meeting of distinct areas of expertise and to encourage the production of knowledge through their confrontation. By initiating and framing debates between experts, they provide decision-makers with a panel of opinions that integrate the interactions between the various dimensions of the issue. The hypothesis is that this eased and increased interaction facilitates the emergence of dominant opinions. Though never formally proved, it is widely accepted based on the observation of existing boundary organizations. Through a multi-agent simulation, we can assess the impact of a boundary organization on the diffusion of opinions among experts of similar and different fields, both quantitatively (the number of dominant opinions and of experts who agree to each) and temporally (the time necessary to observe dominant opinions).

Scientific knowledge is essential to a sound decision-making process, but science is more than a simple reservoir of knowledge, competencies and people: it includes normative

concepts such as objectivity, honesty, neutrality and truth that give it a privileged status (Guston et al., 2000). Yet the vision of a neutral science without influence is an illusion: scientific activities are conditioned by human values and intertwined with the main political, social and economic issues. Science must take into account the values of the society in which it takes place, and acknowledge its responsibility toward the society. The use of scientific knowledge in the elaboration of public policy results usually in hybrid entities, mixing facts and values, knowledge and identity, nature and culture, science and politics in institutions and social networks. Organizations should manipulate information legitimately and objectively without ignoring the subjectivity of science. Science includes in reality sciences, as it covers not only different areas of expertise, but also different approaches such as natural and social sciences. Decision-makers must include all the aspects of science involved in the debate while preserving its integrity: this leads to deconstruction and public controversy which may weaken science yet reveal tacit assumptions and hidden values of science, increasing the transparency of the process and avoiding further controversy (Guston et al., 2000). It should therefore be encouraged and managed to avoid impacting the credibility of science while using efficiently its knowledge: boundary organizations ensure that science brings in pertinent and useful information while maintaining its independence. This implies the ability to cross the boundaries between different areas and types of sciences.

The concept of boundary has been formalized by sciences in order to strengthen their differences with pseudo-sciences and scientific impostures. Boundaries were created to protect organizations from the outside and to maintain an internal order, as well as to impose the organization as a major actor (Davenport & Leitch, 2005). They allowed members to affirm their authority as experts over a field challenged by others, to maintain a monopoly by excluding others, and to enforce their cohesion while protecting their autonomy in front of pressures for control. A boundary is not a simple demarcation line that sets an established limit between two different areas of authority, but an intermediary zone of variable size, permanently challenged. It sets at the same time an area of permission and of restriction. While it plays its role to protect an organization from the outside, it also sets a barrier that limits or prevents flows of information with the outside. When two fields, under the authority of different experts, are involved and brought to interact over an issue, they naturally reinforce their boundaries, in order to avoid confusion and to clarify the responsibility of each. This reinforcement of the boundaries results in a lack of communication between experts of different aspects. Boundary organizations have been designed to manage the meeting of distinct areas of expertise and to encourage the production of knowledge through communication.

Boundary organizations are institutions that cross the gap between different fields of expertise: they are able to act beyond the boundaries while remaining accountable to each side (Guston, 2001). They encourage and manage a blurring of the boundaries to provide a better knowledge and understanding of a situation characterized by

uncertainty. By promoting a flow of useful information, they permit an exchange to take place, while maintaining the authority of experts (Cash et al., 2003; Clark et al., 2002). They integrate the demarcation to allow for communication instead of division, leading to cooperation around common interests (Davenport & Leitch, 2005).

Boundary organizations have been created to allow for the internalization of debates between scientists, while keeping an image of a pure and unified science. They have evolved to handle the relationships between science and political power, where they have proved their interest. Miller defines them as "organizations that sit in the territory between science and politics, serving as a bridge or an interface between scientific research, political decision and public action" (Miller, 2000), and Guston as "institutions that internalize the provisional and ambiguous character of the apparent boundary between science and politics" (Guston, 2000). A boundary organization allows for science to take part in a societal debate while preserving its integrity and independence (Davenport & Leitch, 2005): its participation is managed to avoid impacting its credibility while ensuring an efficient use of its knowledge. Jasanoff showed that a blurry boundary between science and politics, rather than the clear and intentional demarcation traditionally applied, could increase the productivity of the decision making process (Jasanoff, 1990). Boundary organizations may be applied to numerous cases of boundaries: between science and non-science, good science and bad science, as initially done, between science and politics, as currently done, but also between different fields or types of sciences such as natural and social sciences as modern environmental issues may benefit from.

