

Code Documentation

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1 Cohen, March and Olsen's Garbage Can

We discuss Cohen, March and Olsen's Garbage Can Model (GCM) in two subsections which have the purpose of illustrating the general principles of this model and the behaviour of its agents, respectively. In our presentation, we combine the original GCM with subsequent research that highlighted additional features of the basic model.

1.1 General Principles

According to the GCM, organizations can be seen as places where different sorts of agents occasionally meet and, under certain conditions, interact. In particular, four classes of agents populate the GCM: participants, or decision-makers, choice opportunities, solutions and problems. These agents move in a sort of chemical reactor where they occasionally meet; eventually, under conditions that will be specified henceforth, make decisions. Note that the GCM understands organizations as places where decision-makers have little control over the elements they need in order to make decisions, but can exploit serendipitous opportunity windows nevertheless.

In the GCM, two different sorts of organizational decisions are made:

- Decision-making *by resolution* is characterized by the fact that a problem is actually solved. In organizational contexts, solving problems can include anything ranging from planning members' activities, scheduling inputs and outputs, or developing innovative technologies to address consumers' needs.
- Decisions *by oversight* are made without paying any attention to existing problems. Contrary to decisions by resolution, decisions by oversight are not made in order to address specific problems but rather with the sheer purpose of showing that one is using the same solutions that many others are using.

The GCM envisages a third outcome, too. This is not a decision in itself but rather a means to escape from too difficult a problem by postponing it to some future date. This third outcome is called a *flight* because it amounts to flying away from problems, or at least from those that are too difficult to solve. Flights ease decision-making because once participants postponed a difficult problem it may be easier for them to make a

decision on the remaining ones. However, that problem is still there, it has been just postponed.

It has been suggested that buck-passing may be an additional mechanism for flying away from difficult problems [4]. Indeed, passing the buck means that organization members get rid of a difficult problem by attaching it to other organization members, a practice that has the consequence that the remaining problems may be more likely to be solved. For the sake of generality, our model will include both *flights by postponement* and *flights by buck-passing*.

1.2 Agents' Behaviour

According to the GCM, participants, opportunities, solutions and problems walk randomly in organization space. They occasionally meet, eventually making a decisions by resolution or oversight.

Decisions by oversight are easiest to tell. Occasionally, (at least) one participant, (at least) one solution and (at least) an opportunity meet on the same spot, and no problem is there. Whenever this happens, a decision by oversight is made. If several participants happen to be on that spot, all of them are involved in the decision. Note that such a decision is made without solving any problem, simply because no problem was there.

In order to implement decision-making by resolution the GCM assumes that participants are endowed with an *ability* to solve problems, that solutions are characterized by a degree of *efficiency* in solving problems, and that problems are ranked by degrees of *difficulty*¹. Decisions are made by resolution if: (i) the participants involved in a decision process have sufficient ability; (ii) a sufficiently efficient solution is available to them, and (iii) the problems that they are called to solve are sufficiently simple.

Thus, decisions by resolution can be made if (at least) one participant, (at least) one solution, (at least) one problem and (at least) an opportunity meet on the same spot and, additionally, a condition on participants' abilities, available efficiency and problems' difficulty is met. In a nutshell, participants' ability, multiplied by a solution's efficiency, must be greater or equal than problems' difficulty.

Let A_i denote the ability of the i th participant. Let e_j denote the efficiency of the j th solution. Let D_k denote the difficulty of the k th problem. Let us consider a generic opportunity for decision-making and let us denote it by an index l . A decision by resolution is made if the sum of the abilities of participants, multiplied by the efficiency of the most efficient among available solutions, is greater or equal to the sum of the difficulties of problems:

$$\left(\sum_{i \in I_l} A_i \right) \max_{j \in J_l} e_j \geq \sum_{k \in K_l} D_k \quad (1)$$

where I_l is the set of participants on opportunity l , J_l is the set of solutions on opportunity l and K_l is the set of problems on opportunity l .

¹Cohen, March and Olsen [1] actually spoke of the *energy* of participants and problems. We renamed these concepts into ability of participants and difficulty of problems, respectively.

