JASSS

Guido Fioretti and Alessandro Lomi (2008)

An Agent-Based Representation of the Garbage Can Model of Organizational Choice

Journal of Artificial Societies and Social Simulation vol. 11, no. 1 1
<http://jasss.soc.surrey.ac.uk/11/1/1.html>

For information about citing this article, click here

Received: 17-Feb-2007 Accepted: 28-Sep-2007 Published: 31-Jan-2008

Abstract

Cohen, March and Olsen's Garbage Can Model (GCM) of organizational choice represent perhaps the first ñ and remains by far the most influential ñagent-based representation of organizational decision processes. According to the GCM organizations are conceptualized as crossroads of time-dependent flows of four distinct classes of objects: 'participants,' 'opportunities,' 'solutions' and 'problems.' Collisions among the different objects generate events called 'decisions.' In this paper we use NetLogo to build an explicit agent-based representation of the original GCM. We conduct a series of simulation experiments to validate and extend some of the most interesting conclusions of the GCM. We show that our representation is able to reproduce a number of properties of the original model. Yet, unlike the original model, in our representation these properties are not encoded explicitly, but emerge from general principles of the Garbage Can decision processes.

Keywords:
Organization Theory, Garbage Can Model, Agent-Based Modelling

Introduction

1.1

Decisions in organizations can be studied at many different levels of aggregation. For example, in the analysis of organizational decision making processes a common strategy is to reduce a complex social activity to an individual constrained optimization problem. In the study of formal organizations, this analytical strategy emphasizes the information properties of alternative structural arrangements (Burton and Obel 1995) and the capacities of individual decision makers (individually and in teams of variable size) to find, exchange and process the various pieces of information (Miller 2001). Typically — but not invariably — organizational decision processes are assumed to follow a "logic of consequence" according to which the outcomes of decisions are evaluated in terms of individual preferences and expectations about future outcomes (March 1994).

1.2

An alternative way of thinking about how decisions happen in organizations concentrates on the aggregate flows of decision makers, opportunities for decision-making, problems and solutions through organizational networks. This perspective focuses on how aggregate regularities are produced and reproduced through the interaction of elementary components ("agents") defined at lower levels. Such a view starts with a very different position on what the term "organization" means when referred to socially constructed entities. Organizations are seen as regulated and partly self-maintaining flows emerging from the interaction among elementary agents. According to this view organizational "structure" is represented as an emergent set of connections between "decision makers," "problems" and "solutions."

1.3

Within the broadly defined field of "Organization Theory," a prominent example of this second approach to the representation of organizational decision processes is the *Garbage Can Model* of organizational choice (GCM), originally proposed by M.D. Cohen, J.G. March and J.P. Olsen (1972). The motivating claim behind the GCM is that: "Although organizations can often be viewed conveniently as vehicles for solving well-defined problems [...] they also provide sets of procedures through which participants arrive at an interpretation of what they are doing and what they have done while in the process of doing it. From this point of view, an organization is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work" (Cohen, March and Olsen 1972: 2). During the subsequent three decades the view of organizational decision processes that the GCM articulates has been extremely influential in a variety of substantive fields in which our understanding of organizations plays a central role like, for example, political science (Kingdon 1984;Peters 1996), and institutional theory more generally (March and Olsen 1989). To this day, Cohen, March and Olsen's original statement of the GCM remains perhaps one of the most frequently cited articles in contemporary organization theory (a recent search on Google Scholar returned almost 1300 cites) .

1.4

Despite its influence and visibility, we feel that the full potential of the GCM as a model of — rather than a metaphor for — organizational decision processes has not yet been fully realized. In our view the main reason behind this state of affairs is related to the fact that that in their verbal theory Cohen, March and Olsen articulated a clear and very explicit agent-based representation of organizational decision processes, but the actual model could not reproduce their verbal theory faithfully because of the technological constraints of the time (early 1970s). As a consequence the GCM has been frequently treated rather superficially as a metaphor for organizations as "structured anarchies" paying only superficial attention to its internal logic. Alternatively, the GCM has attracted detailed criticism stimulated by the obvious — but apposite — observation that the computer code (that Cohen, March and Olsen reported in an appendix of the original paper) reflected the verbal theory only loosely.

1.5

In this paper we attempt to narrow the gap between the GCM model and its underlying theoretical narrative by building an agent-based model of garbage can decision processes. According to Axelrod and Tesfatsion (2006: 1649) an agent-based model is "[A] method for studying systems (...) composed of interacting agents, and [that] exhibit *emergent* properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents." Because of these two core features, the agent-based technology that we adopt allows us to go beyond the limits of the GCM and those of its critics by (i) making explicit the agent-based nature of the original theoretical narrative, and (ii) re-implementing the GCM in a way that enables direct computer experimentation and facilitates comparison with the results produced by the original model.

1.6

The first step in this direction involves the careful reconstruction of the GCM in a modelling environment that allows the reproduction of the agent-based concepts contained in the verbal theory. Clearly this is not the first attempt to reconstruct the GCM, or translate it into different languages. Other examples are available that have emphasized and developed different aspects of the original model (Masuch and LaPotin 1989;Warglien and Masuch 1996;Takahashi 1997). Since its appearance, the implications of the GCM have also been explored in a number of empirical contexts (Cohen and March 1974;March and Olsen 1976a;Martin 1981;Lynn 1982;Carley 1986a, 1986b;March and Weissinger-Baylon 1986;Levitt and Nass 1989). A number of important refinements (March and Olsen 1989;Mezias and Scarselletta 1994) and extensions (March 1978;Padgett 1980;Lai 1998, 2003) have also been proposed.

1.7

Why dedicate so much attention to such an "old" model? After all so much has happened in organization theory during the intervening period that spending any time dissecting such an old model may seem like a purely academic exercise. Not so. First of all, the GCM continues to generate heated debate among students of organizations and institutions (Bendor, Moe and Schotts 2001), stimulate new applications (Leach 1997;Cherry 2000;Richardson 2001;Romelaer and Huault 2002;Zahariadis 2003;Lipson 2007), and inspire innovative interdisciplinary debate (Gibbons 2003). Second, a translation of the original model in the light of contemporary agent-based technology promises to improve our understanding of aspects of the model that have so far not received proper attention and that may be conductive of further refinements. Third, computer simulation has played a special role in the development of organizational theories (March 2001) and it continues to do so in contemporary research (Lomi and Larsen 2001). We want to contribute to this tradition by showing how new computational models and tools can be used to illuminate central problems in the theory of organizations.

1.8

After this general introduction we organize our argument as follows. In the next section we discuss in some detail the structure of the original model and recall the basic terminology that Cohen, March and Olsen used to define the identities of the various "objects" — or "agents" — in their model. In section three we identify specific points of divergence between the verbal theory and its implementation as a simulation model and we discuss strategies to reconcile this divergence. In section four we introduce our agent-based reconstruction of the GCM. In section five we discuss our own translation of the measures of organizational performance that were defined by Cohen, March and Olsen. Section six contains the main results of our simulation experiments. We allocate a considerable amount of attention to this section because our exercise stands or fall on the ability of our model to reproduce the basic analytical insights of the original model. We conclude the paper with a discussion section in which we also identify a number of potentially interesting avenues for future research.

The Garbage Can theory of organizational decisions

2.1

The Garbage Can Model of organizational choice (Cohen, March and Olsen 1972) represents a unique intellectual effort to understand organizational decision-making in a way that neither reduces organizational decisions to the decisions of individual participants, nor treats organizations as aggregate unitary collective actors endowed with preferences and clearly specified objectives. The GCM is not a model of group or coalition formation either, but rather a description of an ecology of elements that produce decision-making in an organization. The counterintuitive view of organizational decision process that the GCM portrays represents perhaps its most distinctive intellectual feature. According to Daft: "The theoretical breakthrough of the Garbage Can model is that it *disconnects* problems, solutions and decision makers from each other, unlike traditional decision theory" (1982: 139. Emphasis ours).

2.2

The Garbage Can theory of decision-making applies to situations characterised by the following three factors. The first is fluid participation. Fluid participation refers to the well-established fact that the degree of attention that participants typically dedicate to any one decision problem is highly variable. The notion of fluid participation also captures the observation that organizational members tend to enter and exit decision situations according to processes that are not necessarily related to the problems at hand. The second factor is unclear decision technology. Unclear decision technology refers to the fact that causal relations underlying specific organizational decision problems in the form of well specified means-end chains are frequently ambiguous; all too often, clear causal relationships are only ex-post reconstructions aimed at rationalising decisions that have already been made (March 1994;Olsen 2001). The third factor is problematic preferences, a term that Cohen, March and Olsen introduced to capture the general tendency of decision makers to discover their preferences through action rather than acting on the basis of pre-defined and unchanging preferences (Cohen, March and Olsen 1972). Organizations characterized by fluid participation, unclear decision technologies and problematic preferences were labelled by Cohen, March and Olsen "organized anarchies" (Cohen, March and Olsen 1972).

2.3

The GCM describes organizations as a sort of chemical reactors where four kinds of elements interact. They are the participants to an organization, also called decision-makers, the choice opportunities that present to them, the solutions they may employ and the problems that they are called to solve.

2.4

These elements exist independently of one another and, although they might disappear as a consequence of decision-making, their existence is independent of time. Participants do not retire, choice opportunities may present themselves over and over (e.g., a periodically scheduled series of meetings), solutions do not age and problems may represent themselves. Notably, solutions exist independently of problems, implying that decision-makers may seek to apply pre-defined solutions to the problems that they encounter, rather than the other way around (Cohen and March 1974;March and Olsen 1976c;Weick 1979, 1995;Lane and Maxfield 2005).

2.5

By means of this seemingly awkward assumption, the GCM captures a fundamental feature of decision-making. Faced with uncertain environments, decision-makers construct a direction for acting by re-shaping their past experiences into a coherent picture that enables them to apply a solution that worked well in the past to their current setting. In this sense, solutions exist independently of the decision-makers who eventually employ them. The authors of the original GCM were first to point to this interesting feature of decision-making (Cohen and March 1974;March and Olsen 1976c). Later, Weick (1979, 1995) explored it with greater detail. Lane and Maxfield (2005) present an empirical example of how this assumption maps onto actual decision making processes.

2.6

According to the verbal, introductory description of the GCM (Cohen, March and Olsen 1972), decision situations characterized by fluid participation, unclear decision technology and problematic preferences generate three possible outcomes, only two of which are decision styles. The first decision style is characterized by the fact that a problem is actually solved. Thus, it is called decision by resolution. According to the GCM, decisions are made by resolution if: (i) the participants to the decision process are sufficiently able; (ii) a sufficiently good solution is available to them, and (iii) the problems that they are called to solve are sufficiently simple. The second decision style is defined by decisions that are made without any attention to existing problems. This is called decision by oversight. Decisions by oversight are due rituals that confirm the legitimacy of an organization (Di Maggio and Powell 1983), but they solve no problem. The third outcome, called flight, is no decision in itself. Flying from a difficult problem consist of attaching it to a different opportunity, for instance one that will be due at a later time, or one that will be dealt by a colleague (in which case "flight" amounts to buck-passing). Consequently, a flight from a problem helps to make a decision on the remaining ones.

2.7

Figure 1 illustrates the relationships between decisions by resolution, decisions by oversight and flights. If neither a decision by resolution nor a decision by oversight can be made, a flight may allow to consider the decision problem again after the most difficult problem has been set aside.

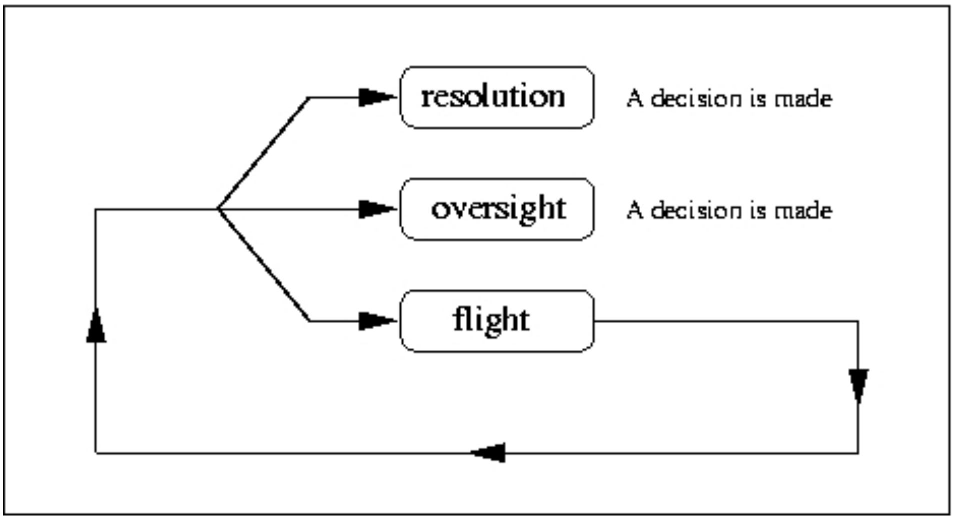

Figure 1. The flow chart of the GCM: resolutions and oversights mark the end of decision-making, flights make it start again

2.8

The choice between decision by resolution, decision by oversight and flight is influenced by the availability of participants, opportunities, solution and problems, as well as by their features. Participants are characterised by an energy that represents their ability as decision-makers. Solutions are characterised by an efficiency that represents their effectiveness. Finally, problems are characterised by an energy that represents their difficulty.

