Simulating the Role of Norms in Processes of Social Innovation: Three Case Studies

Wander Jager[1]**, Amparo Alonso-Betanzos**[2, 5]**, Patrycja Antosz**[3]**, Bianca Beersma**[3]**, Loes Bouman**[1]**, Berta Guijarro-Berdiñas**[2]**, J. Gareth Polhill**[4]**, Alejandro Rodríguez-Arias**[2]**, Doug Salt**[4]**, Noelia Sánchez-Maroño**[2]

[1]*University of Groningen, Hoendiepskade 23/24, 9718 BG, Groningen, The Netherlands*
[2]*University of A Coruña, Computer Science Department, 15071, A Coruña Spain*
[3]*NORCE, Norwegian Research Centre AS, Universitetsveien 19, 4630 Kristiansand, Norway*
[4]*The James Hutton Institute, Craigiebuckler, AB15 8QH, Aberdeen, Scotland, United Kingdom*
[5]*Norwegian University of Science and Technology, Høgskoleringen 1, 7034 Trondheim, Norway*
Correspondence should be addressed to *w.jager@rug.nl*

Abstract: Norms and values are critical drivers in social innovation processes, such as community projects on sustainable energy. Simulating such processes could help uncover conditions that support these social innovations. Capturing the rich literature on drivers of social innovation in more simple computational rules is a challenge however. In this paper, we present three empirically grounded case simulations addressing social innovations where norms and values play a role. The results emphasise that normative influences and values affecting opinions and behaviour cannot be addressed in isolation when studying real cases of social innovation. An integrated perspective is needed to identify who is most likely to deviate from a given norm, and how contagious this deviation is. These factors, such as needs, values, similarity and reputation, are embedded in a wider behavioural and social-cognitive context and hence require embedding into an integrated modelling framework of humans in the community. We conclude by considering how social-economic data can be used in combination with theory-based rules to simulate normative processes in a convincing way.

Keywords: Norms, Values, Social Innovation, Energy, Sustainability

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Introduction

1.1 As an overly abundant species on this planet, we face certain challenges in keeping our habitat safe for the future. This requires changing many behaviours and practices that are endangering our eco-systems, including for example, the eradication of natural habitats, pollution and emissions. Whereas these problems seem to manifest at a global level, it is clear that certain regions are more vulnerable than others. When it comes to adapting behaviour, we realise that this is often a matter of individuals changing their own behaviour.

1.2 Behavioural change often takes place within the context of a local community, especially when it is visible and when scale effects are relevant. Hence, human sociality helps us in coordinating our behaviour in order to

collaborate within a group. Ostrom (1990), in her seminal work, highlights the fact that normative institutions usually emerge in social groups that help protect shared systems [1] from over-exploitation.

1.3 Norms however, also often stand in the way of innovation, as they propagate 'acting-like-the-others' and so promote conservatism. Innovative behaviour by definition deviates from the norm and as a consequence they are not supported by the group norm. This may result in a mild sceptical group verdict, as in watching bemused, "what this innovator is up to now". The deviant behaviour may also be actively discouraged, sometimes even in aggressively. For example, if you are the only person to start cycling to work whereas the rest persist in driving their car, the situation is not likely to be very safe for you. Colleagues may joke about your dare-devil cycling behaviour. You may even experience aggression from certain car drivers. However, the more people start cycling, the stronger the demand for cycling infrastructure which, once installed, will make cycling appealing to more people and therefore 'normal'. Such self-amplifying social processes act upon and change the dominant norms supporting social practices and can be understood as social innovations. In a similar vein, going to a plant-based diet is easier the more people do so, as the food assortment in the supermarkets will adjust to an increasing demand, making it easier and more 'normal' for other people to try plant-based products. Furthermore, joining a heat network will only be possible if a sufficiently large group of people is committed. However, in certain situations only a part of a community is supporting a change and as a result two groups with opposing views can emerge, resulting in a potential polarisation and even conflict. A better understanding of the social dynamics of norms could contribute to our understanding of how to stimulate processes of social innovation, which is relevant in the context of many local projects aimed at sustainability and climate resilience (Green Deal).

