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Finding shared decisions in stakeholder networks: An agent-based approach

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HIGHLIGHTS

- The "Condorcet paradox" is a risk of public engagement in participatory planning.
- Agent-based models are suitable to reproduce opinion dynamics on stakeholder networks.
- Interaction is the key element for a transitive and shared group decision-making process.

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ABSTRACT

We address the problem of a participatory decision-making process where a shared priority list of alternatives has to be obtained while avoiding inconsistent decisions. An agent-based model (ABM) is proposed to mimic this process in different social networks of stakeholders who interact according to an opinion dynamics model. Simulations' results show the efficacy of interaction in finding a transitive and, above all, shared decision. These findings are in agreement with real participation experiences regarding transport planning decisions and can give useful suggestions on how to plan an effective participation process for sustainable policy-making based on opinion consensus.

1. Introduction

In this paper we present an agent-based model (ABM) able to mimic a participatory decision-making process where a given number of stakeholders, linked by a social network, exchange opinions (represented by their individual lists of preferences) in order to find a shared and transitive collective decision (i.e., a collective list). The model can be applied to all the decision-making contexts that involve participation in complex decisions with widespread collective impact, e.g. transport policy-making, environmental policy-making, land use planning, etc.

Lack of public participation in decision-making processes is considered one of the main causes of projects' failure [1], as confirmed by the wide diffusion of public infrastructure projects strongly opposed by the local community protests, with the so called "NIMBY" syndrome ("Not In My BackYard"). It is now widely recognised the importance of involving all the actors (i.e. the stakeholders) along the decision-making processes in order to choose decisions which reflect the real needs

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Table 1
Condorcet cycle resulted from aggregation of preference orders by the PMR (sh = stakeholder).

sh	Preference order	AB	AC	AD	BC	BD	CD
1	A > B > C > D	+1	+1	+1	+1	+1	+1
2	D > A > B > C	+1	+1	−1	+1	−1	−1
3	B > C > D > A	−1	−1	−1	+1	+1	+1
4	D > A > C > B	+1	+1	−1	−1	−1	−1
5	B > A > C > D	−1	+1	+1	+1	+1	+1
PMR result:		**+1**	**+1**	**−1**	**+1**	**+1**	**+1**
Collective list:		A > B > C > D > A					

and opinions of the interested parties (i.e. "most shared" solutions) rather than just the technically "best" ones. This is particularly true for policy-making at the urban scale, where citizens reflect a great variety of interests and opinions.

Public policy-making, in general, requires quantitative methods to evaluate to what degree each alternative satisfies a set of criteria selected to measure the achievement of objectives. Moreover, the decision-maker has to choose or make rankings among more than two alternatives (policies, projects or objectives). In such cases, decision-support methods (DSMs) such as Cost Benefit Analysis (CBA), or Multi Criteria Analysis (MCA) are considered adequate to assess the convenience of each alternative [2]. Finally, the decision-maker has to prioritise the alternatives, usually by a ranking scale. When it comes to participatory decision-making processes, the problem of aggregating individual preferences is not trivial, being largely investigated by social choice theory [3,4]. Indeed, the aggregation of individual stakeholders' preferences could determine an inconsistent decision and, most of all, it could not satisfactorily reflect stakeholders' expectations. Among the many different aggregation methods that can be used to this aim [5], one of the most commonly adopted is the so called Pairwise Majority Rule (PMR). Nevertheless, the result of aggregation by the PMR can be an intransitive collective preference list, also called "Condorcet cycle". This unpleasant phenomenon is also known as "Condorcet paradox" [6].

Based on these premises, the aim of the model here presented is twofold: first, try to understand how it is possible to avoid, through the opinions interaction, the decision deadlock that can arise from the aggregation of the individual preferences with the PMR; second, try to find a collective transitive list able to satisfy stakeholders to a high degree, i.e. to find a highly shared collective decision. In this respect, the model is suitable to simulate group dynamics occurring in participatory decision-making processes, where stakeholders with possibly heterogeneous preferences exchange opinions and, as a result of their interaction, consensus on a shared solution can emerge.

The paper is organised as follows. In Section 2 the problem of inconsistency is introduced together with some strategies elaborated in order to avoid it. In Section 3 an ABM is proposed to analyse some basic conditions to overcome inconsistency, whilst assuring an acceptable degree of collective consensus. There we discuss also the simulations performed and the results together with some preliminary considerations about model validation. Finally, Section 4 provides some general conclusions.

2. The problem of inconsistency in participatory decision-making processes

Let us start with a simple example showing the appearance of the "Condorcet paradox" when the PMR is adopted for generating a collective preference list by aggregating individual ones. Consider five stakeholders ($N = 5$), each one with an individual list of four alternatives A, B, C and D ($n = 4$). Using the PMR, the ranking of the collective list is obtained by computing how many times each alternative in a pair is preferred to the other one. In particular, the pairwise preferences of each individual list are coded as components of a binary vector assuming the values of +1 and −1.[1] Finally, the collective list is derived by applying a majority rule to the binary vectors. As already anticipated, the aggregation of single transitive preference lists by the PMR does not exclude the possibility of intransitive collective lists as result, thus violating the ordering axiom [3]. Actually, by applying the PMR to the individual preference orders shown in Table 1, the final result will be what is called a "Condorcet cycle", i.e. A > B > C > D > A.

It is easy to demonstrate that the probability of falling into a "Condorcet cycle" increases with the number of alternatives: given n alternatives, then $n!$ possible transitive orders do exist, while $n * (n-1)/2$ is the number of pairs and, therefore, $2^{n*(n-1)/2}$ are all the possible - transitive and intransitive - binary vectors. Therefore, the probability to have a transitive list will be $P(n) = \frac{n!}{2^{n*(n-1)/2}}$ and it rapidly decreases with n, going to 0 when $n \to \infty$ (Fig. 1(a)). A helpful way to visualise the increasing asymmetry between the number of transitive and intransitive lists when n increases is shown in Fig. 1(b), representing a simplified pictorial view of the "collective preference space": the black cells in the grid indicate the $n!$ transitivity "islands" randomly distributed over the much larger intransitivity "sea", represented by the white cells (for $n = 6$, only $n! = 720$ transitive lists out of 32748 possible lists exist).

It has been demonstrated that the occurrence of the paradox increases also with the number of agents, for example in "a large population of non interacting voters" [7]. On the other hand, the result changes if agents interact before deciding. Actually, interaction is at the basis of most of the traditional participation tools [8], even in the form of the "remote" and

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[1] As an example, for the couple of alternatives AB, if A is preferred to B then AB = +1, vice versa AB = −1.