2.9

Think of participants, opportunities, solutions and problems moving randomly in the "chemical reactor" that represents an organization. If participants, opportunities and solutions meet, but no problem is there, a decision is made by oversight. If participants, opportunities, solutions and problems meet, they may make a decision by resolution if the energy (ability) of participants, weighted by the efficiency of available solutions, is greater than the energy (difficulty) of problems. Otherwise, the decision process is blocked until its participants succeed to pass some problems to some other opportunity (by postponing decision-making, buck-passing, or else). This is a flight. The energy (difficulty) of the remaining problems may still be too high, in which case the decision process remains blocked. Or, the energy of the remaining problems may be sufficiently low (the remaining problems are sufficiently simple), in which case a decision by resolution is made. In the limit, no problem has remained, in which case a decision by oversight is made.

2.10

The basic GCM described so far has no "organizational structure" in any conventional sense. In order to overcome this shortcoming Cohen, March and Olsen devised the possibility that either opportunities and participants, or opportunities and problems, or all of them, receive an exogenous ordering by "importance." The decision structure specifies which participants are allowed to make use of which choice opportunities (e.g., only the directors may be allowed to attend the board of directors). The access structure specifies what problems are handled in which opportunities (e.g., shop-floor problems may not be allowed to reach the CEO).

2.11

Figures (2) and (3) illustrate the three configurations of the decision structure and the access structure envisaged by Cohen, March and Olsen (1972). Both the decision structure and the access structure can either be non-segmented, hierarchical or specialized.

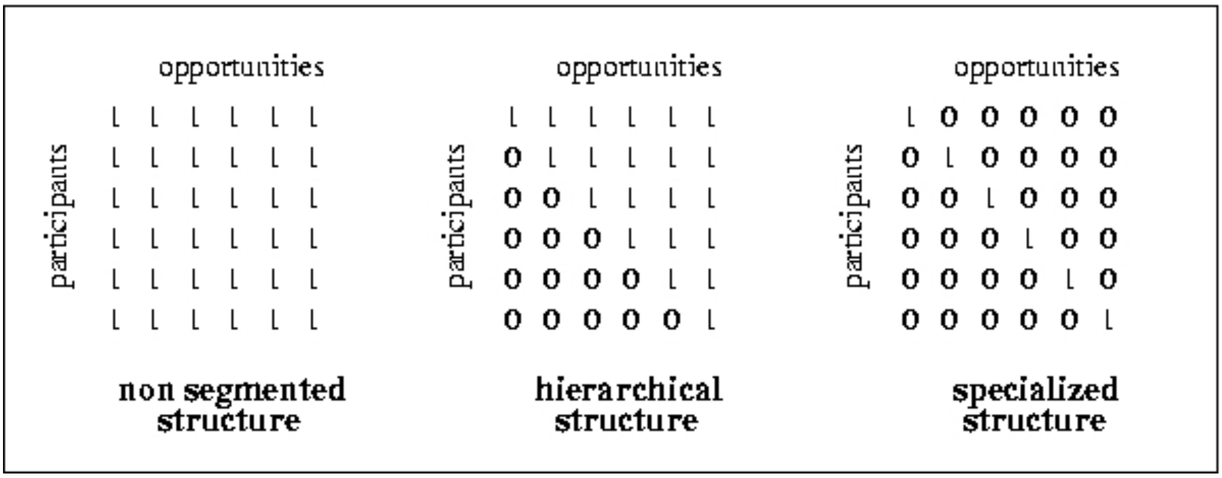

Figure 2. The decision structure can either be non-segmented (left), hierarchical (centre) or specialized (right). In the matrices a "1" indicates that the row element has access to the column element

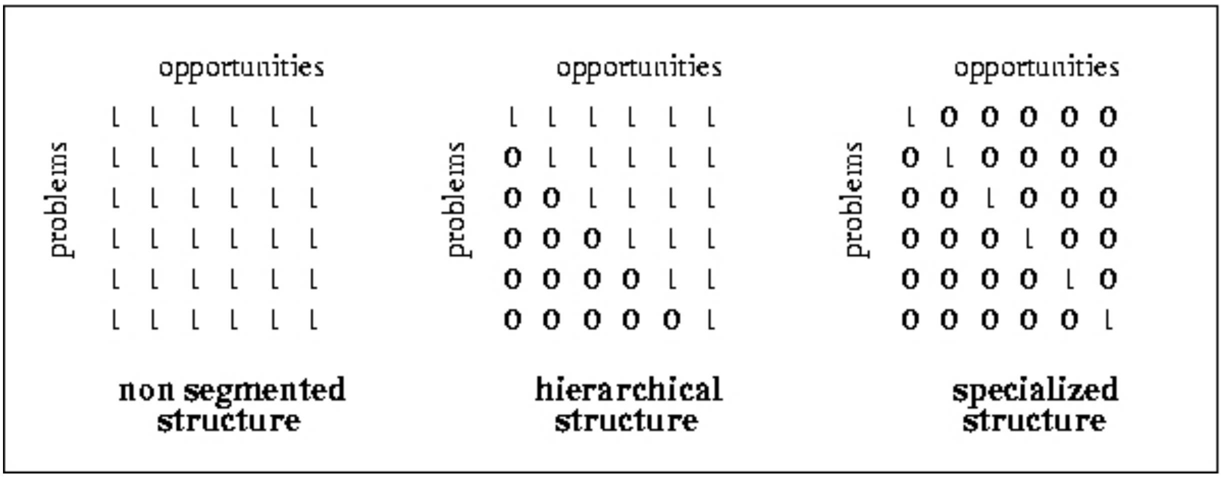

Figure 3. The access structure can either be non-segmented (left), hierarchical (centre) or specialized (right). In the matrices a "1" indicates that the row element has access to the column element

2.12

In the matrices reported in Figures 2 and 3 a "1" in cell a_{ij} indicates that the element in the *i*-th row has access to the element in the *j*-th column. For this reason, within the GCM the matrices are typically interpreted as access structures.

2.13

Non-segmented, hierarchical and specialized structures are characterized as follows:

- **Non-segmented**. A decision structure is non-segmented if all participants are allowed to attend all choice opportunities. An access structure is non-segmented if all problems can be discussed in all opportunities. Non-segmented decision structure and non-segmented access structure is the default setting of the GCM.
- **Hierarchical**. A decision structure is hierarchical if participants are not allowed to attend choice opportunities that are more important than their own level. An access structure is hierarchical if problems cannot be discussed in opportunities that are more important than their own level.
- **Specialized**. A decision structure is specialized if each participant can only attend choice opportunities of his own level of importance. An access structure is specialized if each problem can only be discussed in opportunities of its own level of importance.

Note that this characterization does not account for the possibility that two or more participants (or problems, or opportunities) have the same importance. This is a clear departure from real organizations, where two or more decision-makers may be at the same hierarchical level or — in other words — have the same role. However, the GCM is a stylized conceptual model, not a realistic representation of any specific case.

2.14

Despite the obvious limits imposed by the procedural language used at the time, the GCM represents a clear example of agent-based thinking — perhaps the first example in theories of organizations and one of the first in the social sciences together with Schelling's dynamic model of residential segregation (Schelling 1971). In fact, the GCM is defined in terms of four classes of discrete agents (participants, opportunities, solutions and problems) and of simple rules of interaction among these agents.

2.15

What we do in the next section is to review the internal structure of the original model and to translate it into a more explicit agent-based representation of organizational decision processes. Subsequently, we shall check whether the results found by Cohen, March and Olsen still hold. Although a few of the original conclusions appear as artefacts of the 1972 implementation, the basic insights of the original model are confirmed over a wide range of parameters.

A closer look at the GCM

3.1

The original description of the GCM (Cohen, March and Olsen 1972) entailed several inconsistencies in terminology, as well usage of terms suggesting different meanings from those that were actually implied. The description of §1 is consistent and — we believe — coherent with the spirit of the GCM. However, it differs from the original description in the following three respects:

- The word "technology" is introduced in the following passage (Cohen, March and Olsen 1972: 1): "The second property is unclear technology. Although the organization manages to survive and even produce, its own processes are not understood by its members. It operates on the basis of simple trial-and-error procedures, the residue of learning from the accidents of past experience, and pragmatic inventions of necessity". We believe that the meaning of "technology" as "trial-and-error procedures" as mentioned in the GCM has neither to do with technical specifications as in engineering, nor with the ratio of output to input as in microeconomics. In order to avoid misunderstandings, we employed the expression "unclear decision technology" which, in our intentions, should convey the idea that not only the goals of an organization may be ill-defined, but also the means to reach them. In a later publication, March and Olsen (1976b) write: "The first [lack of clarity] is the ambiguity of *intentions*. Many organizations are characterized by inconsistent and ill-defined objectives. It is often impossible to specify a meaningful preference function for an organization that satisfies both the consistency requirements of theories of choice and the empirical requirements of describing organizational motive. The second lack of clarity is the ambiguity of *understanding*. For many organizations the causal world in which they live is obscure. Technologies are unclear; environments are difficult to interpret. It is hard to see the connections between organizational actions and their consequences". We deem that understanding technologies as "connections between organizational actions and consequences" supports our choice of the term "decision technologies".
- Cohen, March and Olsen (1972: 2) claim that "To understand processes within organizations, one can view a choice opportunity as a garbage can into which various kinds of problems and solutions are dumped by participants as they are generated". Later (Cohen, March and Olsen 1972: 3) they define "choice opportunities" as one of the four agents of the model — the others being participants, solutions and problems. However, from that point onwards, as well as in the abstract of the original article, the expression "choice opportunities" is often shortened into "choices". Furthermore, "choice" is also employed as a synonymous of "decision". We believe that this terminology is misleading. In order to avoid misunderstandings, we shortened "choice opportunities" into "opportunities" and used this word consistently. Furthermore, we employed the word "decision" and dropped the word "choice" altogether.
- In the original article (Cohen, March and Olsen 1972: 8), flights are defined as follows: "In some cases choices [opportunities] are associated with problems (unsuccessfully) for some time until a choice [an opportunity] more attractive to the problems comes along. The problems leave the choice [the opportunity], and thus it is now possible to make the decision". In our exposition of §1, we adhered to this definition. Thus, we defined two decision styles (by resolution and by oversight), plus a trick to unleash blocked decision processes. However, a few lines later Cohen, March and Olsen (1972: 8) warn that their implementation of flights differs from their own definition: "Some choices [decisions] involve both flight and resolution — some problems leave, the remainder are solved. These have been defined as resolution, thus slightly exaggerating the importance of that style. As a result of that convention, the three styles are mutually exclusive and exhaustive with respect to any one choice [decision]". Note that, by accepting this approximation, Cohen, March and Olsen's computational model has three decision styles. This circumstance contributed to a great deal of the misunderstandings that surround the GCM; in our opinion, it is of the utmost importance to revert to the formulation entailed in the first quotation above. In summary, we note that Cohen March and Olsen first defined a 'flight' as a decision of letting an element fly out of a blocked decision process, but later, in the computational model, they understood this as a kind of resolution. We deem it is important that the definition is used, rather than the approximation.

3.2

Making use of our terminology, let us examine the details of Cohen, March and Olsen's computational model. The model involves 10 participants, 10 choice opportunities and 20 problems that interact along 20 simulation steps (Cohen, March and Olsen 1972). Participants, opportunities and problems flow in and out according to the following schedules:

- The 10 participants are in the organization from the very beginning and never exit it.
- The 10 opportunities enter the organization one at a time during the first 10 simulation steps. Each time a decision is made, the corresponding opportunity exits.
- The 20 problems enter the organization two at a time during the first 10 simulation steps. Each time a decision is made, the problem(s) that were eventually involved exit(s) the organization.

3.3

Solutions do not exist as independent variables. Rather, solutions are approximated by a coefficient that multiplies the energy of all participants. The simulations are carried out keeping this coefficient constant. This is equivalent to assume that there exists one single solution which is used in all decisions. Thus, it never exits the organization.

3.4

However, Cohen, March and Olsen inform us in a footnote that simulations were carried out, where the solution coefficient changed at each step (Cohen, March and Olsen 1972: 5). This amounts to assume that at each step the one single solution is replaced, but still, no independent population of solutions exists.

3.5

Participants and problems are characterised by energy values that represent their ability as problem-solvers and their level difficulty as problems, respectively. For any opportunity i the following magnitudes are introduced:

- XERC(i) denotes the energy required at opportunity i in order to resolve the problems that impinge on it. XERC stands for *required energy*;
- XEE(i) denotes the energy that can be expended by the participants who are at opportunity i. XEE stands for *expended energy*.

3.6

At opportunity i, a decision is made if the required energy is not greater than the expended energy. The corresponding FORTRAN instruction is (Cohen, March and Olsen 1972: Appendix):

$$\text{XERC}(i) \leq \text{XEE}(i) \qquad (1)$$

3.7

If condition (1) is satisfied with XERC(i) > 0, this means that the energy of participants is greater than the energy of problems. A decision is made by resolution. If condition (1) is satisfied with XERC(i) = 0, this means that no problem is there. A decision is made by oversight. If condition (1) is not satisfied, a flight is in order.