1.4 A key principle in understanding change processes is that people are not behaving in a social vacuum, but rather that their behaviour is strongly influenced by what is considered to be 'normal'. Since the classic Asch (1956) experiments, much research has been done on norms and how they affect our behaviour. Many different approaches have been taken to describe norms, for example in psychology (Cialdini & Goldstein 2004) and in economics (Young 2015). Norms are generally understood as *shared rules of conduct that are partly sustained by approval and disapproval* (Elster 1989b). Authors often emphasise the emergent nature of social norms and their decentralised origin, seeing them as *unplanned, unexpected results of individuals' interactions* (. . .) *that specify what is acceptable and what is not in a society or group* (Bicchieri & Muldoon 2014). Agent-based models are especially suited to represent normative influences because of the correspondence between how norms come to existence and affect individual behaviour and the causal influences present in agent-based models i.e., the emergence from micro-level interactions and downward causation.

1.5 Several typologies of normative influences have been identified (e.g., Gibbs 1965; Morris 1956; for a wider review see Anderson & Dunning 2014). One of the most common distinctions coined by psychologists distinguishes descriptive and injunctive social norms (Cialdini et al. 1990). Injunctive norms refer to a perceived external force that encourages correct behaviour. Ajzen (1991) writes about perceived social pressure to perform or not perform [a] a given behaviour (p. 188). Anderson & Dunning (2014) emphasise that injunctive norms drive behaviour through a feeling that one "should" or "ought" to act in a certain way (p. 4). Injunctive norms prescribe which actions are approved within a given context. Descriptive norms are the typically performed actions. For example, after entering a lift, most people would face the door. Descriptive and injunctive norms are not two ends of the same continuum, although studies suggest that they are related (Farrow et al. 2017). It is entirely possible that more than one behaviour is acceptable in any given context. For example, in a park it might be acceptable to walk your dog, play basketball, ride a bike and drive a car. However, on a sunny afternoon, most people in a park may join small social get-togethers to share a meal and a beer with their friends. The descriptive norm can serve as an indicator of the injunctive norm (e.g., if one was uncertain whether alcohol consumption is legal in public spaces such as parks), as well as a clear signal (reducing calculations in a decision-making process) of a high payoff behaviour chosen by many.

1.6 Other important and somewhat similar distinctions were made about the injunctive norms between personal/private and social/non-personal norms (Schwartz 1977), moral and social norms (Bicchieri 2006; Elster 1989a), or internalised and not-internalised norms (Scott 1971). Personal (injunctive) norms are often acquired in the process of internalisation and refer to behaviour that the acting individual approves of, often motivated by internal moral beliefs (e.g., values). Social (injunctive) norms are, depending on the scholars, either very close (e.g., Anderson & Dunning 2014) or identical (e.g., Farrow et al. 2017) to the original meaning of the injunctive norm and emphasise the universal external sanctioning of norm violation. As a consequence of external motivation, behaviour aligned with social injunctive norms is followed only conditionally under situations of observability and normative expectations.

1.7 The internalisation of norms, where the behaviour of other people is transferred into a personal norm that is also followed in the absence of other people, connects the concept of norms with personal values. This connec-

tion between norms and personal values can be understood as emerging over time from complex micro-macro dynamics and starts with the raising of children (micro level acculturation or education) with values shared in a group (macro level downward causation) on what is appropriate behaviour. This involves the influence of parents, peers and the wider society (cultural values). In the value-acculturation process, people can maintain a positive self-assessment by identifying with and conforming to (appropriate) behaviour displayed by valued groups (e.g., Brewer & Roccas 2001; Pool et al. 1998). As an exception, in some cases people derive a positive self-assessment from deliberately deviating from the norm, thus emphasising their uniqueness (e.g., Kim & Markus 1999). For example, early adopters of electric cars often reported the importance of expressing their uniqueness as a motive to deviate from the norm of driving a fuel car (e.g., Heffner et al. 2007). Obviously, having access to charging infrastructure and an adequate budget are critical prerequisites for this choice to deviate from the norm. This adds to heterogeneity with respect to the norm-values connection by emphasising personality, as people differ regarding the importance they attach to the norm. This translates into different levels of compliance to a norm, as people differ regarding how many others they need to feel that they fit in. If valued (peer) groups change their behaviour, e.g., start behaving more environmentally responsibly, this may influence the social and personal drivers of others, e.g., children, friends and family. Consequently, in due time (sometimes taking generations) more people will internalise the environmental values and norms. Through such processes of social influence, the personal norm transforms into a social norm as it is diffused in the network and normative influences can have an impact on value changes in society.

