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Modelling stakeholder participation in transport planning

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ABSTRACT

Public Participation in transport planning is often regarded as a formal compulsory phase of the decision-making process and it lacks in its real purpose, i.e. engaging people to find the most shared solution in the shortest time, in order to make the process effective and (cost) efficient. The need to include the public in transport planning and decision-making leads to the effort to understand how to design and speed up the process of taking a public decision and to find out if the communication among stakeholders can influence the process of governance.

In this paper an agent-based model is presented as a contribution to build new tools to support decision-makers and practitioners in designing and guiding effective participation processes. The model reproduces the interaction process in a network of stakeholders by means of a multi-state opinion dynamics and bounded confidence model as a basis to investigate the consensus formation phenomenon. The participatory decision-making process about the acceptability of a parking management strategy inside a University campus in Catania (Italy) was simulated to see to what extent interaction among stakeholders can foster the emergence of consensus. A better parking management is one of the priorities for sustainable mobility proposed by the mobility management office of the University. Results show that many links can help the opinion exchange process and the convergence of opinions and that the final outcome (i.e. approval or disapproval of the parking management strategy) is highly influenced by the initial distribution of opinions. This suggests that having a preliminary knowledge of stakeholders' opinions can be helpful to arrange the participation process and repeated interaction opportunities contribute in smoothing diverging opinions.

1. Introduction

Public participation is an important part of transport planning according to sustainability principles, as confirmed by the EU transport policy tendency, e.g. by fostering the adoption of Sustainable Urban Mobility Plans (Wefering et al., 2014). Transport planning would require a direct and continuous involvement of the public and all the interested parties (i.e. the stakeholders), given the nature of decisions, which are most of the time complex, and the impact these decisions can have on society. Transport planning is a dynamic process with top-down and bottom-up decision-making phases and participation can be at different levels, from stakeholder identification, to listening and communication, consultation and participation, up to the highest level of "citizen control" (Arnstein, 1969; Kelly et al., 2004; Cascetta and Pagliara, 2013; Le Pira et al., 2015a).

The concept of "stakeholder" was originally introduced by Freeman (1984) in the fields of Economy, where there is a well-established literature affirming that the power of a company lies on its relationships with them. Mitchell et al. (1997) report a chronology of the concept of stakeholder and the key constructs in their theory of stakeholder identification and salience.

In transport planning there are lots of different actors to involve, e.g. citizens, policy makers, public institutions, local communities, governmental organizations, NGOs, public transport operators, experts, retailers, the private sectors and the third sector. They can be simply categorized in three classes: experts (i.e. key informants), stakeholders (e.g. institutions, groups, environmental associations, transport companies) and citizens (singles or in groups).

While experts have high competence but low stake, stakeholders have competence and high stake, and citizens have low competence but act in the public interest (Fig. 1). They are all

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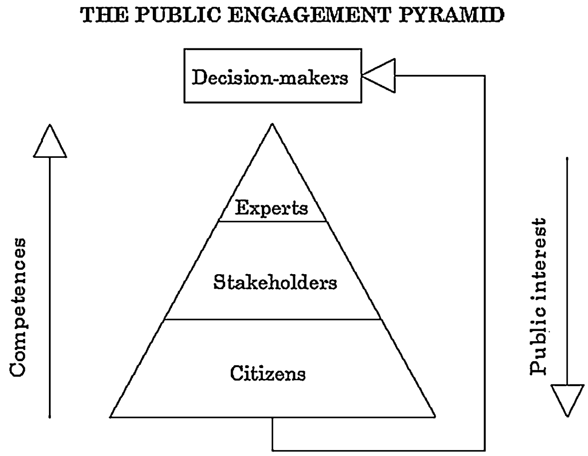

Fig. 1. The Public Engagement pyramid.

included in the engagement process and directly linked with the decision-makers.

Transport planning becomes the management of a bi-directional communication process and it requires specific programs and skills, able to coordinate many players, conflicting interests and variables and anticipate problems. Public participation should be planned well in advance and it requires specific competences and skills. There are several tools that can be used to foster participation: Roden (1984) suggests to develop a "Community Involvement Plan"; Kelly et al. (2004) report different methods of participation according to the phases of the planning process and the purpose of engagement; Whitmarsh et al. (2007) propose a methodology divided into two phases, with expert involvement through focus groups and questionnaires, and citizen involvement through citizen workshops and questionnaires; Mameli and Marletto (2009) propose a participated procedure by involving experts, citizens and stakeholders to implicate in different ways with "top-down" phases (results derived from the work of experts) and "bottom-up" phases (results derived from the participation of citizens and stakeholders). In any case, interaction among stakeholders can be a key of success in participatory decision-making processes, because it fosters the emergence of coalitions facilitating the convergence of different stakeholders to a shared solution. It has been demonstrated through participation experiences that deliberation can change stakeholders' minds about transport policies (Quick et al., 2015).

Nevertheless, all the conventional methods ca be time-consuming and require money, thus making difficult to organize effective participation processes while building transport plans. Besides, it is not easy to have a clear insight on the actors to be involved and the possible results of interaction are often unpredictable, affecting in a significant way the whole planning process.