3.8

Condition (1) is in accord with the verbal statements of the GCM. However, important discrepancies emerge as soon as we examine the algorithms by which XERC(i) and XEE(i) are computed.

3.9

The energy required at opportunity i is equal to the sum of the energies of the problems at i. Let XERP(j) denote the energy required to resolve problem j. The corresponding FORTRAN instruction is (Cohen, March and Olsen 1972: Appendix):

$$\text{XERC}(i) = \text{XERC}(i) + \text{XERP}(j) \qquad (2)$$

3.10

For each opportunity i, the instruction (2) is repeated for all problems j that arrive at i. Thus, the energy required at opportunity i accumulates with the problems that impinge on it. Figure 4 illustrates the mechanism of instruction (2).

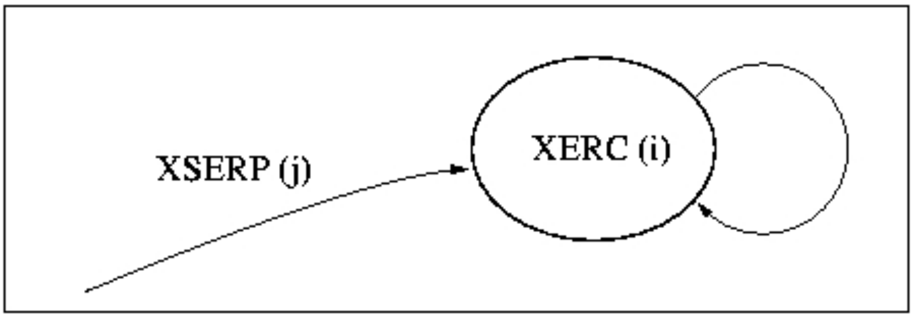

Figure 4. The energy required at the *i*-th opportunity is the sum of the energies of the problems that impinge on it

3.11

The energy that can be expended on opportunity *i* is the sum of the energies of the participants that attend this opportunity. Let XSC(*lt*) be the solution coefficient in the time interval *lt*. Let XEA(*k*, *lt*) denote the energy contributed by participant *k* during the interval *lt*. The corresponding FORTRAN instruction is (Cohen, March and Olsen 1972: Appendix):

$$XEE(i) = XEE(i) + XSC(lt) * XEA(k, lt) \qquad (3)$$

3.12

For each opportunity *i*, the instruction (3) is repeated on all participants *k* that reach *i*. Thus, the energy that can be expended at opportunity *i* accumulates with the participants that attend it. Figure 5 illustrates the mechanism of instruction (3).

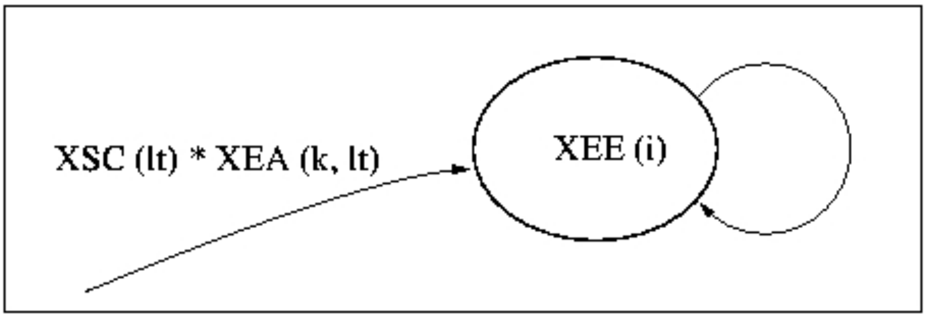

Figure 5. The energy that can be expended at the *i*-th opportunity is the sum of the energies of the participants that attend it

3.13

At each simulation step, participants and problems select an opportunity with the constraints imposed by the decision structure and the access structure, respectively. Among all opportunities that comply with these constraints, they select the one where, in the previous step, a decision by resolution was closest to obtain. This idea is implemented by selecting the opportunity that, in the previous step, minimised the following indicator (Cohen, March and Olsen 1972: Appendix):

$$s = XERC(i) - XEE(i) \qquad (4)$$

3.14

Bendor, Moe and Shotts (2001) pointed out that, particularly because of eq.(4), Cohen, March and Olsen's computational model is quite different from their own verbal exposition of the GCM (Cohen, March and Olsen 1972). In fact, eq.(4) makes all participants and all problems move in block to one opportunity at a time (Bendor, Moe and Shotts 2001). So in the end, if all participants and all problems move together, if only one opportunity is exploited at each step and if only one solution exists, Cohen, March and Olsen's computational model describes an aggregate dynamics that has little to do with random encounters of participants, opportunities, solutions and problems.

3.15

Olsen (2001) replied to Bendor, Moe and Shotts (2001) with the argument that this architecture was chosen because it conveys the idea that the members of an organization often move through choice opportunities meeting the same problems again and again but never solve them. Indeed, this is one of the main results of Cohen, March and Olsen's simulations (Cohen, March and Olsen 1972). However, precisely because they want it to be an emergent property of the model, it should not be prescribed by design. In §5 we shall see that, in our agent-based version of the GCM, the fact that the members of an organization meet the same problems again and again arises naturally from the basic premises of the Garbage Can theory of decision-making. Thus, we are able to strengthen Cohen, March and Olsen's argument while at the same time accepting Bendor, Moe and Shotts' technical criticism. In fact, we show that even if participants and problems do not move together — a feature of the original model that Bendor, Moe and Shotts rightly criticised — the main results still hold.

3.16

Bendor, Moe and Shotts (2001) also pointed out that since participants and problems move in block, flights are such that all problems leave the opportunity where they were blocking the decision process. Thus, after a flight a decision by oversight is necessarily made. However, as we have seen in Figure 1, in general a flight might enable a decision by resolution, a decision by oversight, or it might not enable any decision at all.

3.17

Bendor, Moe and Shotts (2001) stress that this problem is even more serious. In fact, within one single simulation step not only all problems, but also all participants leave the opportunity if a flight takes place. Thus, flights are such that decisions are made without problems and without participants, just because XERC(*i*) is set to zero while XEE(*i*) remains at its value.

3.18

We deem that the problems highlighted by Bendor, Moe and Shotts (2001) are serious and should be taken seriously. The fact that solutions have not been modelled by Cohen, March and Olsen (1972) as independent agents is a fundamental departure from the verbal expression of the GCM, but even more disturbing is the way those agents behave, that should interact with one another. Participants, opportunities and problems, instead of acting according to the outcomes of pairwise interactions, move all together and act all together as if they were one single agent. It seems that, in spite of its verbal expression, in its computational implementation (Cohen, March and Olsen 1972) the GCM became an aggregate model.

3.19

Our agent-based version of the GCM does not merely aim at substituting an obsolete modelling technology with a more modern and appropriate one. Rather, we want to make use of the opportunities offered by the more modern technology — agent based modelling — in order to build a computational implementation of the GCM that is coherent with its verbal expression.

Garbage Can Decision Processes in an Agent-Based Perspective.

4.1

Our agent-based model is implemented on the NetLogo platform. The code is distributed under the GNU public license. It is available on the NetLogo web site among the User Community Models.

4.2

Unlike Cohen, March and Olsen's computational model, but consistently with their verbal description of the GCM, we define four kinds of agents: participants, opportunities, solutions and problems. These agents move on a torus that represents an organization. Entry and exit from the simulation environment are interpreted as entry and exit from the organization, respectively.

4.3

Figure 6 illustrates the parameters that regulate the entry and exit of agents. The user can choose the initial number of agents (`initial-number-of-participants`, `initial-number-of-opportunities`, `initial-number-of-solutions`, `initial-number-of-problems`), impose exogenous in- or out-flows (by means of positive or negative values of `net-flow-of-participants`, `net-flow-of-opportunities`, `net-flow-of-solutions`, `net-flow-of-problems`) as well as the time step where these flows eventually stop (`stop-flow-par-at`, `stop-flow-opp-at`, `stop-flow-sol-at`, `stop-flow-pro-at`). Furthermore, the user can choose whether participants, opportunities, solutions and problems exit the organization after they have been involved in a decision (`participants-exit?`, `opportunities-exit?`, `solutions-exit?`, `problems-exit?`). By means of these parameters, it is possible to explore the GCM in a wide variety of conditions, including those assumed by Cohen, March and Olsen (1972).

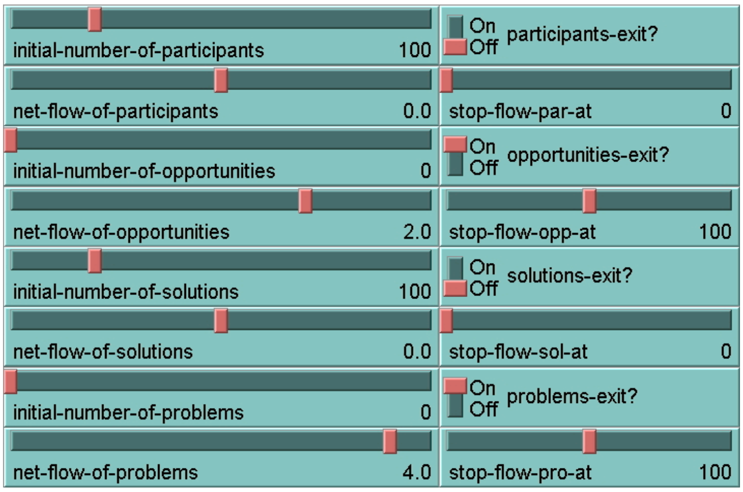

Figure 6. The parameters that regulate the entry and exit of agents. Initial number, exogenous flows, interruption of exogenous flows, and exit of agents once they have been involved in decision-making

4.4

Decision and access structures are selected by means of the buttons illustrated in Figure 7. Our NetLogo implementation facilitates experimentation with alternative access structures that can be specified in the appropriate panel by simply entering a "0" for a non-segmented structure, a "1" for a hierarchical structure and a "2" for a specialized structure. If the structure is either hierarchical or specialized, participants and problems are ordered by increasing importance according to their identification number.

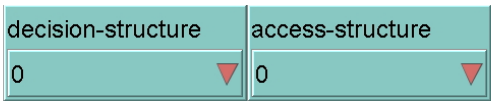

Figure 7. The buttons that select the decision structure (left) and the access structure (right). Non-segmented structures are denoted by 0, hierarchical structures are denoted by 1, specialized structures are denoted by 2

4.5

Consistently with the verbal statement of the GCM, each participant is endowed with an 'energy' that represents its ability as decision-maker. A problem is endowed with an 'energy' that represents its level of difficulty. Each solution is characterised by an efficiency value. Following the insight of Cohen, March and Olsen's verbal theory — but in contrast with their own computational model — in our model not only participants and problems are generally heterogeneous with respect to energy, but also solutions are generally heterogeneous with respect to efficiency. In fact, by means of proper control buttons the user of the model can choose the distribution of energy among participants and problems as well as the distribution of efficiency among solutions.

4.6

Figure 8 shows the buttons that regulate the distribution of energy and efficiency. Following Cohen, March and Olsen (1972), the distribution of energy among participants and problems, as well as the distribution of efficiency among solutions, can be selected according to the three following distributions:

- If the parameter `dist-energy-par` is set to 0, increasing levels of energy (from `min-energy-par` to `max-energy-par`) are distributed to participants of increasing importance. If the parameter `dist-efficiency` is set to 0, increasing levels of efficiency (from `min-efficiency-sol` to `max-efficiency-sol`) are distributed to solutions of increasing importance. If the parameter `dist-energy-pro` is set to 0, increasing levels of energy (from `min-energy-pro` to `max-energy-pro`) are distributed to problems of increasing importance. Since the ordering of participants by importance is only effective if the decision structure is either hierarchical or specialized, only in these cases it makes sense to set `dist-energy-par` to 0. Likewise, since the ordering of problems by importance is only effective if the access structure is either hierarchical or specialized, only in these cases it makes sense to set `dist-energy-pro` to 0. The possibility of distributing efficiency according to the importance of solutions is added for completeness, but has no counterpart in the original model (Cohen, March and Olsen 1972).