1.8 In the Norm Activation Model of Schwartz (1977), personal norms are defined as experiencing a feeling of moral obligation to act in accordance with an individual's own value systems. This highlights the fact that one's values are often the result of the internalisation of social norms, and that behaving according to one's values in turn often sets a normative example for others. The relation between norms and values is therefore a social complex process where values and norms co-evolve in the context of people with different social susceptibilities growing up in a society. As such, it can be seen that environmental values become more important as a result of certain valued group of people starting to behave environmentally responsible. We should remember that the people starting to behave environmentally friendly may do this for various reasons, e.g., environmental values and/or a motivation to stand out. However, they may serve as the pioneers capable of changing the norm and ultimately societal environmental values.

1.9 Being aware of the richness of theoretical work, but also of the more descriptive level of these theories (see e.g. Jager 2021), as modellers, we face the challenge of how to translate this literature into a set of causal rules that capture the core processes in modelling our agents' sociality. A key distinction we make in our modelling approach is between a personal norm, representing an internalised value, versus a social norm, representing behaviours accepted by groups, relating to descriptive norms (most popular behaviour) and injunctive norms (non-compliance with the behaviour is sanctioned) (Cialdini et al. 1990). Social norms force conformity of group behaviour to "blend in" and avoid social disapproval or expulsion, a deep social need that people have (e.g., Maslow 1954). This implies that people may conform to group behaviour (descriptive or injunctive social norm), despite their private preferences (personal norm). As an example, people without a personal norm against littering, will not litter if they are afraid of negative responses from other people, but when nobody sees them, they may throw fast food packages out of their car window. People with a strong personal norm against littering would never do this, not even in the most remote areas at night.

1.10 Especially within the context of social innovation, these norms play a critical role in possible transitions towards new behaviour and social practices. Changing behaviour as a community is usually creating conditions that make it easier to adjust behaviour. Innovation Diffusion Theory (Rogers 2003) specifies that a critical mass of adopters is needed to convince a majority of the benefits of a new behaviour or practice. In terms of social dynamics, we can interpret this as a "tipping point", where the norm changes from "wait-and-see what this new behaviour actually is" towards "joining the bandwagon".

1.11 Pioneers (Nyborg et al. 2016) or innovators (Rogers 2003) play an important role in such processes of change, as they go against the norm and can introduce new practices in a community. As Zappa (1989) stated, "Without deviation from the norm, progress is not possible". These pioneering people may be very involved in exploring new technologies, have strong personal norms (values) about a proper course of action, and may be less sensitive to the existing social norms (non-conformist) or even may value going against the existing norm (anti-conformist), and in that way contribute to the community by exploring the value of new practices and behaviour. If the value of this behaviour is acknowledged by (preferably reputable) others, they may be adopted as well, thus building a local cluster of adopters (Cialdini & Goldstein 2004). If this local cluster of adopters is socially reputable and the new behaviour is visible and/or communicable, and easier to copy, the new behaviour is likely to spread faster and more widely (Paluck et al. 2016). Ultimately, the values of society may change if the norms are internalised.

1.12   These considerations make it clear that norms cannot be studied in isolation, but operate in combination with other behavioural drivers and processes. This is widely acknowledged, for example in the Theory of Planned Behaviour (Ajzen 1991), where a trade-off is made between attitudes and the norm. In Agent Based Modelling, this theory has been formalised in different ways, leading to different outcomes (Muelder & Filatova 2018). Ghorbani & Bravo (2016) developed a model where institutions as a normative structure emerged from individual interactions.

1.13   Hence, in our modelling of normative influences we need to capture the motivation of pioneers to act against the norm, and so the conditions under which this deviation from the norm is contagious to others. We also need to be capable of modelling the population that wait for a critical mass to reconsider their behaviour, as well as the laggards that are hard to change. This requires the fact that normative processes are connected to processes and drivers that act upon the influence of norms, thus requesting a wider theoretical framework. Values and needs are essential in such a framework. For example, a person with strong vegan values is unlikely to eat meat at a neighbourhood barbeque. A person focussing very much on hedonic needs may feast on the meat presented at this barbeque. And when these two people talk to each other, many different interactions can happen, such as one person persuading the other based on arguments, where similarity, status and reputation may all play a critical role. Alternatively, a quarrel may emerge, and if more people get involved this may have negative effects on the neighbourhood network. However, it is also imaginable that these two people will try to avoid each other, not willing to disturb the party, and therefore try to avoid conflict with their neighbours.