In this context, a modelling approach can help to understand the complexity of participatory decision-making processes. Linking together stakeholders in a social network and simulating the communication among them can help to improve the knowledge of the social interaction mechanisms. In particular, complex emergent phenomena like consensus building in a group of interacting stakeholders can be simulated via agent-based modelling (ABM), particularly suitable to reproduce complex social systems.

ABM has already been used to reproduce participatory decision-making processes with reference to a set of policies, a ranking of objectives or criteria (Le Pira et al., 2015a,b). The aim of this paper is to reproduce via an ABM stakeholder involvement related to the decision about a specific transport policy, studying how the network topology and the initial conditions can influence the final outcome, by simulating the opinion dynamics which takes place in the stakeholders' network.

The model can be used for an ex-ante analysis aimed at understanding the conditions that would likely lead to consensus building. It can be placed in the framework of transport planning for a preventive analysis of stakeholder involvement in the decision-making process prior to the phases of consultation and participation in the final decision.

The remainder of the paper is organized as follows. Section 2 will introduce the concepts and methods used in this study, i.e. social network theory, opinion dynamics models and agent-based modelling (2.1) before presenting the implemented agent-based model (2.2); Section 3 will introduce the case study and describe the agent-based simulations performed (3.1), the relevant results of the simulations (3.2) and some policy implications derived from them (3.3); Section 4 will conclude the paper with a discussion of the main results and considerations for further research.

2. Methodology

The methodology proposed is based on an agent-based simulation of the opinion dynamics on a stakeholders' network, through the implementation of a multi-state opinion dynamics and bounded confidence model. It is not intended as an operative participative decision-making tool, but as a strategic and preventive mean to plan an effective participation process and to predict and foster the emergence of a coalition of stakeholders towards a shared decision.

2.1. Modelling social interaction in stakeholder networks

A social network of stakeholders is a graph consisting of nodes (i.e. the social agents) and links (i.e. the relationships among them). Representing stakeholders in social networks can be helpful to have a clear insight on the actors involved in the decision-making process and the interactions among them.

Social networks fall within the category of complex networks, whose structure is irregular, complex and dynamically evolving in time (Boccaletti et al., 2006) and adequate methods are needed to study their structure and dynamics. Social Network Analysis (SNA) allows to quantify the social importance of a given individual in a network via centrality indexes and understand the potential problems due to topology.

The use of SNA in the field of stakeholder engagement can simply consists of stakeholder mapping or it can include centrality measures (Carter, 2009; Prell et al., 2009; Kazmierczak, 2012; García Melón et al., 2013). According to Schonk (2010), with social network visualization, project managers within construction projects are helped in identifying which stakeholders to engage, while stakeholders have clear insights of their positions in relation to the others.

Stakeholder engagement is a dynamic process and it is characterized by several reassessment of the network. Together with the network analysis it can be helpful to simulate how the opinions flow through the set of connections in order to improve the knowledge of the involvement process at the earliest stage. Opinion dynamics models have been largely used in the last years to capture the opinion evolution of groups of agents both on regular and complex network topologies. A comprehensive review of the main opinion dynamics models and their usefulness to reproduce social interaction can be found in Castellano et al. (2009). These models can be used to study the interaction process in a network of stakeholders involved in transport decisions. Once the relationships, the relative influence of the nodes and all the network characteristics are known, it will be possible to simulate how the information flows through the edges and how (or if) consensus will be reached.

In general, the opinion dynamics models consist of algorithms that can be analytically or numerically solved; the dynamics is usually simulated by means of Monte Carlo algorithms. Agent-based modelling (ABM) is a powerful instrument in simulating the opinion dynamics for many reasons, i.e. (i) the relative easiness to represent a network of nodes (agents) linked together with ties, (ii) the possibility to ask the agents (endowed with own properties) to have an opinion and act according to simple behavioural laws, (iii) the power of visualization, that can help the analysis, (iv) the opportunity to change the global variables, which makes generalization possible and (v) especially for the emergence of collective behavioural patterns which are not predictable from the simple initial rules and that come out from simulations. For all these reasons, ABM has been chosen to represent the stakeholder network and to simulate the opinion dynamics. We used NetLogo (Wilensky, 1999), a multi-agent programmable modelling environment which can reproduce a lot of characteristics of complex systems, following the time evolution and the significant parameters real-time. NetLogo has been previously used in transport modelling, e.g. for the simulation of pedestrian behaviour (Camillen et al., 2009) and the impact of real time information on transport network routing (Buscema et al., 2009). Besides, stakeholder engagement in transport decisions has been studied via ABM by simulating the opinion dynamics on stakeholder networks (Le Pira et al., 2015a, 2015b) proving that interaction is beneficial to find a convergence of opinions in heterogeneous groups that have to choose a collective ranking of alternatives. In this paper, the consensus building process about a specific transport policy is simulated via ABM. Next section will show the main routines of the implemented model.

2.2. Agent-based model of opinion dynamics on a stakeholder network

In the proposed model stakeholders are agents in a social network composed of nodes (i.e. the agents) and links (i.e. the relationships among them). They can interact with the neighbours (i.e. the directly linked nodes) and they can change their opinion according to an opinion dynamics model.