- If the parameter `dist-energy-par` is set to 1, energy levels are drawn from a uniform distribution in the [`min-energy-par`, `max-energy-par`] interval and assigned randomly to participants. If the parameter `dist-efficiency` is set to 1, efficiency levels are drawn from a uniform distribution in the [`min-efficiency-sol`, `max-efficiency-sol`] interval and assigned randomly to solutions. If the parameter `dist-energy-pro` is set to 1, energy levels are drawn from a uniform distribution in the [`min-energy-pro`, `max-energy-pro`] interval and assigned randomly to problems. Since all rankings by importance are ignored, these options make sense if both the decision structure and the access structure are non-segmented. Also note that drawing from a uniform random distribution is a generalisation with respect to Cohen, March and Olsen (1972), where all participants, all solutions and all problems had the same values. This case can be obtained by posing `min-energy-par=max-energy-par`, `min-efficiency-sol=max-efficiency-sol` and `min-energy-pro=max-energy-pro`.
- If the parameter `dist-energy-par` is set to 2, increasing levels of energy (from `min-energy-par` to `max-energy-par`) are distributed to participants of decreasing importance. If the parameter `dist-efficiency` is set to 2, increasing levels of efficiency (from `min-efficiency-sol` to `max-efficiency-sol`) are distributed to solutions of decreasing importance. If the parameter `dist-energy-pro` is set to 2, increasing levels of energy (from `min-energy-pro` to `max-energy-pro`) are distributed to problems of decreasing importance. Since the ordering of participants by importance is only effective if the decision structure is either hierarchical or specialized, only in these cases it makes sense to set `dist-energy-par` to 2. Likewise, since the ordering of problems by importance is only effective if the access structure is either hierarchical or specialized, only in these cases it makes sense to set `dist-energy-pro` to 2. Also in this case, the possibility of distributing efficiency according to the importance of solutions is added for completeness but has no counterpart in the original model (Cohen, March and Olsen 1972).

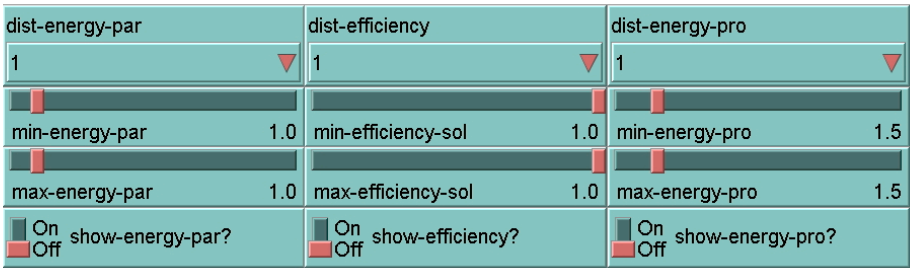

Figure 8. The buttons that specify the energy distribution, its minimum and maximum values and whether the energy values are shown aside the agents

4.7

By default, participants, opportunities, solutions and problems move randomly on the torus. A grid is defined on the torus, which identifies a finite number of squares. Decisions and flights are made according to the following rules:

- If at least one participant, at least one opportunity, at least one solution find themselves on the same square and if no problem is there, a decision by oversight is made. If several participants are on the square, all of them are involved. If several opportunities are on the square, one of them is chosen at random to be involved in decision-making. If several solutions are on the square, one of them is chosen at random to be involved in decision-making.
- If at least one participant, at least one opportunity, at least one solution and at least one problem find themselves on the same square, a decision by resolution can be made if the following condition is satisfied:

$$\left(\sum_{i \in \mathcal{I}_S} A_i \right) \max_{j \in \mathcal{J}_S} e_j \geq \sum_{k \in \mathcal{K}_S} D_k \qquad (5)$$

where A_i denotes the ability (the energy) of the i-th participant, e_j denotes the efficiency of the j-th solution, D_k denotes the difficulty (the energy) of the k-th problem and I_S, J_S, K_S denote the set of participants, solutions and problems on square S, respectively.

According to (5), if several participants and several problems are on the square, all of them are involved in decision making. If several opportunities are on the square, one of them is chosen at random to be involved in decision–making. If several solutions are on the square, only the most efficient one is involved in decision making.

- If at least one participant, at least one opportunity, at least one solution and at least one problem find themselves on the same square but condition (5) is not satisfied, the decision process is blocked. All agents stay on the square.
- A blocked decision process can be unleashed if an opportunity, in its random movements, ends on a square where a decision process is blocked. If this happens, the most difficult problem among those that are blocking the decision process is attached to the newly arrived opportunity, which goes away with it: This is a flight. The opportunity and the problem move together randomly until they meet a solution and (at least) one participant such that condition (5) is satisfied. The destiny of the agents remaining on the square takes one of the following branches:
    - If the problem that was carried away was the only problem on the square, no problem remains to be solved. In this case, the flight is followed by a decision by oversight.
    - If at least one problem remains after the most difficult one has been carried away, and if condition (5) is satisfied, the flight is followed by a decision by resolution.
    - If at least one problem remains after the most difficult one has been carried away, but condition (5) is not yet satisfied, the decision remains blocked. Eventually, it will be unleashed by another flight.

4.8

These rules translate into the flow chart of Figure 9, which describes the possibility tree at each particular square. The flow chart of Figure 9 is our instantiation of the flow chart of Figure 1.

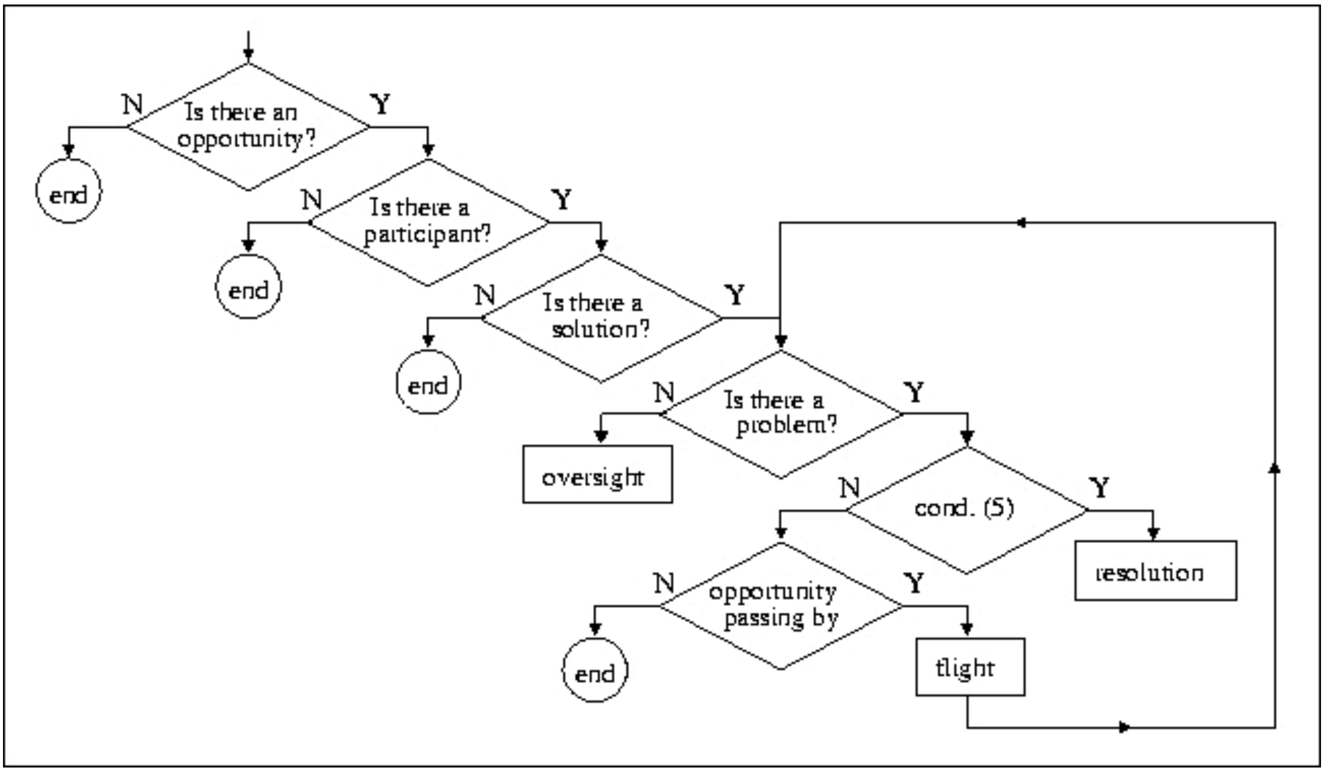

Figure 9. The flow chart at a particular square. The program goes through the five rhombi along the diagonal during one single step. The sixth rhombus at the bottom requires one step by itself. If the loop on the right is entered, the two last rhombi on the diagonal require one simulation step

4.9

Figure 10 is a snapshot of a portion of the torus where agents interact. Participants are depicted as blue squares, opportunities as orange arrows, solutions as red circles and problems as yellow triangles.

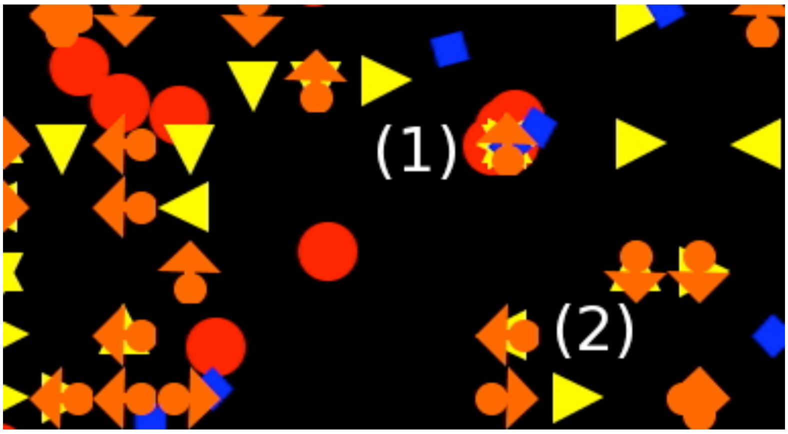

Figure 10. A snapshot of the simulation screen. Blue squares are participants, orange arrows are opportunities, red circles are solutions and yellow triangles are problems

4.10

The dynamics of Figure 9 can be recognized in Figure 10. At (1), a decision process is blocked. In fact, we see a mass of agents piled up on a single square, which they cannot leave. At (2), we see three examples of an opportunity (an orange arrow) taking away a problem (the yellow triangle behind it). Other agents are moving freely.

4.11

The ensuing section 4 translates the indicators of Cohen, March and Olsen (1972) into our framework. In the subsequent section 5, the results obtained by Cohen, March and Olsen will be revisited.

Performance in Garbage Can Organizations

5.1

Cohen, March and Olsen (1972) analysed the behaviour of their model by means of several indicators, which we attempted to replicate in our agent-based context. Figure 11 illustrates their monitors.

Problem Jumps	Problem Latency	Participant Jumps	Used Energy	Unexploited Opportur
25	23039	13	63.0	145
Problem Bindings	Unsolved Problems	Participant Bindings	Excess Energy	Waiting Time
1006	394	354	3.0	10061

Figure 11. The monitors of the main indicators of the model, grouped by the agents on which they are based

5.2

Since Cohen, March and Olsen's computational model is quite different from our agent-based version (see sections 2 and 3), the transposition of its indicators into our context is not trivial. Even the names of the indicators do not always correspond, also because Cohen, March and Olsen (1972) sometimes defined an indicator with a sentence but did not give a name to it. Let us examine these indicators one by one.

`Problem Jumps`
: Cohen, March and Olsen (1972) count "the total number of times that any problem shifts from one choice [opportunity] to another". We translated this indicator with "Problem Jumps", counting the number of times a problem jumps from one opportunity onto another one. In our model, this indicator is equivalent to the number of flights; it has been included only for compatibility with Cohen, March and Olsen's model. However, since Cohen, March and Olsen's model is such that all problems move in block from one opportunity to another (Bendor, Moe and Shotts 2001), our indicator is inherently different from theirs.

`Problem Bindings`
: Cohen, March and Olsen (1972) count "the total number of time periods that a problem is

active and attached to some choice [opportunity], summed over all problems". By means of this indicator Cohen, March and Olsen want to express the idea that a problem might be solved because a choice opportunity is there, but instead it is not solved. We expressed this idea by means of the length of time a problem cannot be solved, either because it is in a blocked decision process where participants have too low energy or because it is flying away with an opportunity. Following Cohen, March and Olsen, we summed this quantity over all problems. In order to express the idea that a problem is "attached", or bound to an opportunity, we called this indicator "Problem Bindings".

`Problem Latency` Cohen, March and Olsen (1972) define "Problem Latency" as "the total number of periods a problem is active, but not attached to a choice [opportunity], summed over all problems". We interpreted "being active" as "being in the organization" and measured problem latency by the length of time a problem is in the organization without being bound to any opportunity. Following Cohen, March and Olsen, we summed this quantity over all problems.

`Unsolved Problems`

Cohen, March and Olsen (1972) count "the total number of problems not solved at the end of the 20 time periods". Following this statement, we defined the indicator "Unsolved Problems" as the number of problems in the organization at the end of the simulation. Note that this indicator only makes sense if — as in the case of Cohen, March and Olsen's simulations — problems exit the organization once they have been solved. Since it is not necessarily so, our model allows to select this mode or its opposite by means of the switch `problems-exit?`. Obviously, Unsolved Problems is computed only if this switch is ON.

`Participant Jumps`

Cohen, March and Olsen (1972) measure "the total number of times that any decision-maker shifts from one choice [opportunity] to another". We translated this indicator with the number of times a participant leaves an opportunity after staying some time with it. This happens because of a flight. However, this indicator is not equivalent to the number of flights that cause decision-making because several participants may be involved. Similarly to Problem Jumps, our indicator may be inherently different from Cohen, March and Olsen's because their model is such that all participants move in block from one opportunity to another (Bendor, Moe and Shotts 2001).