When at least one participant, at least one solution and at least one problem meet with opportunity l but condition 1 is not satisfied, the decision process is blocked. A decision by oversight cannot be made because one or several problems are there, and a decision by resolution cannot be made either, because those problems are too difficult for available participants given the solutions that they can employ.

On such occasions, participants typically wish to get rid of the most difficult problems. Flights are the means to achieve this goal.

Making a flight by postponement means that a difficult problem will be addressed at a later, possibly unspecified point in time. In the GCM, participants postpone a difficult problem by attaching it to a different choice opportunity.

A blocked decision process stays put in space while all other participants, opportunities, solutions and problems keep moving randomly. If it happens that an opportunity ends up where (at least one) participant(s), a solution, an opportunity and (at least one) problem(s) are blocked, then the blocked participant(s) attach the most difficult problem to the newly arrived opportunity. This amounts to postponing the most difficult problem. From this forward, the postponed problem and its opportunity move randomly together until they meet one (or more) participant(s) and a solution who are able to solve that problem.

If the remaining problems are sufficiently simple, then a decision by resolution is made. If no problem is left after this flight, a decision by oversight is made. If the remaining problems are still sufficiently difficult to block decision-making, another flight will be attempted later on.

Making a flight by buck-passing means that a difficult problem is shifted to someone else, hopefully — but not necessarily — someone who is better able to solve it. In the GCM, buck-passing means that blocked participants pass their most difficult problem to a freely walking participant.

If a randomly walking participant ends up on a blocked decision process, the blocked participants pass on to him their most difficult problem, i.e., the buck. Henceforth, this problem and this participant move randomly together until they meet an opportunity, a solution and possibly other participants that succeed to solve the problem.

Just as it happens with flights by postponement, if the remaining problems are sufficiently simple, then a decision is made by resolution. If no problem is left after the flight, a decision is made by oversight. If the remaining problems are still sufficiently difficult to block any decision, another flight — either by postponement or by buck-passing — will be attempted later on.

Figure (1) illustrates a participant's algorithm for decision-making. Participants' goal is making decisions, either by resolution or by oversight, again and again. If neither is possible a flight is attempted, either by postponement or by buck-passing, until a decision becomes possible.

The basic GCM described so far has no organizational structure, as if organizations were places where equally ranked people occasionally participate into randomly occurring decision processes. Cohen, March and Olsen presented also a refined version [1] where they overcame this shortcoming by imposing exogenous structures on the model. They did so by assuming that opportunities are ranked by importance and that participants and problems would select opportunities depending on hierarchical level (for participants) and relevance (for problems). In our extension, structures arise

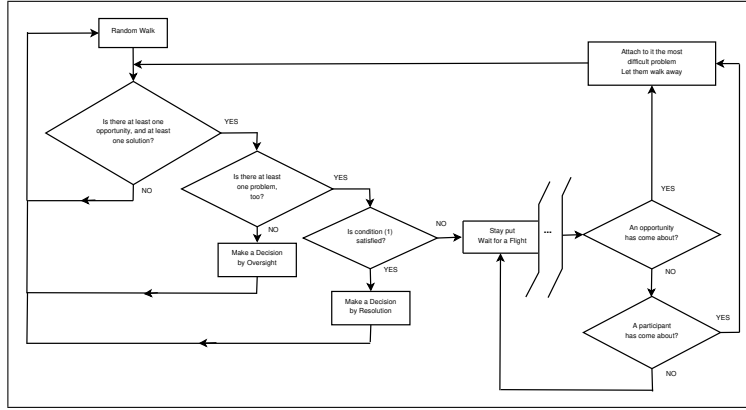


Figure 1: Participants' decision process in the GCM. A decision is attempted, either by resolution or by oversight. If no decision can be made because too difficult problems are there, a flight — either by postponement or buck-passing — may unlock the process.

endogenously as soon as organizations emerge.

2 An Ecology of Garbage Cans

In this section we expound our own model. First, its general principles in § (2.1). Secondly, the algorithms followed by our decision-makers in § (2.2).