The implemented opinion dynamics model is inspired to the majority rule (MR) model (Galam, 2002), where all the agents at time t are endowed with binary opinions (+1, −1) and they can communicate with each other. At each interaction, a group of agents is selected at random (discussion group): as a consequence of the interaction, all agents take the majority opinion inside the group. This assumption can appear quite simple but, on the other hand, the MR model is the result of an extended interaction which is influenced by topological complexity and by the initial distributions of opinion. Therefore, it allows to simulate a community with distributed opinions that can change through frequent opportunities of interaction. The MR model has been extended to multi-state opinions and plurality rule (Chen and Redner, 2005) with a number of opinion states s and size of the interaction groups G.

Our model can be considered a multi-state opinion model with $s = 3$, where agents are endowed with one opinion among approval, disapproval or neutral, denoted by +1, −1 and 0 respectively. The neutral opinion is considered less significant and "contagious" than the two others, so the latter were assigned with a double weight. It is also a bounded confidence model, because of the

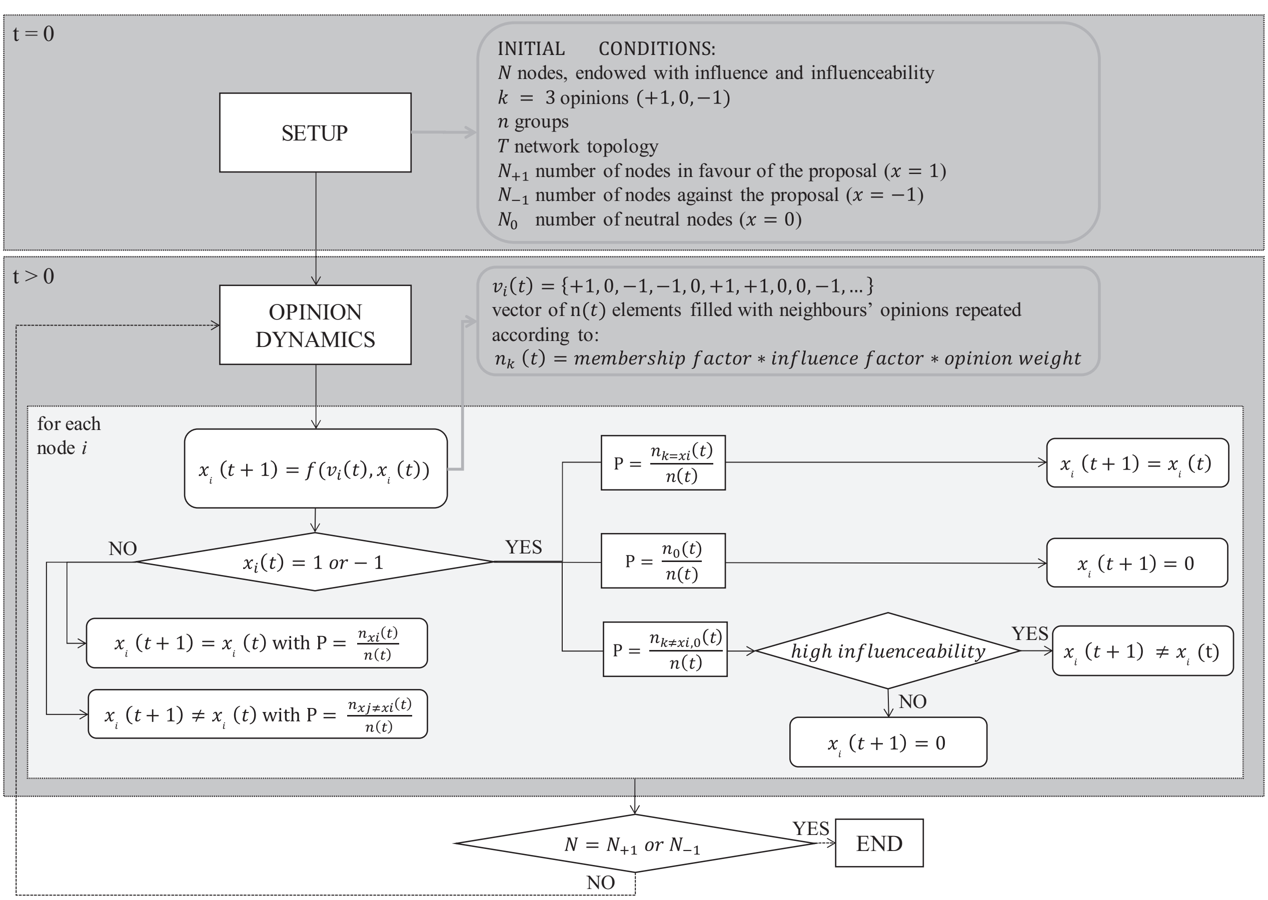

Fig. 2. Main routines of the agent-based model.

definition of a confidence bound which limits the way a node can change its opinion: a node with +1 cannot directly change its opinion in −1 (and vice versa), but it must pass through the opinion 0 before. Considering the neutral state as a transit opinion is reasonable because it represents a phase of indecision. The nodes which assume the neutral state can change their opinion at the next step, so opinion changing is not conditioned by a specific time but it depends from the neighbours' opinions.

The algorithm of the model can be described in two main steps: setup of the initial conditions and the opinion dynamics (see Fig. 2).