`Participant Bindings`

Cohen, March and Olsen (1972) count "the total number of time periods a decision-maker is attached to a choice [opportunity], summed over all decision-makers". In our model, a participant is bound to an opportunity over several time steps only when it is involved in a blocked decision process. Thus, we defined "Participants Bindings" as the length of time a participant cannot make a decision because (s)he is involved in problems for which (s)he does not have sufficient energy, summed over all participants.

`Used Energy`

Cohen, March and Olsen measure "the total amount of effective energy available and used". By "effective energy available and used", Cohen, March and Olsen (1972) mean participants's energy multiplied by the solution coefficient that, in their computational model, stands for solutions as independent agents. However, since participants use their energy independently of the solutions that they employ, we deem that the efficiency of solutions should have no place in this definition. Furthermore, Used Energy should be defined also when decisions are made by oversight so the efficiency of the solution does not play any role. Thus, our indicator Used Energy measures the cumulative energy expended by all participants involved in decision-making, both by resolution and by oversight.

`Excess Energy`

Cohen, March and Olsen (1972) measure "the total effective energy used on choices [decisions] in excess of that required to make them at the time they are made". In our context, this is the difference between the cumulative energy used by all participants who resolved problems, multiplied by the efficiency of the solution that they employed (i.e., Used Energy), and the cumulative energy of all the problems that they solved. Excess energy is not computed when a decision is made by oversight.

`Unexploited Opportunities`

Cohen, March and Olsen (1972) measure "the total number of choices [decisions] not made by the end of the 20 time periods". If opportunities exit when a decision is made, then the number of opportunities in the simulation denotes the number of unexploited occasions for making a decision. Thus, we defined Unexploited Opportunities as the number of opportunities left at the end of the simulation. This indicator is not available if the switch `opportunities-exit?` is OFF.

`Waiting Time`

Cohen, March and Olsen (1972) measure "the total number of periods that a choice [an opportunity] is active, summed over all choices [opportunities]". In fact, if opportunities exit when a decision is made, then the time they spent in the organization measures the time before a decision was made. Thus, we defined an indicator Waiting Time as the time to be waited before a choice opportunity is used, i.e. the cumulative lifespan of all opportunities. This indicator is not available if the parameter `opportunities-exit?` is OFF.

5.3

If the decision structure is either hierarchical or specialized participants are characterised by a degree of importance, meaning that only certain participants are allowed to make use of certain opportunities. Likewise, if the access structure is either hierarchical or specialized problems are characterised by a degree of importance, meaning that only certain problems gain access to certain choice opportunities. In both cases, choice opportunities are ordered by their importance as well.

5.4

Cohen, March and Olsen (1972) make certain claims concerning the quality of decision-making (by oversight or by resolution) depending on the importance of opportunities. In order to verify these claims, we need indicators of the number of resolutions and oversights per classes of importance of opportunities. Since some of these claims involve the possibility of different trends within classes of low importance and classes of high importance, we need to subdivide opportunities in at least four classes of importance in order to verify all claims.

5.5

The degree of importance of opportunities, just like the degree of importance of participants and problems, is indicated by their identification number. The lowest numbered opportunities are the most important ones. Since the number of opportunities may vary during a simulation, the classes of importance of opportunities must be defined in percent terms with respect to their current population. Four quartiles have been defined by subdividing opportunities into four groups of equal size at each simulation step.

- %O-I reports the percentage of decisions by oversight over total decisions, that are made on opportunities in first quartile. The first quartile entails one fourth of all opportunities, the most important ones.
- %O-II reports the percentage of decisions by oversight over total decisions, that are made on opportunities in the second quartile. The second quartile entails one fourth of all opportunities, just less important than those of the first quartile.
- %O-III reports the percentage of decisions by oversight over total decisions, that are made on opportunities in the third quartile. The third quartile entails one fourth of all opportunities, less important than those of those of the second quartile and yet not the least important ones.
- %O-IV reports the percentage of decisions by oversight over total decisions, that are made on opportunities in the fourth quartile. The fourth quartile entails one fourth of all opportunities, the least important ones.
- %R-I reports the percentage of decisions by resolution over total decisions, that are made on opportunities in first quartile. The first quartile entails one fourth of all opportunities, the most important ones.
- %R-II reports the percentage of decisions by resolution over total decisions, that are made on opportunities in the second quartile. The second quartile entails one fourth of all opportunities, just less important than those of the first quartile.
- %R-III reports the percentage of decisions by resolution over total decisions, that are made on opportunities in the third quartile. The third quartile entails one fourth of all opportunities, less important than those of the second quartile and yet not the least important ones.
- %R-IV reports the percentage of decisions by resolution over total decisions, that are made on opportunities in the fourth quartile. The fourth quartile entails one fourth of all opportunities, the least important ones.

These indicators are not available if the opportunities do not exit the organization after decision-making, or if both the decision structure and the access structure are non-segmented. Furthermore, even if these conditions are satisfied these indicators remain unavailable until at least one decision is made.

Results

6.1

Cohen, March and Olsen (1972) drew the following conclusions from their simulations:

1. Only a few decisions solve problems. Most decisions are made by oversight.
2. The efficiency of an organized anarchy depends on the energy (difficulty) of the problems that it is called to solve.
3. Some problems stay unsolved for a long time, independently of the structure of decisions and the structure of accesses.
4. Participants and problems chase one another across choice opportunities. Thus, the participants have the impression of facing always the same problems.
5. If opportunities are ordered by importance, then the most important opportunities are least likely to solve problems.
6. If opportunities are ordered by importance, then the unexploited opportunities are most often the most important and the least important ones.
7. If problems are ordered by importance, then the most important problems are solved first.
8. Hierarchical and specialized structures have non-linear effects that cannot be isolated from one another.

6.2

These properties have been derived from simulations lasting 20 steps, where 10 participants are present all the time, 10 opportunities enter the organization one at each step during the first 10 steps and 20 problems enter the organization two at each step during the first 10 steps. All participants had energy (ability) equal to 0.55, the solution coefficient was 0.6 and all problems had energy (difficulty) equal to 1.1, 2.2 or 3.3. We want to translate these parameters into our model, check the above properties (1)-(8) at the settings of Cohen, March and Olsen and, subsequently, in more general conditions.

6.3

The following parameters are as close as possible to those employed by Cohen, March and Olsen (1972). Let us impose that all participants have energy (ability) equal to 1.0, that all solutions have efficiency equal to 1 and that all problems have energy (difficulty) equal to 1.5. In this way, similarly to the original setting it is necessary to have at least two participants in order to solve a problem. In general we run the simulation for 200 steps (instead of 20), with 100 participants (instead of 10) who never exit the organization, and 200 opportunities (instead of 10) entering the organization during the first 100 steps and exiting it after they have been used for making a decision. In some experiments we run the simulation assuming 100 solutions that never exit the organization and 400 (instead of 20) problems that enter the organization during the first 100 steps and exit it after they have been solved.

6.4

Most parameters have been multiplied by 10 with respect to the original simulation (Cohen, March and Olsen 1972). However, a higher proportion of opportunities is necessary because they are not selected deterministically as in the original simulation. The proportion of problems is also higher than in the original simulation, making it even more likely that decisions are made by resolution and thus stressing the final result. Henceforth, these values will be referred to as base values.

6.5

Our NetLogo implementation of the GCM disconfirms properties Nos. 6, 7 and 8, which may be considered not to be any longer relevant or meaningful. In contrast, properties Nos. 1, 2, 3, 4 and 5 are confirmed. Their validity across alternative implementations of the GCM suggests that these properties can illuminate a number of interesting aspects of the original model. Let us examine them in detail.

Most Decisions are made by Oversight.

6.6

The first property of the GCM is that most decisions are made by oversight. Indeed, Figure 12 shows that at base values the proportion of decisions by oversight is much higher than the proportion of decisions by resolution.

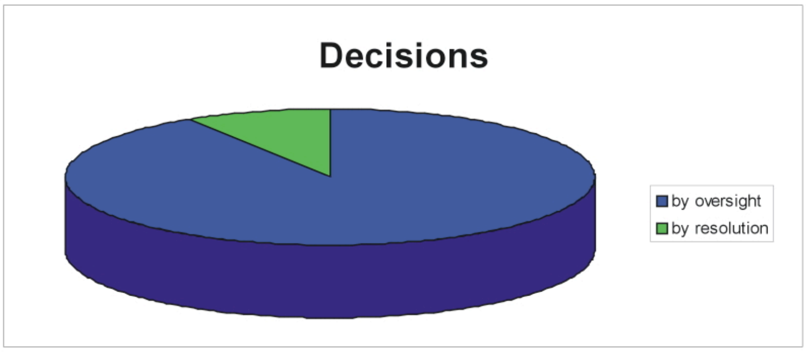

Figure 12. The proportion of decisions by oversight and by resolution with respect to total decisions, with all parameters at base values. Outcomes have been averaged over 100 runs

6.7

This result is very stable for any parameters configuration. The reason is simply that it is much more likely that three agents are in the same position (a participant, an opportunity and a solution) than that four agents are in the same position (a participant, an opportunity, a solution *and* a problem) and, furthermore, that the condition (5) is satisfied.

6.8

This dynamics makes our result even more robust than in Cohen, March and Olsen's original simulations. In fact, in Cohen, March and Olsen's model there did exist parameters configurations where most decisions were made by resolution. On the contrary, in our agent-based version of the GCM this result holds for any parameter configurations, even very far from base values.

6.9

A similar pattern is observed if we distinguish between flights that cause decisions by oversight and flights that cause decisions by resolution. However, Figure 13 shows also that most flights do not cause any decision at all. Eventually, they may be followed by another flight after some time.

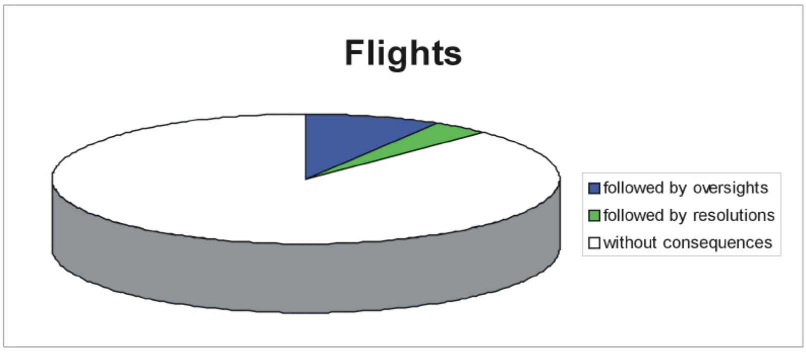

Figure 13. The proportion of flights followed by decisions by oversights, flights followed by decisions by resolution and flights without immediate consequences when all parameters are at base values. Outcomes have been averaged over 100 runs

6.10

Outcomes of experiments where parameters were set very far from their base values indicate that there exist configurations such that the number of flights that cause decisions by resolution is approximately equal to the number of flights that cause decisions by oversight. However, in these cases the total number of decisions is rather small.

Efficiency Depends on the Difficulty of Problems

6.11

Cohen, March and Olsen (1972) claim that the efficiency of an organization, measured by its ability to solve problems, decreases with problem difficulty. Specifically, they measure the un-efficiency of decision making by means of the following compound indicators:

- The *activity of problems*, measured by the number of jumps made by a problem from an opportunity to another one (`Problem Jumps`), by the number of steps during which a problem is bound to a particular opportunity (`Problem Bindings`) and by the number of unsolved problems (`Unsolved Problems`) at the end of the simulation.
- The *activity of participants*, measured by the number of jumps made by a participant from an opportunity to another one (`Participant Jumps`), by the number of steps during which a participant is bound to a particular opportunity (`Participant Bindings`), by the amount of energy used (`Used Energy`) and by the energy used in excess with respect to what had been strictly necessary (`Excess Energy`) at the end of the simulation. However, we have checked that the ratio of Used Energy to total decisions and the ratio of Excess Energy to resolutions are better descriptors of the inefficiency of decision-making (Fioretti and Lomi 2008).
- The *difficulty to make a decision*, measured by the number of unexploited opportunities (`Unexploited Opportunities`) and by the time to wait before a decision is made (`Waiting Time`) at the end of the simulation.
- The number of flights and the number of decisions by oversight at the end of the simulation. However, we have checked that the ratio of oversights to total decisions is a better indicator of the inefficiency of decision-making (Fioretti and Lomi 2008).

6.12
All these indicators are expected to increase with the difficulty of problems. Cohen, March and Olsen claim that they do, though only aggregate values (of unspecified indicators) are shown in their article (Cohen, March and Olsen 1972).

6.13
Figure 14 illustrates the percent variations of the above indicators with respect to the difficulty of problems. Their values have been set at 100 when the difficulty of problems is 0.5. Since the percent variations differ widely from one another, logarithmic values have been shown.