Boundary organizations are similar to an interface between two dimensions, established and influenced by both sides, but independent. It allows for each side to express its reactions to the other's expectations, avoiding the traditional one-way flow or lack of communication. This capacity is unique to the boundary organization and this role could not be held by individuals of either side (Davenport & Leitch, 2005). To ensure the participation of actors from two socially different worlds, it is critical for boundary organizations to cross the functional and cultural boundaries. They in fact apply the principal-agent principle which defines organizational relations as delegations of authority toward agents by a principal who does not have the necessary information and/or competencies (Atkinson-Grosjean, 2007). Efficient boundary organizations are those that can answer to two different principals, while remaining stable despite external pressures and an internal instability of the boundary. Boundary organizations appear to face a reductive double set of constraints, but the different groups of experts, seen as distinct social organizations, are more similar than it seems, at least in their structure and behavior. In addition, the wider the zone between the respective boundaries, the greater the autonomy and the capacity for innovation (Miller, 2000). The double responsibility makes boundary organizations stronger, giving them a unique support that guarantees their impartiality (Guston et al., 2000): this dependence of boundary organizations on each side is as important as their independence (Guston, 2001). Boundary organizations are not fighting

against a strong solid demarcation, but helping to stabilize or even create the boundary. They do not limit themselves to the zone between two areas, but extend inside each side, widening the boundary zone to internalize the possible areas of ambiguity and to handle on-going fluctuations. The boundary is permanently defined, criticized, challenged, defended and adjusted. The goal is to involve both sides in the construction of a boundary favorable to each perspective, while setting the limits to potential intrusions of one sphere into the other: the boundary organization must encourage interactions by increasing the permeability of the separation, while guaranteeing the integrity of each side by limiting the porosity (Socci, 2001). The blurring of the boundary is beneficial, but no one can actually determine the optimal level, and especially what may be more destructive than constructive (Guston et al., 2000).

Boundary organizations are not a new concept, but modern successful applications, such as the Health Effects Institute, the Office of Technological Assessment, the Agricultural Extension or the International Research Institute for Climate Prediction, demonstrate the diversity and interest of such institutions (Guston et al., 2000). Boundary organizations result in a structure able to integrate information from two different dimensions into one single analysis. Decision-making with respect to technological choices that enhance the well-being of society by modifying the man-environment relationship, associated with risk and uncertainty, requires considering norms and practices from natural sciences and economics. Boundary organizations appear as an interesting solution to integrate the different aspects of environmental issues, and it has been suggested as a possible evolution of existing organizations, such as the European Environment Agency (Scott, 2000).

The hypothesis that supports the existence of boundary organizations is that the resulting eased and increased interaction facilitates the attainment of dominant opinions among experts of different fields. Though never formally proved, this is accepted based on the observation of existing boundary organizations (Guston et al., 2000). Through a multi-agent simulation, we can assess the impact of a boundary organization on the diffusion of opinions and final positioning of experts of different fields, both quantitatively and temporally. The methodology is based on simulations where agents positioned on a continuous model of opinion over two dimensions interact and modify their positions through series of one-to-one discussions; once the system is stabilized, we observe the number of opinions expressed, the ratio of experts agreeing to each opinion and the number of exchanges necessary to reach this distribution. A boundary organization of increasing importance is simulated to see the impact on those three indicators.

The model relies on a Multi-Agent System (MAS), a computer simulation where autonomous heterogeneous agents interact with their environment and with each other. MAS allow us to observe an emerging recurrent macroscopic behavior resulting from microscopic interactions that could not be deduced by simply aggregating the properties of the agents (Axelrod & Tesfatsion, 2006). Our model uses no desire or motivational