SETUP (t = 0). The social network of stakeholders is created, according to a fixed topology. In particular, we distinguish between "strong ties" and "weak ties", a standard description in community structure analysis for indicating, respectively, links between nodes belonging to the same group and links between nodes belonging to different groups (Granovetter, 1973). The "degree" is the total number of links (strong + weak) of a given node and "z-out" is the number of weak links of the same node. Each node (agent) is endowed with two main properties: (i) an influence, which is an integer number in the range [0,10] reflecting the social importance of the node; (ii) an "influenceabiliy", which is a random real number in the range [0,1] representing the probability that a node directly changes its opinion without considering the confidence bound. In other words, if this parameter has a value close to 1, the probability to directly change its opinion without passing through the neutral stance is high; vice versa when the value is around 0. Finally, at $t = 0$, an opinion is assigned to all the nodes by setting a "positive initial group", i.e. a group of nodes that are initially in favour of the proposal.

OPINION DYNAMICS ($t \geq 0$). At each step of the simulation, each agent can change its opinion based on its neighbours' ones. The implemented algorithm consists of the creation, for each node, of a vector filled with the weighted opinions of all the neighbours. Let $x_i(t)$ be the opinion of the node i at time t; the opinion at time $t+1$ will be:

$$x_i(t+1) = f(v_i(t), x_i(t))$$

where $v_i(t)$ is the vector of the neighbours' opinions, which are repeated, for each neighbour, a number of time $n_k(t)$ related to the *opinion weight*, the *influence factor* and according to a *membership factor*, considering that there are more possibilities to interact within the same group:

$n_k(t) = membershipfactor * influencefactor * opinionweight$ with $k = -1, +1, 0$.

At each time, an element of the vector will be randomly chosen, therefore the most numerous opinion will be the most likely to be selected.

In order to reproduce potential external influences to the opinions, it is assumed that the dynamics can be modified by means of a Changing-Mind-Rate (CMR), a factor that represents the probability that a given node would randomly change its opinion at a given time.

The dynamics can be followed in time by plotting three curves, each representing a different opinion against time. In Fig. 3a we show a single typical event in which, starting from a given distribution of opinions among the agents and after a struggle among the three opinions, the simulation ends with all agents converging towards the same opinion. In Fig. 3b we report the frequency distribution of the final surviving opinions cumulated over 10 events with the same parameter setting but different extraction of the random variables: we observe that the main opinions (approval and disapproval) are the only one that survives while the neutral stance is only a transition opinion.

3. Case study

This study is conducted at University of Catania, one of the oldest (1434) and largest in Italy with approximately 53,000 students and 2500 staff. It is located in the city of Catania with 300,000 residents, in the southeast of Italy. About a quarter of students and personnel commute every day in the main campus, located up on a green hill in the north of the city. It is one of the biggest open spaces in Catania, a 70 ha area experienced by students, teaching staff and employees. It contains a number of sites spread over the area, including lecture rooms, offices, student residences, parking lots and few utilities.

Though it was designed as pedestrian campus, its location far away from the city centre and the lack of transit accessibility have encouraged a high rate of car travels and a consequent high pressure on campus governance to build parking lots in the last decades (Fig. 4). Nevertheless, parking spaces are overcrowded during peak hours and the continuous search for available spaces degrades both the accessibility and the liveability of the campus. Indeed, campuses must balance competing needs for parking supply, sustainability goals and budget constraints (Riggs, 2014).

Nowadays more attention is paid by the University to sustainability; a Mobility Management Office (MOMACT) was established and a University Travel Plan was issued in 2009 to promote sustainable mobility of the university community, mainly

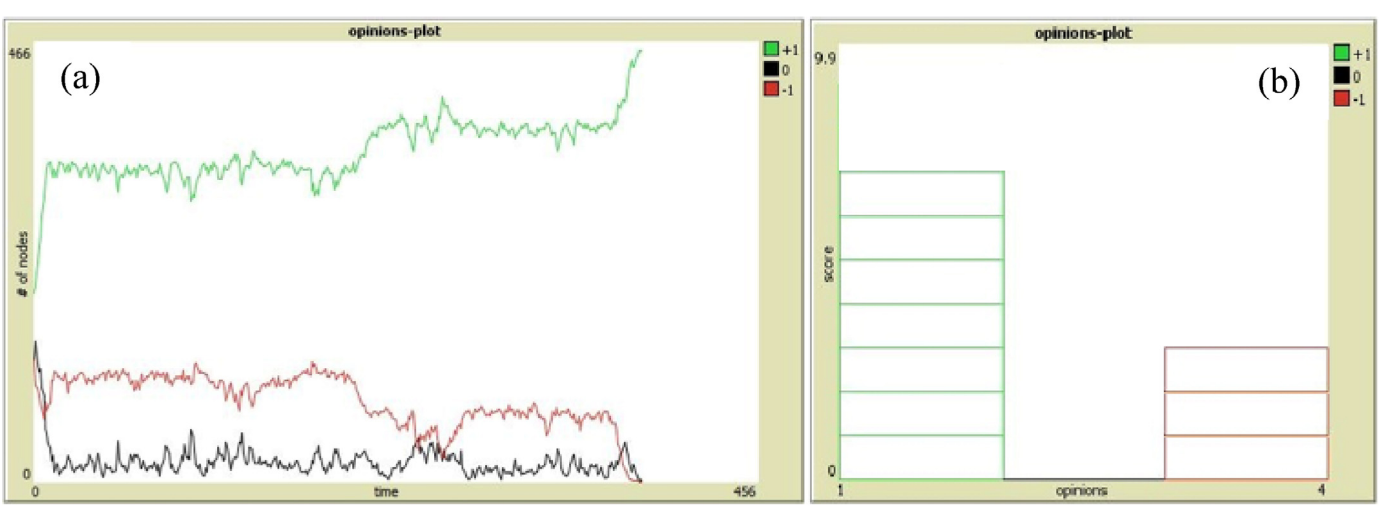

Fig. 3. Opinions' plot for a single event (a) and for ten events (b).