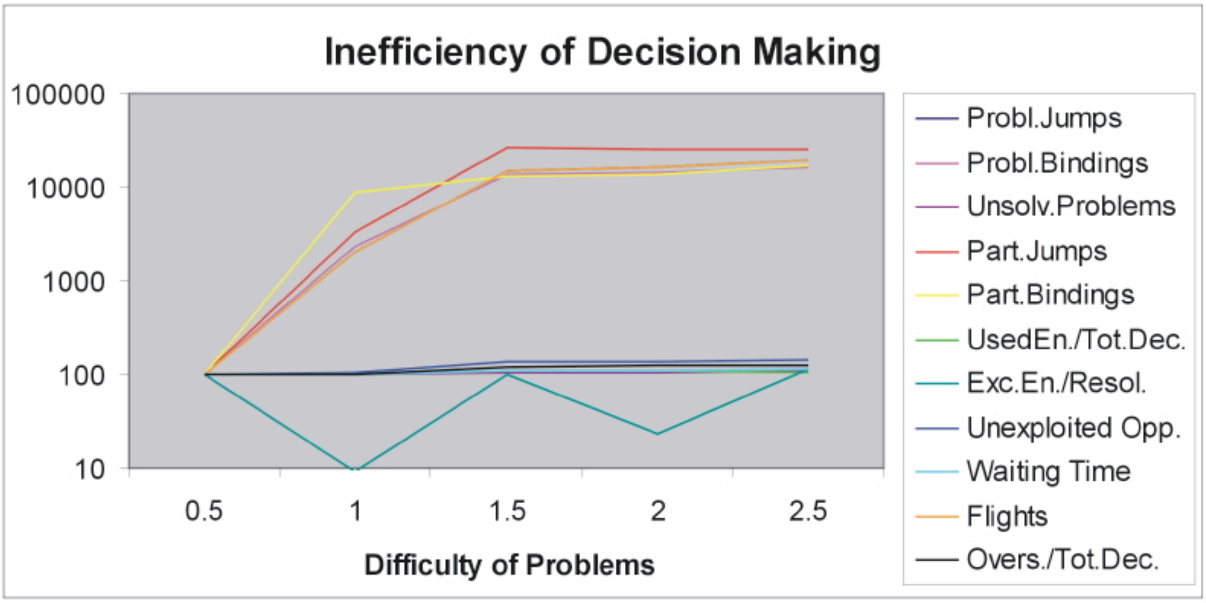

Figure 14. The indicators proposed by Cohen, March and Olsen (1972) to represent the inefficiency of decision making, plotted as functions of the difficulty of problems. Logarithmic scale of percent values. Original values have been averaged over 100 runs

6.14
Figure 14 highlights that the following indicators are particularly sensitive to the difficulty of problems: `Problem Bindings`, `Participant Jumps`, `Participant Bindings`, and `Flights`. Since all these indicators are closely related to the number of flights, we may conclude that this is the feature of decision-making that is most affected by the difficulty of problems.

6.15
Casual explorations of the parameters space have shown that this property is robust for all values of difficulty greater than the product of average efficiency with average ability, and smaller than the product of average efficiency with the sum of the abilities of a number of participants that, given the total number of participants and the available space, are sufficiently likely to gather at an opportunity.

6.16

Finally, Cohen, March and Olsen (1972) also claim that in organizations with specialized decision structure and non-segmented access structure the efficiency of decision-making is independent of the difficulty of problems, but that this only occurs because such organizations simply do not solve any problem. Our agent-based model does not confirm this claim (Fioretti and Lomi 2008).

Many Problems Remain Unsolved

6.17

Cohen, March and Olsen (1972) observed that many problems stay unsolved for quite a long time. Thus, they asked whether particular decision or access structures would perform better under this respect.

6.18

Since in their setting — as well as according to our "base values" — when a decision by resolution is made the corresponding problem exits the organization, March and Olsen evaluated the tendency not to solve problems by means of the following indicators:

- The time spent by problems inside the organization before some participant attempts to solve them (`Problem Latency`);
- The number of unsolved problems in the organization at the end of the simulation (`Unsolved Problems`);
- The time an opportunity remains in an organization, waiting for a decision to be made on it (`Waiting Time`).

6.19

We evaluated these indicators with all parameters at base values, but, since we aimed at reaching general conclusions, we also explored a neighbouring region in parameters space. Since we know that the difficulty of problems may affect efficiency (§5.2), we measured the above indicators for problem difficulty at 0.5, 1.5 and 2.5 (all other parameters at base values). Figures (15), (16) and (17) illustrate the results.

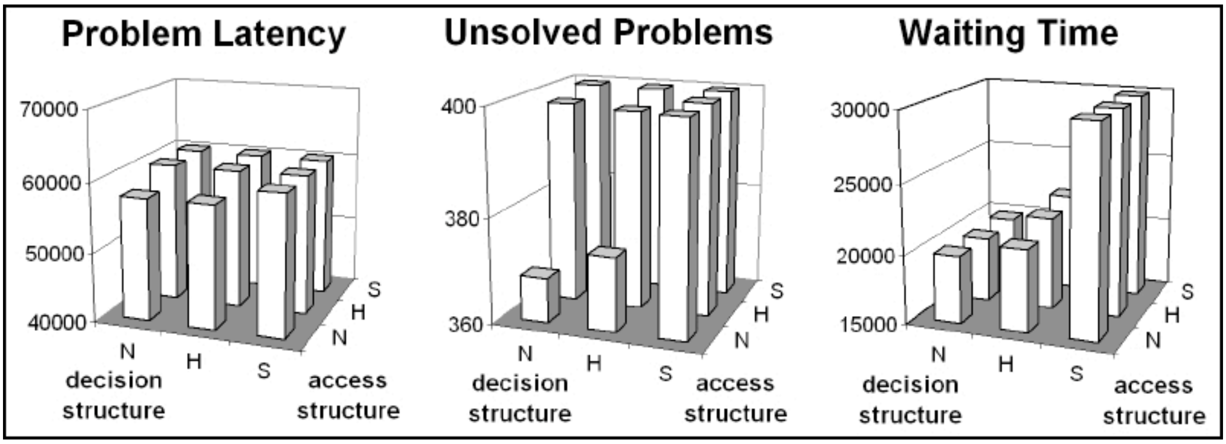

Figure 15. Problem latency, number of unsolved problems and waiting time when problem difficulty is at 0.5. The labels N, H and S denote the non-segmented, hierarchical and specialized structure, respectively. All other parameters at base values. Outcomes have been averaged over 100 runs

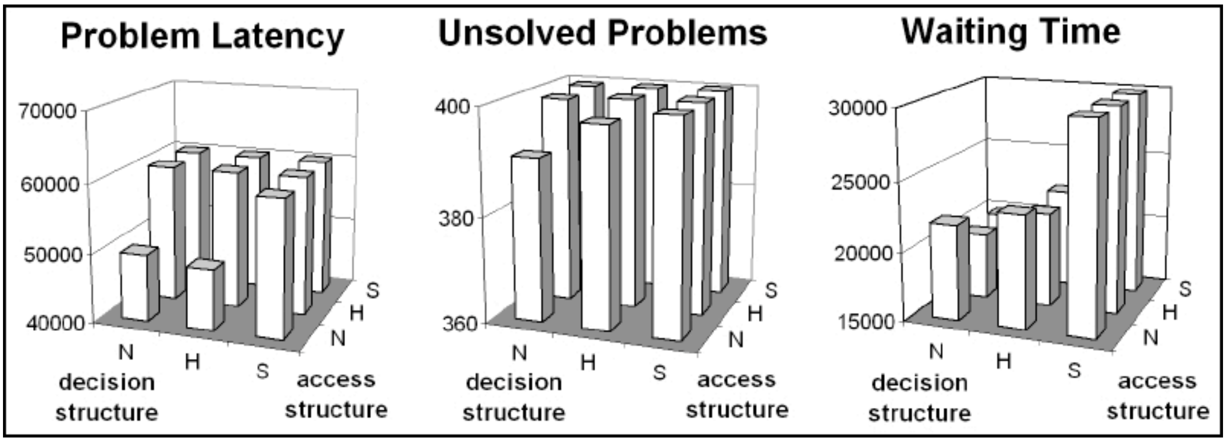

Figure 16. Problem latency, number of unsolved problems and waiting time when problem difficulty is at 1.5. The labels N, H and S denote the non-segmented, hierarchical and specialized structure, respectively. All other parameters at base values. Outcomes have been averaged over 100 runs

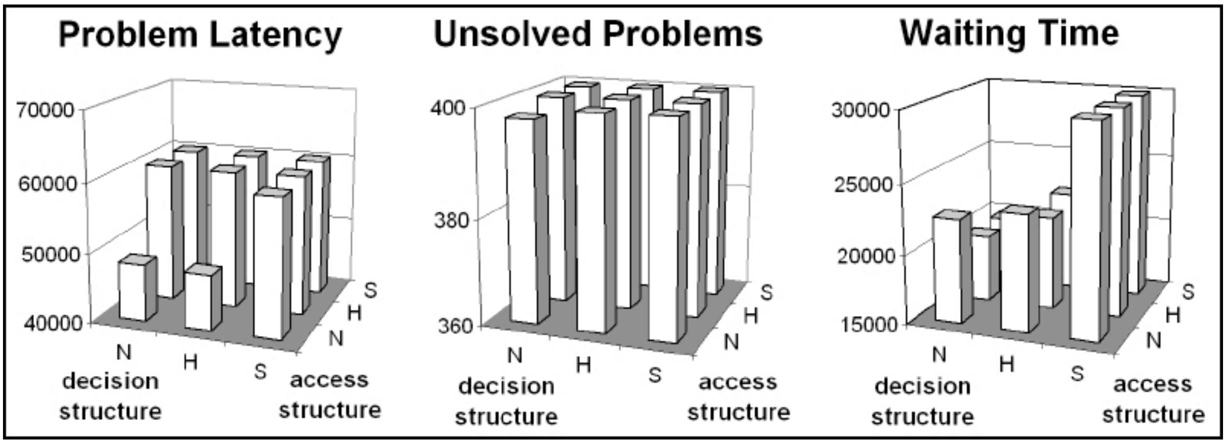

Figure 17. Problem latency, number of unsolved problems and waiting time when problem difficulty is at 2.5. The labels N, H and S denote the non-segmented, hierarchical and specialized structure, respectively. All other parameters at base values. Outcomes have been averaged over 100 runs

6.20

Cohen, March and Olsen (1972) carried out a separate analysis of each indicator. Let us compare their findings with those produced by our model:

`Problem Latency`
: According to Cohen, March and Olsen hierarchical and specialized decision structures decrease problem latency. In contrast, hierarchical and specialized access structures increase problem latency. In our model, hierarchical decision structures may slightly decrease problem latency if the access structure is non-segmented and all parameters are at base values but in general, the effect is in the opposite direction. Also specialized decision structures always increase problem latency. These results are different from those of Cohen, March and Olsen. However, in our as in the original simulation hierarchical and specialized access structures increase problem latency.

`Unsolved Problems`
: According to Cohen, March and Olsen hierarchical and specialized decision structures increase the number of unsolved problems. In contrast, hierarchical and specialized access structures decrease the number of unsolved problems. Our model confirms the first claim, but falsifies the second one. In fact, hierarchical or specialized structures mark a sharp increase of the number of unsolved problems. A partial exception is the configuration with hierarchical decision structure and non-segmented access structure when problem difficulty is 0.5, in which case the increase of the number of problems is not as large as in the other cases — see Figure 15.

`Waiting Time`
: According to Cohen, March and Olsen hierarchical and specialized decision structures increase the waiting time. Furthermore, hierarchical and specialized access structures have "in most cases" the same effect. According to our model, hierarchical and specialized access structures increase the waiting time if they are combined with specialized decision

structures but, if problem difficulty is sufficiently large, they can decrease the waiting time if they are combined with a non-segmented or hierarchical decision structure.

6.21

In general, our agent-based model suggests that hierarchical or specialized structures increase all three indicators. Furthermore, it points to the following notable properties:

- If the decision structure is non-segmented and if the difficulty of problems is sufficiently high, hierarchical or specialized access structure are able to decrease the waiting time, though the other two indicators increase.
- The configuration with hierarchical decision structure and non-segmented access structure is quite peculiar. It is the only configuration where, if problem difficulty is sufficiently low, the number of unsolved problems increases very little with respect to the configuration where both structures are non-segmented. It is also the only configuration where, if problem difficulty is sufficiently high, latency can slightly decrease with respect to the configuration where both structures are non-segmented.
- Independently of access structure and independently of the difficulty of problems, if the decision structure is specialized the waiting time is extremely high.

The Same Problems Again and Again

6.22

Cohen, March and Olsen (1972) claimed that in the GCM participants and problems chase one another across choice opportunities. Thus, the participants have the impression of facing the same problems again and again.

6.23

This claim has been challenged by Bendor, Moe and Shotts (2001), who observed that this is not an emergent property of Cohen, March and Olsen's simulation but rather a hypothesis of their implementation of the GCM. In fact, Cohen, March and Olsen's implementation of the GCM requires that all participants and all problems utilise one choice opportunity at a time. Thus, all participants meet always the same problems because they are forced to do so. It is not a spontaneous consequence of the verbal theory, but an artefact obtained by adding a mechanism that is not in the theory.

6.24

Olsen replied to Bendor, Moe and Shotts that this property is crucial to the GCM and, for this reason, it was explicitly included in the computational model (Olsen 2001). Nevertheless, it would be interesting if it could simply emerge from the general principles of the GCM, rather than being imposed on it.