2.1 General Principles

We envisage the following mechanisms for organizational evolutionary dynamics:

Birth If no organization exists, a new organization is born whenever an independent participant makes a decision, either by resolution or by oversight. The participant retains the solution that (s)he employed and this pair 'participant + solution' constitutes the core of the new organization, which stops moving while independent participants continue their random walk. The solution owned by an organization stays in the same location as the organization founder. If at least one organization already exists in the primordial soup, a diffusion mechanism operates as well (see below).

Diffusion Not all independent participants come to the idea of founding organizations. Only those who have met at least one organization try to imitate its founder. Thus, if at least one organization exists in the primordial soup, only those independent participants who have seen organizations in their neighbouring positions create in their turn a new one as soon as they make a decision.

Growth Randomly walking independent participants who happen to jump where a member of an organization is, they join that organization in the role of organization associates. Organization associates place themselves around the organization founder.

Death Organizations are born with an endowment of resources which is equal to their founder's ability. Throughout their existence, every time organizations make a decision by resolution they increase their endowment by the difficulty of the problems that they solved. However, at each time step their endowment decreases by a fixed decay rate multiplied by organization size. If this endowment shrinks down to zero, the organization is dismantled. The members of a dismantled organization become independent participants, their memory is erased so they act as if they never met any organization throughout their life. The solution owned by a dismantled organization becomes publicly available and start its random walk.

These forces generate a rich evolutionary dynamics that superimposes itself to the typical GCM decision processes. Decisions by resolution, decisions by oversight, flights by postponement and flights by buck-passing are made by independent participants with the same rules as in § (1). However, for organization members a few qualifications are in order:

- Organization members who make a decision *must* use their organization's solution even in the rare, but conceptually interesting case that a more efficient solution has become available on their location.
- Randomly walking problems approach organizations along their fringe. Unless organizations are very small, founders are at the centre whereas organization associates are on the fringe. Thus, low hierarchical levels typically receive more problems to solve than high hierarchical levels do, as Property P2 prescribes. In order to provide a symmetrical bias for decisions by oversight we imposed that opportunities approaching organizations meet the founder first, and later on proceed with their random walk either meeting organization associates or exiting the organization.
- Opportunities entering an organization's area are allowed to make one single decision before they exit (since organizations own a solution, they would make a disproportionately high number of decisions by oversight once an opportunity entered their area). The one exception is for opportunities that get involved in blocked decision processes.
- Organization members whose decision process is blocked on a very difficult problem can postpone it to any opportunity available in the organization that has not already been charged with a problem and is not involved in a blocked decision process. Unlike independent participants, they may not need to wait for a randomly moving opportunity to come where they are.

- Organization members whose decision process is blocked on a very difficult problem can pass it to any other organization member who has not already been charged with a problem (they can pass it to organization members who are stuck in a blocked decision process, anyway). Unlike independent participants, organization members do not need to wait for a randomly moving participant to come where they are in order to pass the buck.

2.2 The Algorithms

We illustrate the algorithms for organization members' behaviour by means of three flow charts. First, Figure (2) illustrates the circumstances that make independent participants join an organization, or eventually found a new one. Subsequently, Figure (3) recapitulates the rationales for making decisions by either resolution or oversight and the consequences for organizations that either accumulate resources or go bankrupt. Finally, Figure (4) illustrates how flights are sought, first by postponement, then by buck-passing, first outside the organization, then outside it. Figure (2) links to a block that pertains to Figure (3), so this block is shown in dashed lines in Figure (2). Likewise, Figure (3) links to a block that pertains to Figure (4) so this block is shown in dashed lines in Figure (3).

Figure (2) starts with independent participants making their random walk. Independent participants can possibly meet an organization if they happen to jump on a position where one of its organizations member is, or they can see an organization if they happen to jump on a position that has an organization member in one of its surrounding positions. Their random walk continues unless they meet an organization or, if they saw one, their random walk continues until they make a decision and found a new organization.