Fig. 4. Campus: Building (red) and parking (blue and orange). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

through awareness campaigns and transport demand management measures. The campus, likened to a small town, was thought as an ideal place to experiment actions for influencing travel behaviour.

A critical challenge for transport decision-makers is to identify effective strategies for rebalancing the modal split between private car and public transport. Adopting economic measures, such as imposing fares to access parking spaces (Inturri and Ignaccolo, 2011), establishes the right distinction between those road users with the greatest need of access and parking in more attractive urban areas and those who have less (Hensher and King, 2001).

Danaf et al. (2014) found that increasing parking fees and decreasing bus travel time through the provision of shuttle services or taxi sharing could be promising strategies for mode switching from car to public transport for campus students of the American University of Beirut.

Based on these premises, MOMACT proposed a parking pricing scheme of the campus according with the following actions (Fig. 5):

- Building a Park-and-Ride facility at a distance of 1.5 km from the campus
- Linking the P&R to the campus by a free shuttle bus line
- Adopting a parking pricing scheme:
  - free parking and transit ride from P&R facility to the campus;
  - parking pricing inside the campus.

One important precondition for the successful implementation of transport pricing strategies is public acceptability which is generally low (Schade and Schlag, 2003). May (2015) argues that involving stakeholders in Sustainable Urban Mobility Planning from the initial stages of determining objectives to the final process of implementation and evaluation will enhance the acceptability of final decisions. Attard and Ison (2015) illustrate the effects of stakeholder constraints on the effectiveness of parking policy. Reis and Macario outline an approach in which public transport stakeholders' business models are integrated to enhance public policy benefits (Reis and Macario, 2015).

The decision-making process regarding transport planning is characterized by a high level of complexity and it is not simple to be described with a model. Therefore, in order to apply our methodology to a case study, we decided to represent a simple, real situation of a decision-making process regarding transport issues. In particular, we depicted a well-known situation of a restricted homogeneous community of people with the same interest, i.e. easy access to the workplace. In particular, the case study is about the idea of adopting parking pricing inside the University Campus. The topic involves all the University staff, including full professors, associate professors and assistant professors, while students are excluded because they cannot

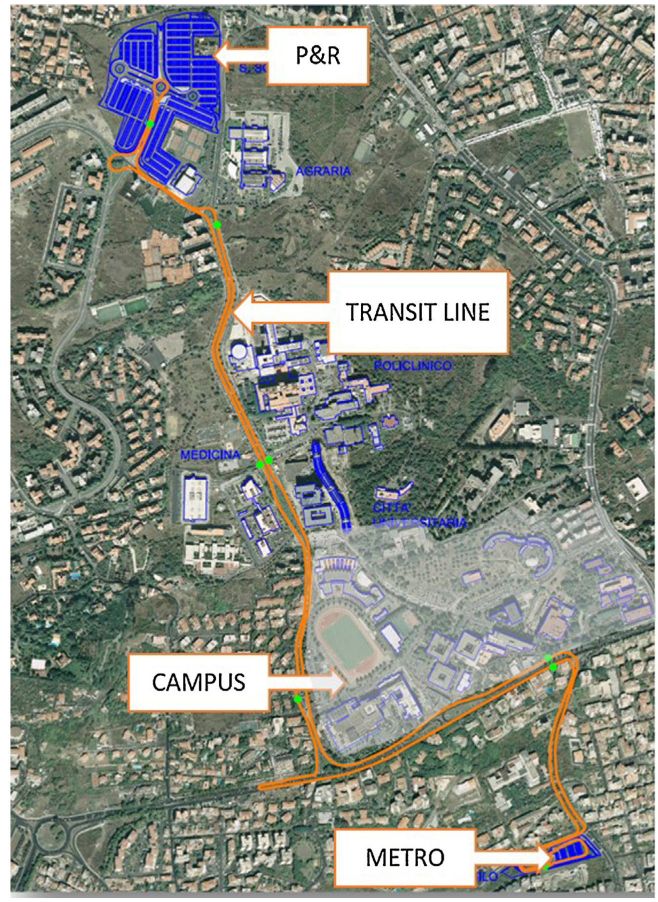

Fig. 5. Case study area: campus, P&R and transit line.

access those parking spaces. In this respect, student consultation showed that a better management of the parking spaces (where they can access) is one of main priorities for them (Le Pira et al., 2015a).