6.25

Let us run the model with the assumption that, each time a decision is made, the opportunities, the solutions and the problems involved in it exit the organization. In contrast, participants stay. In this conditions it is possible to define approximate measures for the fraction of times that participants meet opportunities, solutions and problems that they have already met.

6.26

The number of times that a participant meets an opportunity is approximately equal to the number of decisions by resolution and by oversight, plus the number of flights because the participant meets an opportunity that takes away a problem, plus the number of meetings spent on blocked decision processes because s(he) meets the same opportunity again and again. Let us suppose that meetings on blocked decision processes are made with the purpose of disengaging decision-making by means of a flight. Thus, the number of these meetings is also equal to the number of flights. Since only this last term refers to meetings with opportunities that have already been met, the fraction of *dejà vu* opportunities is:

$$d_{opp} \approx \frac{flights}{oversights + resolutions + flights \times 2} \times 100 \quad (6)$$

6.27

The number of times that a participant meets a solution is approximately equal to the number of decisions by resolution and by oversight, plus the number of meetings spent on a blocked decision process because (s)he meets the same solution again and again. With a similar reasoning as above, the fraction of *dejà vu* solutions is:

$$d_{sol} \approx \frac{flights}{oversights + resolutions + flights} \times 100 \quad (7)$$

6.28

The number of times that a participant meets a problem is approximately equal to the number of decisions by resolution plus the number of meetings spent on a blocked decision process because (s)he meets the same problem again and again. With a similar reasoning as above, the fraction of *dejà vu* problems is:

$$d_{pro} \approx \frac{flights}{resolutions + flights} \times 100 \quad (8)$$

6.29

Equations (6), (7) and (8) are exact if all meetings concern one participant, one opportunity, one solution and eventually one problem. To the extent that this is not the case, they yield approximate values.

6.30

Let us run the model for 200 steps with 200 initial participants, opportunities, solutions and problems, no in- or outflows except that opportunities, solutions and problems (but not the participants) exit the organization once decisions are made, non-segmented structures and energy levels at base values. We obtain $d_{opp} \approx 13.4\%$, $d_{sol} \approx 15.5\%$ and $d_{pro} \approx 63.2\%$. Figure 18 illustrates these figures.

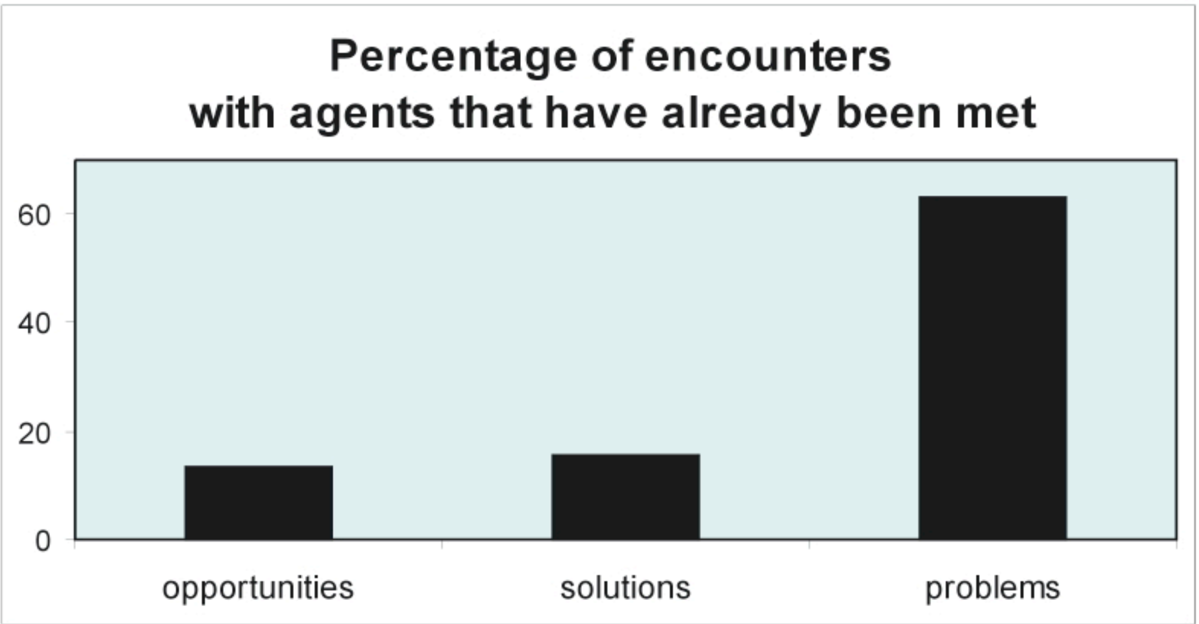

Figure 18. Percentage of the total number of encounters with opportunities, solutions and problems, that occur with opportunities, solutions and problems that have already been met. In order to measure these quantities it has been stipulated that opportunities, solutions and problems exit the organization once a decision is made, and that no other in- or out-flows take place. All other parameters are at base values. Outcomes have been averaged over 100 runs

6.31

Note that, in order to measure these quantities, we had to stipulate that not only opportunities and problems, but also solutions exit the organization after a decision is made. Furthermore, in order not to distort measurements with spurious data, all exogenous in- and outflows were set to zero. Having done this, the number of initial participants, opportunities, solutions and problems had to be changed. Even if their initial number was chosen to keep the simulation as close as possible to its base values, a departure from the parameters used in the previous sections could not be avoided.

6.32

Since it is not possible to make the above measurements for all possible combinations of parameters, the above results cannot claim the same generality as those of the previous sections. However, by running the model with random combinations of admissible parameters the numerical outcomes change but the prevalence of dejà vu problems remains. Thus, qualitatively the results of Figure 18 are relatively general in the context of the model.

6.33

These results confirm Cohen, March and Olsen's claim. Notably, they have emerged spontaneously from the assumptions of the GCM. In fact, according to these assumptions the problems that block decision-making may eventually fly away and subsequently represent themselves. For this reason, participants end up with chasing the same old problems.

Few Problems are Solved on Important Opportunities

6.34

If either the decision structure or the access structure is hierarchical, the ordering of participants or problems in terms of importance reflects into an ordering of opportunities. Cohen, March and Olsen (1972) remarked that in these conditions on the most important opportunities very few decisions are made by resolution, much less than on the least important ones.

6.35

This property is intriguing, because it has a straightforward interpretation in the real world. In fact, it suggests that problems are actually solved at the shop floor, whereas deciding by oversight would be the rule for top managers.

6.36

In order to observe this property it is necessary to choose parameters that enable a large number of decisions by resolution. There should be enough many problems to solve and, furthermore, the energy distribution should be such that the problems of highest energy (difficulty) find participants of a corresponding high energy (ability).

6.37

In our simulator the distribution of energy may either be proportional to importance, or inversely proportional to importance. According to the first option, the most important participants have the greatest ability and the most important problems are the most difficult ones. According to the second option, the most important participants have the least ability and the most important problems are the least difficult. We deem that, for the purposes of this simulation, it is correct to select the first option both for participants and for problems.

6.38

Let us start with 100 participants, 200 opportunities, 100 solutions and 400 problems. Exogenous flows do not exist but, similarly to the setting of §4.1, opportunities and problems exit the organization after having been involved in decision-making. Energy values from 0 to 2 are distributed to participants and problems in order of importance, efficiency is equal to 1 and uniformly distributed to solutions. Simulations have been run for different numbers of steps.

6.39

Our model is able to measure the percentage of decisions by resolution on opportunities of different degree of importance (by means of %O-I, %O-II, %O-III, %O-IV, %R-I, %R-II, %R-III, %R-IV). Figure 19 reports these values for different combinations of structures distinguishing decisions by resolution depending whether they have been made on the 50% most/least important opportunities.

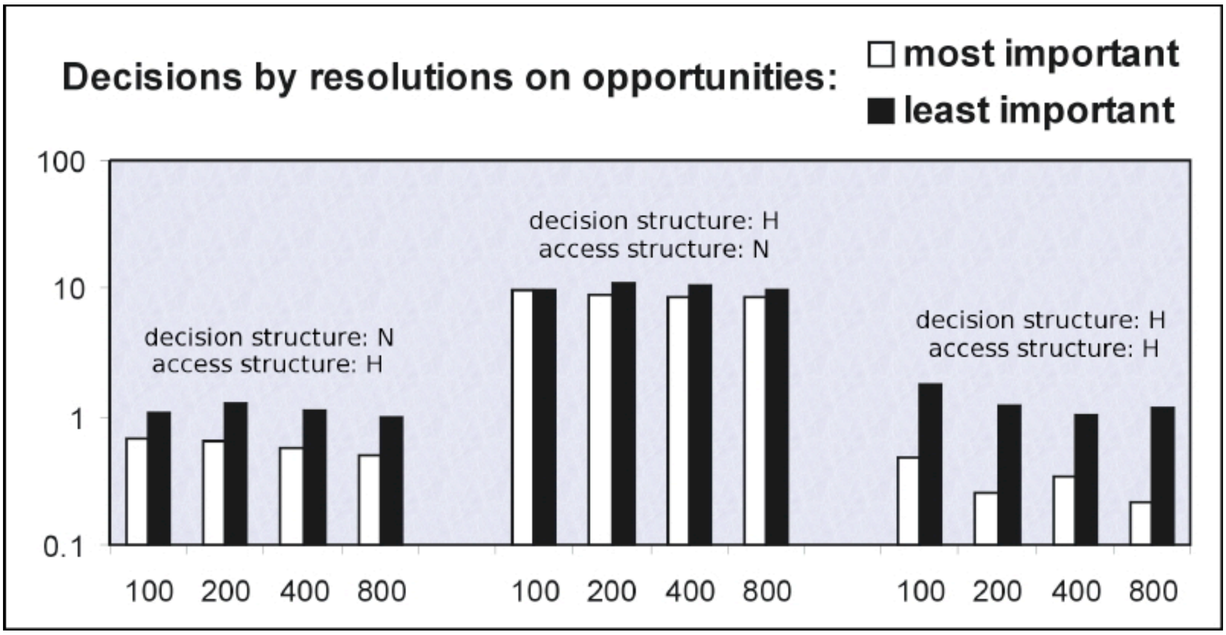

Figure 19. The percentage of decisions by resolution on the most important opportunities (white bars) and the least important opportunities (black bars), for various combinations of non-segmented (N) and hierarchical (H) structures. Outcomes have been averaged over 100 runs

6.40
Figure 19 confirms the claim made by Cohen, March and Olsen. In fact, the fraction of resolutions on the most important opportunities (white bars) is always lower than the fraction of resolutions on the least important opportunities (black bars).

6.41
Notably, Cohen, March and Olsen's claim has been extended to the configuration where both structures are hierarchical. Unfortunately, the configurations where one structure is hierarchical and the other one is specialized could not be considered because too few decisions were made by resolution. The results are robust with respect to parameter variations that still produce a large number of decisions by resolution, but the measurements cannot be carried out beyond this range.

6.42
All results have been shown for simulations running 100, 200, 400 and 800 steps in order to show why it happens that on the least important opportunities more decisions by resolution are made. In fact, most indicators show that the proportion of decisions by resolution first increases, then decreases with the number of steps. This means that in an initial phase the least important opportunities are preferred because all participants and all problems are allowed to use them. Subsequently, after the least important opportunities exited the organization only the most important ones can be used. Thus, the property that most decisions by resolution happen on the least important opportunities merely arises from the fact that all participants and all problems can access them.

Discussion and Conclusions

7.1
Our main goal in this paper was to re-interpret the original GCM as an agent-based model and verify whether the new representation would reproduce the insights that the original formulation supported. Although some among the less important conclusions had to be revised in the light of the results that we have reported, the main claims supported by the original GCM appear to be confirmed. In particular we found that — for a very wide range of parameter values — most decisions are indeed made by oversight. Furthermore, the decisions by oversight are made on the most important opportunities. Consequently, problems tend to stay unsolved for a long time and participants meet the same problems again and again.

7.2
An innovative aspect of our current work is that the properties of the GCM that we have observed in our simulation experiments do not derive directly from the internal structure of our

model — a critique frequently made to Cohen, March and Olsen's original simulation model (Bendor, Moe and Shotts 2001). Rather, we showed that these properties emerge from patterns of interaction among the agents that populate the "Garbage Can world" that we have re-created on the basis of the indications contained in the original paper. This observation suggests that other interesting speculations might be explored with relative minor modifications of the current model.

7.3

The analytical objectives that we pursued in this paper forced us to implement a rather literal a translation of the original GCM. As a consequence our own model suffers from many of the limitations of the original model. Yet, in the context of our representation these limitations suggest potentially interesting directions for future research. We identify at least four broad categories of limitations of the current model that may be conductive of future research efforts.

7.4

The first category of limitations is inherent to the assumption of independence between the different flows of agents that populate the model. In the light of more recent studies on organizational decision processes one limitation of the original GCM is its insistence on the independence of "problems," "solutions," and "participants" (decision makers). This has attracted severe criticism because within the GCM the decision makers appear as completely uninterested in the decisions they take (Bendor, Moe and Shotts 2001). As a consequence the GCM seems to lack some of the characteristics that we tend to associate more readily with organizations like, for example, routinisation, stabilisation and differentiation (Padgett 1980;Nelson and Winter 1982) or knowledge integration and knowledge management properties (Spender 1996;Spender and Grant 1996). Future refinements of the model could address this problem by equipping the different agents with more specific identities (not only with levels of energy). In this case specific problems could be taken only by specific decision makers and specific solutions could attach themselves only to specific problems. We feel that this joint representation of "resources" and "identities" would be a very fruitful direction for future research particularly in the light of the new literature on "identity-based" definitions of organizational forms (Hsu and Hannan 2005).