1.14   This example shows that the societal functioning of norms can only be understood in a broader context, hence several key concepts and theories from the social sciences have to be integrated. Some of these theories and factors address the individual cognitive level. Others relate to the social psychological level of interaction and persuasion. So, the properties of the social networks the people are interacting in are very important to understand the spread of new practices.

1.15   Many projects on a neighbourhood level require the support of the local community to be successful. For example, a heat network can only be realised if a sufficient number of people join the project. The challenge often resides in starting from a small group of people (pioneers) being interested and motivated to change behaviour towards a wider community embracing the change. In such cases of social innovation, norms usually play a critical role in the success or failure of a project (tipping point). Whereas often, the initial small group of pioneers or innovators are knowledgeable about the (technical) advantages of implementing the project, many other people, with less knowledge and/or being less involved, are more sensitive to how many and which other people support a plan before deciding to join the bandwagon and supporting the project as well.

1.16   Increasingly, policy makers acknowledge that local social innovation is a necessary process in projects aiming to change practices related to energy-use and other environmentally relevant behaviour. In these processes, community dynamics bring in a dimension of social complexity that is difficult to understand from an individualistic and deterministic perspective. Whereas it is very well possible to make an inventory of the interests, motivations and perspectives of different citizens within a community, the complex interactions and persuasive processes that happen during a project can result in surprises for those managing such projects.

1.17   To develop a better understanding of the social dynamics in local social innovation projects, the SMARTEES projects (`https://local-social-innovation.eu`) used agent-based modelling as a methodology to simulate such dynamics. The empirical cases were modelled and from a calibrated starting situation, using rich quantitative and qualitative data sources, the basic simulation runs were capable of reconstructing the empirically observed time-line of the social innovations. Having this basic simulation allowed for additional simulation runs to explore the possible scenarios that could develop given certain events, and how policies could interfere with such scenarios.

1.18   Within the SMARTEES project many cases have been explored, all dealing with the complexities of different local social innovations, addressing for example the implementation of a heat network, making city blocks free from transit traffic, refurbishing older apartment buildings, and making islands energy independent in a sustainable manner (Bouman et al. 2021). In all these cases, the modelling of social influences and in particular norms, play a critical role in addressing the social dynamics. The simulation models used an integrated approach in modelling human decision-making and behaviour, incorporating norms and values in a broader context of social innovation. For example, the HUMAT framework (Antosz et al. 2019) integrates concepts of social networks, the communication and persuasion process between agents, and the different needs of agents and associated motives to persuade others.

Modelling Norms in SMARTEES

2.1 Here, we focus in particular on how normative influences were modelled in the SMARTEES project, using three different case studies as practical examples. The first case is the project of implementing a heat network in different neighbourhoods in Aberdeen. Here, trust in the organising agency was important for people to join in. When "visionaries" (Moore 2014) support the project, they set a norm for "pragmatists" to embark on a project too. The second case focuses on a referendum to close a city park in Groningen to cars. Before the referendum, an experiment took place where the local municipality closed the road temporarily for car traffic, thereby allowing for a new norm to be enforced in a top-down manner. The norm was both descriptive and injunctive, because the majority did not drive their cars through the park. We explored the emergence of norms by modelling both top-down and bottom-up policy experiments. We learned that top-down enforced norms are more widely accepted compared to bottom-up policy interventions. More details on the operationalization and modelling of the norms is described in the second case below. The third case is a project aimed at making the energy use of the island of El Hierro 100% renewable. The local authority (Cabildo) developed this project. Therefore, it was a top-down rule imposed on the citizens. Contrary to the Groningen case, the citizens did not directly perceive the project's benefits, because when turning on a switch at home, the source of the energy used is often unknown. Even worse, some citizens thought that there would be a reduction in the bill due to the use of renewable energy sources. In addition, the promoters did not communicate with them adequately, which caused many citizens to reject the plan. Experimental results will show how improving the communication strategy together with social dynamics may bring about accepting the project to be the social norm.