Figure (3) illustrates the consequences of decisions made by organization members. Since we assumed that problem-solving yields resources whereas obtaining social legitimacy does not, organizational resources may either increase or decrease depending on what decisions are made. If resources shrink down to zero organizations are dismantled, yielding independent participants that feed back into Figure (3).

Figure (4) illustrates flights by organization members. First flights by postponement are attempted, then flights by buck-passing. In each category, organization members first check with independent participants or opportunities that happen to be on the spot where a decision process is blocked. If there are none, then they either pass the buck to other organization members or look for opportunities that are at other sites occupied by the organization.

Independent participants who stay independent make decisions by resolutions, decisions by oversight and flights as in Figure (1). Likewise, opportunities, solutions and problems that have no contacts with organizations behave according to the basic GCM.

Figure (5) illustrates the algorithm of opportunities. Opportunities walk randomly anywhere, but special care must be taken as soon as they enter an area where an organization is. Opportunities randomly walking within the area occupied by an organization would make it make a decision by oversight at each step, which clearly makes little sense. In order to avoid this, we imposed that opportunities can only be involved once in a decision process once they entered an organization's area and until they exit it,

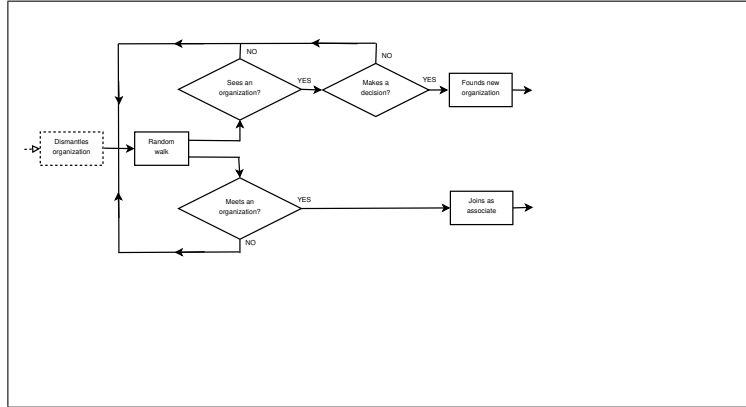


Figure 2: Independent participants join an organization if they happen to jump where an organization is. If they did not jump where an organization member is, but there is one in one of its neighbouring position, then those independent participants have “seen” an organization. Hence, the first time they make a decision they capture the solution that they used and found a new organization.

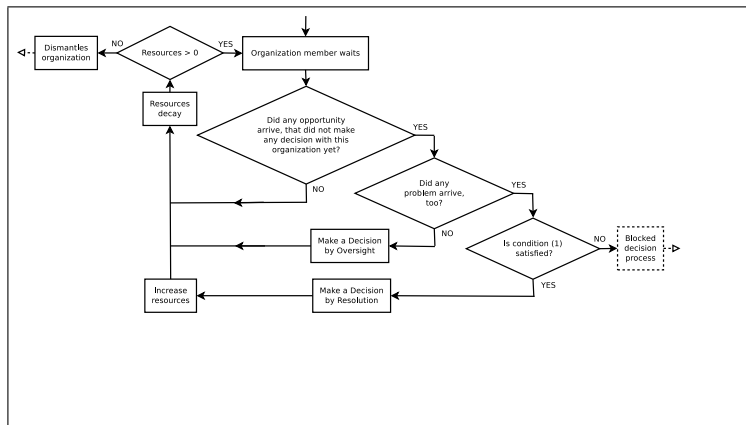


Figure 3: Organization members can only make decisions with opportunities that did not yet make any decision since they entered the organization’s area in their random walk. If they find one, they check whether a problem is there, too. If there is, they check whether condition (1) holds. Once all these hurdles have been overcome they can make a decision by resolution, which eventually increases the organization’s resources. If they do not, organizational resources decay until the organization is eventually dismantled.