7.5

The second category of limitations of our current modelling effort is strictly related to the first. Agents in the GCM have no memory and therefore can form no expectations about future encounters. For the same reasons agents in the GCM cannot have meaningful search or learning strategies — an implication that seems at odds with established behavioural theories of organizations (Cyert and March 1963;Nelson and Winter 1982;Cohen and Sproull 1996;Greve 2003). Related to this point more attention could be dedicated to the representation of the degree of ambiguity that a given opportunity represents. This could be done, for example, by designing a probabilistic mechanism that regulates the outcome of the interaction between "problems," "decision makers," and "solutions." These limitations should not be particularly difficult to overcome in future refinements of the basic model. More recent research on organizational decision making that has emphasized the "forward looking" character of organizational decisions (Gavetti and Levinthal 2000) is likely to provide useful indications about how to design appropriate expectation formation mechanisms that may regulate and guide the problem-solving activity of the agents. A first step in this direction has been taken by Ashworth and Louie (2002) who attempt to align — or "dock" — the Garbage Can and the NK models.

7.6

The third category of limitations providing a clear opportunity for future research, concerns the lack of evolutionary mechanisms that regulate the dynamics of the original GCM in which arrival of different categories of agents into the model are simply generated by a stochastic queuing process. One direction in which we think the current model could be extended involves the design of evolutionary mechanisms responsible for the reproduction of the various agents at internal rates that may depend — for example — on some measure of relative "fitness." A similar direction is pursued by Lomi and Cacciaguerra (2003) in the context of a model of Garbage Can -like decision processes in which all the entities have differential reproduction rates that depend on their accumulated levels of energy.

7.7

Finally, it may be useful to reflect on the behaviour of the model across different scales and different patterns of entry and exit of the agents. A greater size of the model may simply imply an increase in the number of interacting agents but also an increase in hierarchical levels so that different "garbage cans" may be coupled within a complex hierarchy of decision processes (Baum 1999). In this paper we followed the lead of the original model and limited out attention to a small set of actors that enter the organization according to a schedule as similar as possible to the one employed by Cohen, March and Olsen (1972). How the results that we have reported would change across different scales, different event schedules, and across multiple hierarchical levels remains a matter for speculation. In particular, no prediction is possible about the ability of Garbage Can decision processes to coordinate organizational behaviour at much higher levels of system size and with more complex — possibly interdependent — rates of arrival and departure of the different agents into the model.

7.8

In the light of these various limitations our current effort is perhaps best understood as a fist step in the direction of reaching a fuller understanding of how computational approaches can shed light on a variety of issues that are of interest to students of organizations in the context of simulation models constrained and defined by clear theoretical claims.

Acknowledgements

Financial support for this work has been provided — in part — by MIUR (The Italian National Ministry of University and Scientific Research) through the FIRB research funding scheme (grant code number RBNE03A9A7_005)."

References

ASHWORTH M.J. and Louie M. (2002), *"*Alignment of the Garbage Can and NK Fitness Models: A virtual Experiment in the Simulation of Organizations*",* Carnegie Mellon University *working paper*, Pittsburgh.

AXELROD R. and Tesfatsion L. (2006), "A Guide for Newcomers to Agent-Based Modeling in the Social Sciences", in L. Tesfatsion and K.L. Judd (eds.) *Handbook of Computational Economics*, Vol. 2: *Agent-Based Computational Economics* (Appendix A), Elsevier North-Holland, Amsterdam.

BAUM J.A.C. (1999), "Whole-Part Coevolutionary Competition in Organizations", in J.A.C. Baum and B. McKelvey (eds.) *Variations in Organization Science: In Honor of Donald T. Campbell*, Sage Publications, Thousand Oaks.

BENDOR J., Moe T.M. and Shotts K.W. (2001), "Recycling the Garbage Can: An Assessment of the Research Program", *American Political Science Review*, 95, 169-190.

BURTON R.M. and Obel B. (1995), "The Validity of Computational Models in Organization Science: From model realism to purpose of the model", *Computational and Mathematical Organization Theory*, 1: 57-72.

CARLEY K.M. (1986a), "Measuring Efficiency in a Garbage Can Hierarchy", in J.G. March and R. Weissinger-Baylon (eds.), *Ambiguity and Command: Organizational Perspectives on Military Decision-Making*, Pitman Publishing Inc., Marshfield.

CARLEY K.M. (1986b), "Efficiency in a Garbage Can: Implications for crisis management", in J.G. March and R. Weissinger-Baylon (eds.), Ambiguity and Command: Organizational Perspectives on Military Decision-Making, Pitman Publishing Inc., Marshfield.

CHERRY B. (2000), "The Irony of Telecommunications Deregulation: Assessing the Role Reversal in U.S. and EU Policy", in I. Vogelsang and B.M. Compaine (eds.), *The Internet Upheaval: Raising Questions, Seeking Answers in Communication Policy*, The MIT Press, Cambridge (MA).

COHEN M.D. and March J.G. (1974), *Leadership and Ambiguity: The American college president*, McGraw-Hill, New York.

COHEN M.D., March J.G. and Olsen J.P. (1972), "A Garbage Can Model of Organizational Choice", *Administrative Science Quarterly*, 17, 1-25. Reprinted (1986) in J.G. March and R. Weissinger-Baylon (eds.), *Ambiguity and Command: Organizational Perspectives on Military Decision-Making*, Pitman Publishing Inc., Marshfield. Reprinted (1988) in J.G. March (ed.), *Decisions and Organizations*, Basil Blackwell, Oxford.

COHEN M.D. and Sproull L.S., eds. (1996), *Organizational Learning*, Sage Publications, Thousand Oaks.

CYERT R.M. and March J.G. (1963), *A Behavioural Theory of the Firm*, Prentice-Hall, Englewood Cliffs.

DAFT R. (1982), "Bureaucratic vs non bureaucratic structures and the process of innovation and change", *Researh in the Sociology of Organizations*, 1, 129-166.

DI MAGGIO P.J. and Powell W.W. (1983), "The Iron Cage Revisited: Institutional isomorphism and collective rationality in organizational fields", *American Sociological Review*, 48, 147-160. Reprinted (1991) in W.W. Powell and P.J. DiMaggio (eds.), *The New Institutionalism in Organizational Analysis*, The University of Chicago Press, Chicago.

FIORETTI G. and Lomi A. (2008), "The garbage Can Model of Organizational Choice: An Agent-Based Reconstruction", *Simulation Modelling Practice and Theory*, forthcoming.

GAVETTI G. and Levinthal D. (2000), "Looking forward and looking backward: Cognitive and experiential search", *Administrative Science Quarterly*, 45, 113.

GIBBONS R. (2003), "Team Theory, Garbage Cans and Real Organizations: Some history and prospects of economic research on decision making in organizations", *Industrial and Corporate Change*, 12, 753-787.

GREVE H. (2003), *Organization Learning From Performance Feedback. A Behavioural Perspective on Innovation and Change*, Cambridge University Press, Cambridge.

HSU G. and Hannan M.T. (2005), "Identities, genres, and organizational forms", *Organization Science,* 16, 474 - 490.

KINGDON J.W. (1984), *Agendas, Alternatives, and Public Policies*, Little, Brown and Company, Boston.

LAI S.K. (1998), "From Organized Anarchy to Controlled Structure: Effects of Planning on the Garbage-Can Decision Processes", *Environment and Planning B: Planning and Design*, 25, 103-126.

LAI S.K. (2003), "Effects of Planning on the Garbage-Can Decision Processes: A Reformulation and Extension", *Environment and Planning B: Planning and Design*, 30, 379-389.

LANE D.A. and Maxfield R.R. (2005), "Ontological Uncertainty and Innovation", *Journal of Evolutionary Economics*, 15, 3-50.

LEACH S. (1997), "The Local Government Review: A 'Policy Process' Perspective", *Local Government Studies*, 23, 18-38.

LEVITT B. and Nass C. (1989), "The Lid on the Garbage Can: Institutional Constraints on Decision Making in the Technical Core of College-Text Publishers", *Administrative Science Quarterly*, 34, 190-207.

LIPSON M. (2007), "A Garbage Can Model of UN Peacekeeping", *Global Governance*, 13, 79-97.

LOMI A. and Cacciaguerra S. (2003), "*Organizational Decision Chemistry Part I: Representation*." Paper presented at the 2003 Conference of the North American Association for Computational Social and Organizational Science (NAACSOS), Pittsburgh.

LOMI A. and Larsen E., eds. (2001), *Dynamics of organizations: Computational models and organization theories*, The MIT Press, Cambridge (MA) / AAAI Press, Palo Alto.

LYNN L.H. (1982), *How Japan innovates: A comparison with the U.S. in the case of oxygen steelmaking*, Westview Press, Boulder.

MARCH J.G. (1978), "Bounded rationality, ambiguity, and the Engineering of Choice", *The Bell Journal of Economics*, 9, 587-608.

MARCH, J.G. (1994), *A Primer on Decision Making*, The Free Press, New York.

MARCH J.G. (2001), "Foreword", in A Lomi and E. Larsen, (eds), *Dynamics of organizations: Computational models and organization theories*, The MIT Press, Cambridge (MA) / AAAI Press, Palo Alto.

MARCH J.G. and Olsen J.P., eds. (1976a), *Ambiguity and Choice in Organizations*, Universitetsforlaget, Bergen.

MARCH J.G. and Olsen J.P. (1976b), "Organizational Choice Under Ambiguity", in J.G. March and J.P. Olsen (eds.), *Ambiguity and Choice in Organizations*, Universitetsforlaget, Bergen.

MARCH J.G. and Olsen J.P. (1976c), "Organizational Learning and the Ambiguity of the Past", in J.G. March and J.P. Olsen (eds.), *Ambiguity and Choice in Organizations*, Universitetsforlaget, Bergen.

MARCH J.G. and Olsen J.P. (1989), *Rediscovering Institutions: The organizational Basis of Politics*, The Free Press, New York.

MARCH J.G. and Weissinger-Baylon R. (1986), eds., *Ambiguity and Command: Organizational Perspectives on Military Decision-Making*, Pitman Publishing Inc., Marshfield.

MARTIN J. (1981), "A Garbage Can Model of the Psychological Research Process", *American Behavioural Scientist*, 25, 131-151.

MASUCH M. and LaPotin P. (1989), "Beyond Garbage Cans: An AI model of organizational choice", *Administrative Science Quarterly*, 34, 38-67.

MEZIAS S.J. and Scarselletta M. (1994), "Resolving Financial Reporting Problems: An Institutional Analysis of the Process", *Administrative Science Quarterly*, 39, 654-678.

MILLER J. (2001), "Evolving Information Processing Organizations", in A. Lomi and E. Larsen (eds.), *Dynamics of organizations: Computational models and organization theories*, The MIT Press, Cambridge (MA) / AAAI Press, Palo Alto.

NELSON R.R. and Winter S.G. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge (MA).

OLSEN J.P. (2001), "Garbage Cans, New Institutionalism, and the Study of Politics", *American Political Science Review*, 95, 191-198.

PADGETT J.F. (1980), "Managing Garbage Can Hierarchies", *Administrative Science Quarterly*, 25, 583-602.

PETERS B.G. (1996), "Political Institutions, Old and New", in R. Goodin and H.D. Klingemann (eds.), *A New Handbook of Political Science*, Oxford University Press, New York.

RICHARDSON J. (2001), "Policy-making in the EU: Interests, ideas and garbage cans of primeval soup", in J. Richardson (ed.), *European Union: Power and policy-making*, Routledge, London.

ROMELAER P. and Huault I. (2002), "International Career Management: The Relevance of the Garbage-Can Model", CREPA *working paper* 80.

SCHELLING T.C. (1971), "Dynamic Models of Segregation", *Journal of Mathematical Sociology*, 1, 143-186.

SPENDER J.C. (1996), "Making Knowledge the Basis of a Dynamic Theory of the Firm", *Strategic Management Journal*, 17, 45-62.

SPENDER J.C. and Grant R.M. (1996), "Knowledge and the Firm: Overview", *Strategic Management Journal*, 17, 5-9.

TAKAHASHI N. (1997), "A Single Garbage Can Model and the Degree of Anarchy in Japanese

Firms", *Human Relations*, 50, 91–108.

WARGLIEN M. and Masuch M. (1996), eds., *The Logic of Organizational Disorder*, Walter De Gruyter, Berlin.

WEICK K.E. (1979), *The Social Psychology of Organizing*, Ch. VII, Random House, New York.

WEICK K.E. (1995), *Sensemaking in Organizations*, Sage Publications, Thousand Oaks.

ZAHARIADIS N. (2003), *Ambiguity & Choice in Public Policy*, Ch. VI, Georgetown University Press, Washington.