The Aberdeen case: Joining a heat network

2.2 Aberdeen is a city of approximately 200,000 citizens in north-east Scotland, which identifies itself as the 'Energy Capital of Europe' following its selection in the 1970s as a base for UK operations in the oil fields of the North Sea, and more recent rebranding given the relevance of off-shore engineering skills to the expansion of renewables. Despite wealth in Aberdeen, fuel poverty – defined as needing to spend more than 10% of income to maintain a liveable indoor temperature – is an ongoing issue for many of its citizens. In 2002, 29% of Aberdeen's households were in fuel poverty. The City Council formed Aberdeen Heat and Power as a not-for-profit arms-length organisation with the mission to reduce fuel poverty by installing district heating systems in various tower blocks owned by the Council for social housing. Over the subsequent ten to fifteen years, drawing in part on various government grants to reduce fuel poverty, separate combined heat and power systems using gas boilers were installed in five multi-storey housing estates in Aberdeen, typically enabling a 50% reduction in heating costs for residents. By 2019, fuel poverty was reported at 21% of households (Scottish Government 2019).

2.3 By 2018, when the SMARTEES project started, the Council were planning an energy-from-waste plant on the south side of the city to address landfill tax legislation, and Aberdeen Heat and Power had launched a for-profit business to supply commercial properties. With the potential to generate a significant amount of heat from waste incineration, there was an opportunity to expand the heat network to more sites in Aberdeen, and interconnect the disjoint networks to enable greater resilience of the existing systems. However, the cost-per-dwelling of district heating installation is lowest in tower blocks, these costs increasing through tenements and terraced housing to semi-detached and detached properties. A further complication is that such housing has a much more mixed tenancy. Though the multi-storey apartments are not all owned by the Council for social housing, the vast majority of them are. Buildings with a greater mix of tenancy make the process of routing district heating more socially complex, as the financing depends on levels of adoption street by street.

2.4 To explore scenarios of district heating adoption in Aberdeen, we developed the ACHSIUM agent-based model (Polhill et al. 2021), the NetLogo visualisation of which is shown in Figure 1. The model focused on the Torry district of Aberdeen, which is nearest the energy-from-waste plant, and contains a diversity of housing and inhabitants that, for the purposes of the model, make it a microcosm of Aberdeen as a whole. To allow the exploration of scenarios leading to more or less adoption, we modelled a counterfactual scenario in which streets having a junction with other streets in which the heat network was installed would be invited to vote on whether they wanted the heat network installed in their street. In reality, the installation of the heat network requires more in the way of top-down planning due to engineering constraints.
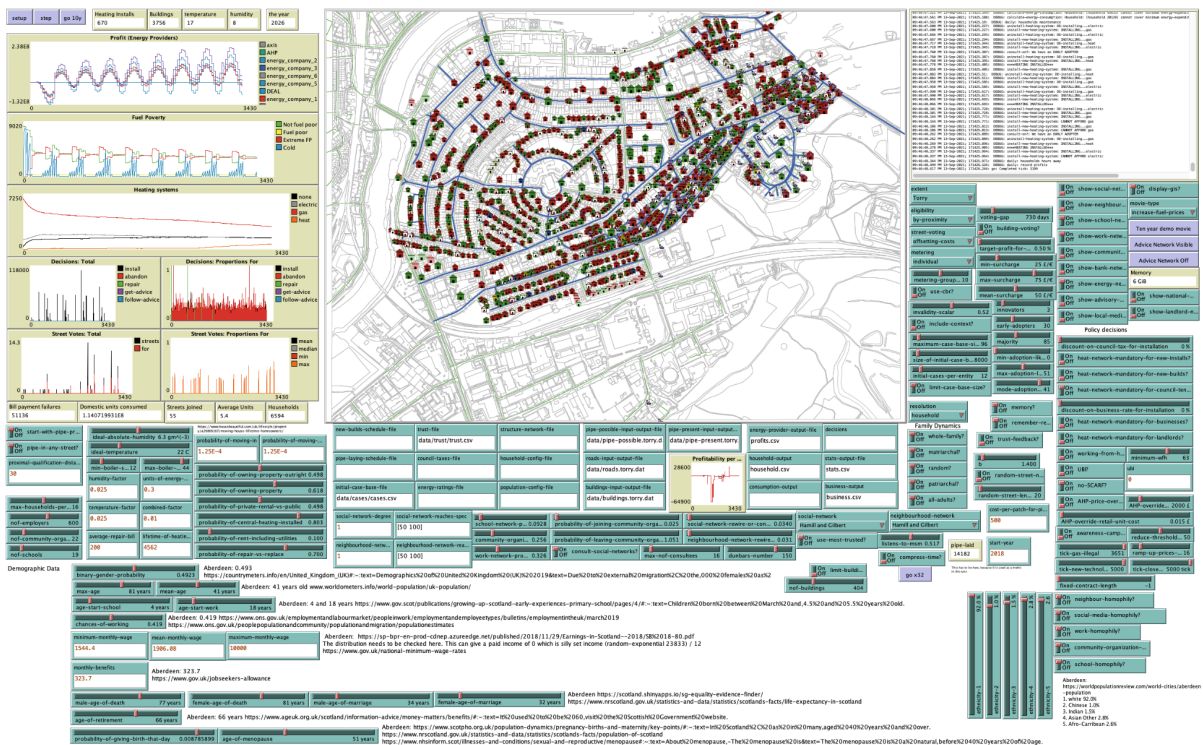
Figure 1: Screenshot from the ACHSIUM model with the parameters and output area cropped.