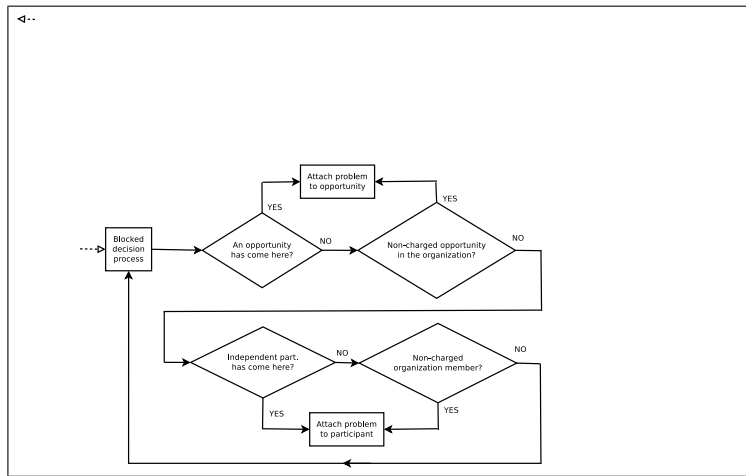


Figure 4: Organization members stuck in a blocked decision process first check whether a second opportunity has come where they are, then whether an opportunity that is not already charged with a problem is anywhere else in the organization. In either case, they attach their most difficult problem to that opportunity. If no opportunity is available, they first check whether by chance an independent participant has come where they are. If none did, they look for an organization member that is not already charged with a problem. In either case, they attach their most difficult problem to another participant.

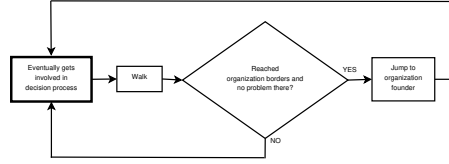


Figure 5: Opportunities walk around and, if they reach the borders of an organization and no problem is there, they jump to the place where the founder is where they either make a decision by oversight, or they continue with their random walk. The square representing decision-making has been depicted with thick borders because it subsumes many details of the decision process.

with the one exception of opportunities to whom a difficult problem is passed. This detail is not shown in Figure (6).

Furthermore, we want decisions by oversight to be preferably made at high hierarchical levels. Thus, if a freely moving opportunity reaches the borders of an organization and no problem is there (thus, no decision by resolution can be made), it immediately jumps to the founder or one of its closest organization members, provided that no problem is with them.

Figure (6) illustrate the algorithm of solutions. Solutions generally walk randomly, but they stay put when they are involved in blocked decision processes as well as when they serve as an organization's solutions.

Figure (7) illustrates the algorithm of problems. Since our organizations are made of associates that surround the founder at the centre, randomly walking problems naturally meet organization associates before founders, thereby generating the property that low hierarchical levels typically solve more problems than high hierarchical levels. In other words, organizations filter problems through hierarchical levels in order to let as few as possible reach the top. Thus, it is not necessary to add further mechanisms to problems simply walking around.

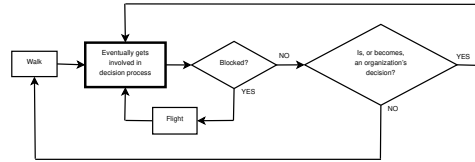


Figure 6: Solutions walk randomly unless they are involved in a blocked decision process or they are an organization's solution. With some simplification, this figure does not distinguish the point in time when a solution is captured by a founder from all the time it remains an organization's solution. The square representing decision-making has been depicted with thick borders because it subsumes many details of the decision process.

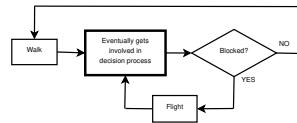


Figure 7: Unless involved in a blocked decision process, problems just walk around. The square representing decision-making has been depicted with thick borders because it subsumes many details of the decision process.

References

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- [2] Michael D. Cohen, James G. March, and Johan P. Olsen. A garbage can model of organizational choice. In James G. March and Roger Weissinger-Baylon, editors, *Ambiguity and Command: Organizational Perspectives on Military Decision-Making*, chapter Appendix, pages 311–336. Pitman Publishing Inc., Marshfield, 1986.
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