Some observations carried out during several meetings on these issues, though not systematic and statistically significant, were useful for the construction of the model. The network was created according to relationships derived by roles and by department organization (institutional relationships). Thanks to the knowledge of all the elements it was possible to build the network and simulate the opinion dynamics which should lead to a consensus/dissent (see Table 1). The "institutional" stakeholder network was reproduced by dividing all the departments' members into the three categories (assigning the role of head of department to one of the full professors), and then creating the links among them; in particular, heads of department are linked with all the members of their departments (Fig. 6).

3.1. Simulations performed

Simulations were performed by exploring the parameter space with different setting choices in order to have a records of multiple interaction processes among stakeholders and derive some general considerations from them.

Three main elements can be modified in the model: (1) the topology (i.e. the average degree, average z-out), (2) the initial conditions (i.e. the positive initial group) and (3) the opinion dynamics (i.e. the Changing-Mind-Rate CMR) (Table 2).

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Table 1
Details of departments' structure.

DEPARTMENTS	FULL PROFESSORS	ASSOCIATE PROFESSORS	ASSISTANT PROFESSORS	TOT
Architecture	10	22	15	47
Physics and Astronomy	27	27	24	78
Civil and Environmental Engineering	14	17	10	41
Electric, Electronic and Informatics Engineering	21	20	13	54
Industrial Engineering	16	9	17	42
Maths and Informatics	23	27	30	80
Chemical Sciences	28	14	18	60
Pharmacy	14	20	22	56
TOT	153	156	149	458

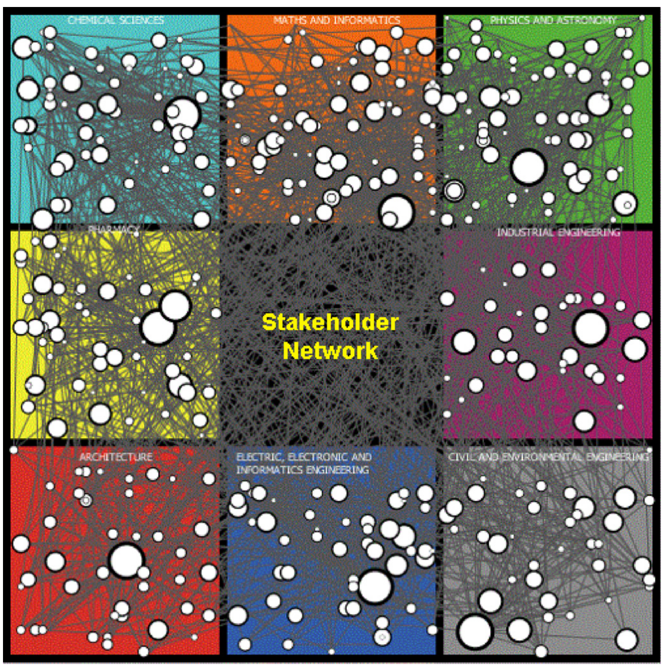

Fig. 6. Representation of the stakeholder network in NetLogo.

Two different topologies were considered to simulate stakeholder interaction on low-connected networks, with average degree 10 (i.e. on average each node is connected with other 10 nodes) and high-connected networks, with average degree 20 (i.e. on average each node is connected with other 20 nodes). These assumptions seem quite realistic considering that on average departments are composed of about 57 people, and each of them could likely communicate with 10–20 colleagues of the same department. The simulations were performed by varying the number of weak ties to reproduce communication with members of other departments, i.e. with a parameter z-out ranging, on average, from 1 to 5 for degree 10 and from 5 to 10 for degree 20 (both degree and z-out are extracted from normal distributions). The higher connectivity inside the same department reflects the higher frequency of occasional discussion, i.e. official department meetings, sharing of the same working spaces.

The rationale behind the choices made is to see how the level and the type of connections among stakeholders can affect the convergence of opinions.

Different initial positive groups, i.e. nodes in favour of the given proposal, were considered to understand the impact on the final result of the interaction process, i.e.: nodes with the same role (heads of departments, full professors, associate professors, assistant professors), nodes belonging to the same department and number of departments (1 department, 2, 3 or 4 departments), number of random positive nodes (from 0 to 400), random +1, 0, −1 nodes. In this respect, the influence of each node is chosen at random following a normal distribution with standard deviation equal to 2 and an average decreasing with the role (i.e. 10 for heads of department, 8 for full professors, 6 for associate professors and 4 for assistant professors).

A series of simulations was made by assuming a certain probability of random changes of opinion (CMR = 0.5%) in order to understand the impact of external influences. Several runs have been performed, since the outcomes of different simulations with the same initial conditions (i.e. multiple events) can be different.

3.2. Simulation results

Considering E events for each simulation, we are interested into the following results: the number of events ended with a complete consensus (all the opinions equal to +1) or complete dissent (all the opinions equal to −1) and the average time for reaching consensus or dissent. In order to convert the final outcome of the events into a unique parameter we calculated an acceptance rate W as the weighted average of the final network state, i.e. the net frequency

Table 2
Parameter values used for the simulations.