2.5 In Figure 1, the installed heat network is shown with a blue line. Fuel poverty status is indicated by the colour of the building: green indicating no fuel poverty, red and yellow fuel poverty; darker shades indicate connections to the heat network; lighter shades buildings not yet connected. The second graph from the top indicates a slow decline in fuel poverty (red and yellow lines) and number of households who switch the heating off (blue line), as the number of households using the heat network increases (orange line in the third graph from the top). Though the model features GIS data initialised from the Torry area of Aberdeen, the households are artificial and the depiction does not represent the real fuel poverty status of any living household in the area.

2.6 The decision-making algorithm used by the agents was based on Moore's (2014) elaboration of Rogers's (2003) work on the diffusion of innovations. For Moore (2014), there is a 'chasm' between what he calls 'visionaries' (innovators and early adopters) and pragmatists (early and late majorities); the latter being most interested in what technologies are used by people like them (and whether they are good enough for the job) than the former, who are primarily interested in novelty (innovators) and functionality (early adopters), and thus have a stronger personal norm regarding new technology. The simulation of the pragmatists, therefore, draws heavily on implementing descriptive social norms as per Cialdini et al. (1990, p. 1015): "what is typical or normal."

2.7 The decision-making procedure for the early and late majorities uses an agent-specific 'adoption-likelihood-threshold' (initialised from a triangular distribution). If this proportion of the n most trusted of the agent's alters have adopted the heat network is higher than the adoption-likelihood-threshold, then the agent will be in favour of its installation in their street (where n is a model parameter.) The heat network is then scheduled for installation in streets in which more than 50% of resident agents are in favour.

2.8 To summarise our simulation of Moore's elaboration of Roger's innovation diffusion and the relationship to norms, agents decide as follows:

- Innovators (personal norm: "I try what's new") – vote in favour of adopting the heat network if I have not experienced it before.

- Early adopters (personal norm: "I try something new if it works") – vote in favour of adopting the heat network if I know someone who has it who is happy with it.

- Majority (descriptive norm: "it is normal?") – vote in favour of adopting the heat network if the proportion of my n most trusted alters who have adopted is more than my adoption-likelihood-threshold.

2.9 Descriptive norms are therefore active in the case of the majority, while personal norms are active for innovators and early adopters. Note that for innovators, adoption is contextualised by the agent's own experience. For early adopters and the majority, the ego network provides a social context for decision-making. In the latter case, this is an obvious necessary condition for descriptive norms to operate. For early adopters, the personal norm is contextualised by the experience of others.