component for agents, but a belief that evolves through time with respect to an interaction function between the entity and other agents. Those reactive agents have no representational function of their environment and show a reflex behavior with respect to one-to-one encounters. The model is based on previous work done on a model of continuous opinion dynamics (Deffuant & al., 2001) extended over two dimensions of opinion, representing two independent fields of expertise. Agents interact through one-to-one exchanges at each time unit and modify their position as a result. Agents are differentiated by credibility and uncertainty. The credibility of an agent represents how much other agents may be influenced by this agent, with respect to their own credibility. The uncertainty reflects the maximum distance between the position of an agent and that of his interlocutor. It is also used to influence the change of opinion of interlocutors, based on the uncertainty of each agent over the total uncertainty. The more interactions an agent has, the smaller his uncertainty becomes, hence the stabilization of the system. Due to the heterogeneity of agents, the change of positions is not reciprocal. Two kinds of agents (scientists and economists) are left free to interact in their respective field represented by two different axes. The boundary organization is introduced through agents called borgs: open to trans-disciplinary discussion, they are able to cross the boundary between the two axes, opening possibilities of exchange on both dimensions, while other agents remain limited to interactions within their field of expertise. Borgs are regular agents who gain a new property, no matter what their initial position is, mainstream or minor, extreme or average.

The simulation involves 200 agents equally spread over two fields of expertise and is left running over 1000 time units. The ratio of borgs is increased from 0 to 50%, by steps of 1% up to 10% and of 5% beyond 10%, with ten simulations at each value. Results are analyzed in terms of the number of opinions expressed once the positions are stabilized, the ratio of experts agreeing to each, and the number of time units necessary to observe 50% of the stable figures.

The impact on the number of opinions gathering each more than 1% of all agents is significant: 5% of borgs reduce it by 11%, 10% by 22% and 30% lead to a decrease of 32% of the final number of opinions, with no variation beyond this level. Opinions representing at least 5% are only slightly positively affected and require a minimum level to show a significant impact (increase of 3% with 10% of borgs, but of 30% with 20%, and no variation beyond). Opinions supported by at least 10% of agents are significantly increased, even with low ratios of borgs: they are increased by 19% with only 5% of borgs, and by 24% with 10%, to reach a maximum of 33% with 50%. The impact of a boundary organization is not linear, with the stabilization of the impact at a certain level, and a threshold effect in some cases. At low realistic levels of agents involved in the boundary organization, the impact is significant and immediate on the reduction of total opinions expressed and on the increase of opinions gathering the largest shares of experts, while average opinions are not significantly affected: the

global reduction of the diversity of final opinions expressed is confirmed by an apparent transfer from minor to dominant opinions.

The impact on the concentration of agents around each final opinion is quite similar: 5% of borgs are sufficient to increase the number of agents agreeing to the dominant opinion by 19% to reach a maximum of 25% increase with 50% borgs. If we consider the sum of agents agreeing to the two main opinions, the increase is reduced to 17% at 5% but reaches 23% at 10%, for a maximum of 43%. A similar situation is observed for the five main opinions with an increase of 20% at 5% and a maximum of 41%. The sum of the ten main opinions increases by 15% with 5% borgs, by 20% for 10%, and by 35% for 20% to reach a maximum of 45% at 50%. The correlation factor of the variation of the dominant opinion is 80% for a boundary organization going from 0 to 10%, and between 87 and 93% for the six to ten dominant opinions from 0 to 50%. An other indicator is that without a boundary organization, it requires the 7 dominant opinions to gather 50% of the experts, when it requires 6 with 1% of borgs, 5 with 3%, 4 with 5% and only 3 with 15%. The concentration of agents around final opinions is significantly impacted by the existence of a boundary organization, even at low levels, with a stabilization of the impact at a certain level.

When considering the impact of a boundary organization on the time necessary to reveal dominant opinions, through the number of interactions necessary to reach 50% of the final situation, we can conclude that there is no significant impact. The correlation factor is below 40%, and the maximum impact does not exceed 10% in most extreme cases. This observation could reinforce the idea that the boundary organization does not influence the results of the debates.

We see that the rising interest for boundary organizations supported by successful cases is confirmed by virtual simulations. They reveal that boundary organizations do not require the involvement of a large share of experts to show a significant impact on the reduction of the diversity of opinions expressed and on the increase of the concentration of experts around dominant opinions, making it easier for the decision-maker to consider together the different aspects of an issue. Nevertheless, we cannot expect from a boundary organization to reduce the time necessary for experts to reach their final opinion. Boundary organizations seem to be able to increase the scale of confrontation between groups of opinion: they do not emerge as opinion leaders, but encourage the exchanges between experts by easing and increasing the transfer of information from one sphere to the other, which results in more affirmed positions of experts over the different dimensions of an issue.

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