Model setup	Parameter	Low-connected networks	High-connected networks
Topology	av. degree (normal distribution)	10	20
	z-out (normal distribution)	1, 2, 3, 4, 5	5, 6, 7, 8, 9, 10
Initial positive group	Nodes with the same role	heads of departments, full professors, associate professors, assistant professors	heads of departments, full professors, associate professors, assistant professors
	Number of +1 departments	1, 2, 3, 4	1, 2, 3, 4
	Number of random positive nodes	0, 50, 100, 150, 200, 250, 300, 350, 400	0, 50, 100, 150, 200, 250, 300, 350, 400
	+1,0,-1 nodes	Random assignment	Random assignment
Opinion dynamics	CMR (probability)	0	0.5%

of the events which end with +1:

$$W = \frac{E_{+1} - E_{-1}}{E}$$

where E_{+1} is the number of events ended with consensus ($k = +1$), E_{-1} with dissent ($k = -1$) and E is the total number of events. W is included in the interval $[-1,+1]$, where the extreme values -1 and +1 represent, respectively, 100% of events ended with dissent or consensus. Notice that this parameter does not indicate the rate of agents which have the opinion +1 at a certain step of the simulation, but it only measures the average tendency of the final state of the system towards the full consensus or the full dissent.

A time threshold was defined in order to exclude the cases in which the process took too long time ($t > 500$) before reaching consensus (or dissent). Therefore, when time exceeds the threshold without reaching any convergence of opinions, we say that the simulation ended with "no convergence" ("nc").

Fig. 7 shows some simulation results in terms of the parameter W above defined.

By considering different initial groups, it is clear that a too small number of weak ties critically slows down the information exchange; actually, when a node has on average 10 links, it is evident that we need more than 2 weak ties in order to reach convergence of opinions. Furthermore, the parameter W is minimum when the positive initial nodes are heads of departments (a minority, but very much influent) or assistant professors (more numerous, but less influent), that is to say that it is very difficult to reach consensus when only one of these groups is originally positive about the given topic (in our case the parking pricing). On the other hand, higher W values are achieved with entire positive departments.

If we study the behaviour of the parameter W versus an increasing number of randomly chosen initially positive nodes (ranging from 0 to 400), there is a transition from dissent ($W = -1$) to consensus ($W = +1$) in correspondence of around 150 positive nodes (Fig. 8a). Indeed, all the events end with dissent up to 50, then there is a transition phase with some events ended with dissent and some others with consensus (from 50 to 250 nodes) and where the lines for different z-out can intersect, whilst all the events end with consensus when there are more than 250 (randomly chosen) initially positive nodes.

For what concerns the average time to reach the final decision, it is possible to plot it as a function of the number of random positive nodes and for several values of z-out (Fig. 8b).

It results that the convergence time presents a peak exactly in correspondence of the transition from total dissent to total consensus. Such a peak is much more pronounced for smaller values of the average z-out, i.e. when the small number of weak ties does not allow the positive opinions to spread over the entire network.

If we consider high connected networks (average degree = 20) the results are similar. The greater number of links improves the communication among nodes, so a convergence of opinions is always reached, even when the number of weak ties is small. If we consider the presence of external influences, represented by non-zero values of the CMR indicator (CMR = 0.5%) in general it produces an increase in convergence time but does not significantly affect the transition from dissent to consensus, which occurs between 150 and 200 initially positive (randomly chosen) nodes. The external influences represent "rumours" which modify the dynamics and slow down the process. Indeed, people will be changing their mind at some steps (related to the CMR) at random, without following the original opinion dynamics rules. This is the reason why the convergence process slows down.

3.3. Policy implications

Some policy implications can be derived from simulation results. It is evident that parking management strategies involving an increase in the parking fee are difficult to be accepted. Nevertheless, knowing in advance what could be the possible outcome of an interaction process can be helpful to plan an effective participation process. It is worthy of notice that the authors are not interested in the final result derived from interaction (i.e. approval or disapproval of the parking management strategy); on the contrary, it is useful to see how the process

Acceptance rate W (av. degree = 10, CMR = 0%)	low-connected networks					high-connected networks					
	z-out					z-out					
Positive initial group	1	2	3	4	5	5	6	7	8	9	10
heads of department (8 nodes)	nc	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
full professors (149 nodes)	nc	nc	0.2	1	0.4	0.4	0.6	1	0.8	0.2	0.8
associate professors (156 nodes)	nc	nc	-0.6	0	-0.8	0.2	0.2	0.2	-0.4	-0.8	0
assistant professors (149 nodes)	nc	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
random nodes	nc	nc	0.4	-0.2	0.4	-0.2	0.2	0.2	0	0	0
1 department	nc	nc	0.2	0.4	0.6	0.6	0.8	0.6	0.2	1	0.6
2 departments	nc	nc	0.4	0.2	0.6	1	1	1	1	1	0.8
3 departments	nc	nc	1	1	1	1	1	1	0.8	1	1
4 departments	nc	1	1	1	1	1	1	1	1	1	1

Fig. 7. Acceptance rate (W) with initially positive groups (av. degree = 10, CMR = 0.0%).