ABM simulation results

2.10 We ran an experiment in which the adoption-likelihood-threshold for households belonging to the 'majority' psycho-demographic profile – 70% of the population according to Rogers (2003) – was randomly sampled in the range [0-100%], while other options in the model were held constant and the variance of the triangular distribution for this agent attribute set to 0. At 0%, a 'majority' agent will not need any other agents to have adopted before they will; at 100%, they will need everyone they know to have adopted. The results from 212 runs are shown in Figure 2.
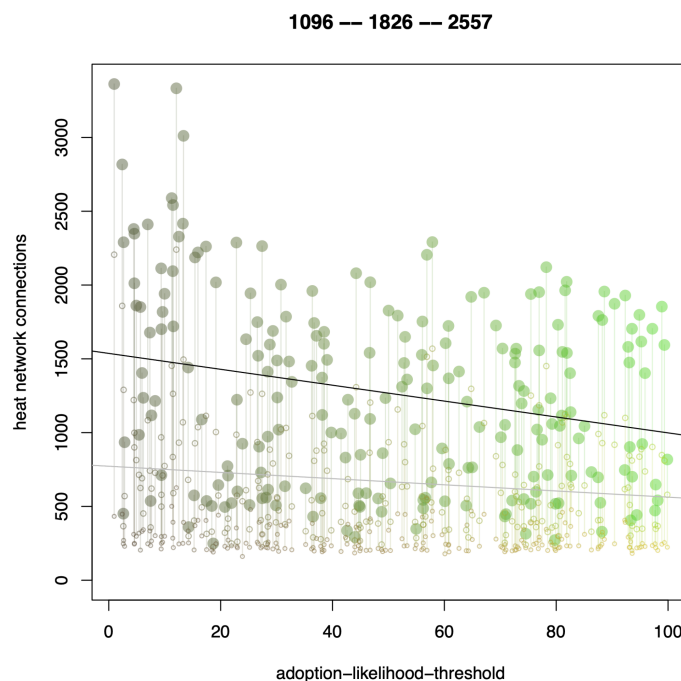
1096 —— 1826 —— 2557

Figure 2: Number of adopters depending on adoption-likelihood-threshold for 212 runs.

2.11 In this simulation experiment the adoption-likelihood-threshold was set to the same value for all agents in the 'majority' psycho-demographic profile, sampled uniformly in the range [0-100%]. In Figure 2, each of just over 200 runs is shown as a line with the number of connections at years 3, 5 and 7 plotted using a small, medium and large-filled circle. The black and grey lines show linear models fitted to years 5 and 7. They both show a trend of declining connections as adoption-likelihood-threshold is increased, with a greater decline for year 7 than year 5.

2.12 The spatial complexity of the model (streets can only connect to the network if a neighbouring street has already connected) combined with the fact that social tenants (25% of the simulated population) will automatically adopt means there is quite some variability in the number of connections to the heat network in each simulation. However, there is a clear trend towards reduced connections as the adoption-likelihood-threshold increases (illustrated by the black and grey lines that fit linear models to the data for years 7 and 5 respectively), with a possible tipping point between 10-20%.

2.13 The simulation results indicate that in general, stronger social norms (i.e., a greater proportion needed) may have a negative impact on joining a heat-network. However, even for individual runs with a higher adoption-likelihood-threshold, tipping points may be reached where a sufficient number of adopters cause the norm to become positive for joining the heat network. These results indicate that it is critical in such social innovation

projects to communicate that "people like you" are also joining a project. Eventually, people will simply expect that the way the social innovation did things is the way things will be done. In Aberdeen, that may mean that people will ask when considering renting or buying a property whether it is connected to the district heating. Following Nyborg et al. (2016), the more a social norm is emphasised that is supporting the innovation, the more likely it is that a tipping point is reached and that a project requiring a significant proportion of the community to join will become a success.

The Groningen case: A referendum on closing a road in a park to cars

2.14 In the past decades, the municipality of Groningen, the Netherlands, shifted focus in urban traffic planning from prioritising car traffic to actively prioritising cyclists and pedestrian spaces. The transitional process in the traffic system was marked by the implementation of the *Traffic Circulation Plan* in 1977 and is documented in detail by Tsubohara (2007). One of the key implementations was to temporarily close a road for cars in 1993 in the Noorderplantsoen. The Noorderplantsoen is an important park at the heart of the city that connects suburban areas to the city-centre via through traffic. Citizens of Groningen reacted differently to this closure, and therefore the municipality of Groningen organised a referendum in which citizens could vote whether the road in the Noorderplantsoen should be permanently closed for cars or remain open. The referendum yielded a turnout of 30% from which 51% voted in favour of closing the park for cars. The division between pro and against closure was polarised and the result was a close call.