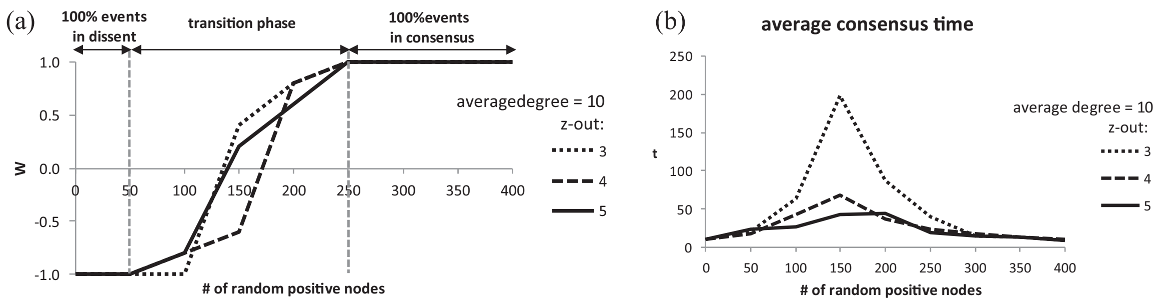

Fig. 8. (a) Acceptance rate W and (b) average convergence time as a function of the number of random positive nodes on varying z-out (av. degree = 10, CMR = 0.0%).

of convergence of opinions can change according to different setting and how it can be favoured. In this respect, many links help the communication exchange and speed up the process of taking a shared decision. This suggests the importance of planning a series of meetings that sees the participation of members of the same department (i.e. departmental meetings) and especially of members belonging to different departments (i.e. interdepartmental meetings), since a short number of "weak ties" critically slows down the opinion convergence process. Besides, entire departments in favour of the proposal can influence the final outcome of the interaction process; this can give some suggestions on how to program the participation process, e.g. by making at the beginning departmental meetings in order to favour the convergence of opinions inside the same group and eventually making interdepartmental meetings to foster further opinion exchange.

Given the hierarchical structure of departments, with different roles associated to the academic position, one would think that more "important" people could substantially affect the final result by influencing the others. Simulation results show that this is not obvious, e.g. it is not sufficient to speak with heads of department to reach the overall consensus even if they are all in favour of the proposal and they can easily influence all the members of the same departments; on the contrary, a large number of in-favour influential nodes is necessary (e.g., full professors). This confirms that a participation process should involve all the interested parties to be successful and not only the spokespeople or the most influential people.

Independently on the influence of stakeholders, it is demonstrated that a good majority in favour of the proposal would likely leads to a total consensus in a short time, while unpredictable results can occur when there are more divergent opinions and it usually takes more time. This suggests that a good knowledge of the initial opinions of stakeholders can be helpful to have an idea on how much time a participation process would take to reach a shared decision.

Based on these quite general considerations, some specific suggestions can be formulated in the context of a University campus where a decision has to be made about optimizing the parking supply through pricing measures. Actually, interaction among professors can be favoured, not only by increasing the number of interdepartmental or departmental official meetings, but also through targeted outreach on sustainability issues, or encouraging the use of alternative modes of commuting to University. The attitude to change opinion, included in the model, becomes realistic if all possible information gaps of professors are filled with: (i) the general objectives of the decision, (ii) the impact of alternative measures on the environment and (iii) the knowledge of alternative transport options available to them (discounted public transport, carpooling, bicycle facilities, etc.). Both information and interaction are therefore critical to carry out an effective decision-making process and increase the probability that a decision will be implemented and accepted.

Finally, some key points emerge:

- stakeholder analysis is fundamental to reproduce the existing network of relationships among the multiple actors that, to different extents, can influence and are influenced the final decision;
- having a preliminary knowledge of the distribution of opinions among stakeholders can be helpful to arrange the participation process;
- diffuse and repeated interaction (and information) opportunities contribute in smoothing strongly diverging opinions and achieving a shared decision in a short time.

4. Conclusions and discussions

In this paper an agent-based model is presented to reproduce the social interaction in a participatory decision-making process about a transport decision. Social interaction is reproduced via a multi-state opinion dynamics model with 3 different opinions (approval, disapproval, neutral opinion). The model was applied in a very simple case study, both to test the model and to capture the intrinsic essence of the complex phenomena of social interaction. The decision-making process regards the introduction of a parking charge inside a University Campus, where a restricted and homogeneous community of people (professors) with the same interest made quite reasonable the simple opinion dynamics model we implemented.

Simulation results show that a high connectivity helps the communication among nodes, in particular when different departments are highly connected, and it takes few time to reach the final decision; on the contrary, few links slow down the process and sometimes it requires too much time to reach consensus or dissent. A substantial majority in favour of the proposal would likely lead to consensus, while the outcome is not trivial with more divergent opinions or when the favourable group is composed of influential agents.

These results suggested some policy implications on how to conduct a real participation process that should be effective (in reaching a shared decision) and efficient (in short time), by fostering repeated interaction occasions and by appropriately informing stakeholders on the decision to be made.

Further research will tend to modify: (i) the opinion dynamics, e.g. by increasing the number of possible opinions or changing the model from a discrete choice model to a continuum one, or including the possibility that the stakeholders could change their mind by policy persuasion or awareness raising; (ii) the stakeholder network, e.g. by seeing how the geographical distance and the department affinity can influence the topological distance of the nodes, affecting the information exchange. Besides, it would be helpful to compare the results of the simulations with a real situation with systematic observations to see if the model results are in agreement with reality.

In conclusion, the model can be useful to the design of the stakeholder involvement at an early stage of the planning process, because it can predict the possible results of interaction; consequently, it allows to set up the priority for information and it helps to understand how to improve the linkages among stakeholders in order to facilitate the involvement process.

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