Modelling the case of Groningen using the HUMAT architecture

2.15 The presence of different interest groups and numerous discussions that took place before the referendum make this an interesting case for exploring the emergence of norms. Novel organisation of a city-traffic system is closely connected to existing normative influences. Before the referendum took place, as an experiment, the park was closed for car traffic for a year. This allowed for a new norm to be enforced in a top-down manner. The norm was both descriptive and injunctive, because the majority did not drive their cars through the park, and because driving a car through the park was penalised with a traffic ticket. The temporary character of the experiment was visually signalled by the presence of heavy work construction equipment by the entrance to the park. At the time of referendum, the voters could experience and compare living in two different realities. From a normative perspective, the Groningen agent-based model focuses on another important aspect, as it shows how the result of the referendum that determined the new normal emerged from individual preferences of the local community members. The model focuses on representing the dynamics of motives (experiential needs, social needs and values) which influence individual choices. We postulate that values, among other motivations, translating into personal norms are an effect of communication and opinion formation processes: in the context of the first referendum in the Netherlands, the Groningen residents discussed the pros and cons of both choices (i.e., car-free and car-full) between one another, and individually made up their minds about why each option is positive and negative (Maslow 1954; Max-Neef 1992; Kenrick et al. 2010).

2.16 Since the implementation of the Traffic circulation plan, deprioritizing car traffic has been actively advocated by key stakeholders and innovators in the city council at that time. Since then, there has been a gradual normative change on car traffic and environmental values in city planning.

2.17 To replicate the empirical case of Groningen, model interaction and opinion formation, and explore policy scenarios, we built an ABM. We used the HUMAT socio-cognitive architecture (Antosz et al. 2019) that constitutes artificial populations in which agents have dynamic beliefs about how satisfying behavioural alternatives are for their needs and values, and can grow social networks to communicate with one another about these beliefs. The HUMAT framework represents social influence in the context of the (dis)satisfaction of different needs and values as motives for action, in this case the action consists of making the decision to adopt or reject a social innovation of a car-free park. Multiple needs can be grouped in the three basic categories of (1) experiential needs related to the short-term outcomes, (2) social needs related to fitting in the group and (3) values. *Needs and values* vary with respect to their importance to the individual. Moreover, alternative choices differently satisfy those needs and values. For example, when an agent is in favour of a car-free park because this alternative satisfies experiential needs and values, but at the same time it dissatisfies the social need as the majority of linked others are in favour of driving cars through the park, the agent will experience cognitive dissonance. From the perspective of that agent, the preferred alternative is internally inconsistent (has pros and cons), and the dissonant state will inhibit action and motivate the agent to reduce the inconsistency: try to convince other agents in its ego-network to change their minds. We introduce an important extension to social theory of normative influence: the idea of a perceived local norm. In the Groningen model, the agent does not have perfect

knowledge of the descriptive norm (because the referendum establishes rules for future behaviours), the opinions of others are hidden from agent's direct access, and only educated guesses about the descriptiveness of the norm come from speculating what alternatives others within the agent's social network choose. The perceived local norm, i.e., a belief about what is the most followed behaviour in an ego-network, rarely represents the global norm (i.e., the actual result of the referendum had it taken place at a given point in time). HUMAT also emphasises individual differences in sensitivity to social normative influence agents vary with respect to the importance of the social need.

2.18 Depending on the satisfaction of social needs, information exchange can take two forms: *signalling* and *inquiring*. If the slightly preferred option is not popular enough among alters, ego signals to his/her most gullible alter with an opposite preference and tries to convince/inquire them to change their mind. If the strategy of signalling is not suitable to decrease the dissonance experienced by an agent, he/she chooses to inquire about the slightly preferred option (open or close the park for car traffic). When inquiring, Groningen residents can ask the most persuasive alter in his/her social network for advice. Persuasiveness depends on perception of the communicating agent as being trustworthy as an information source, and is based on similarity between the communicating agents. *Decisions* on whether to adopt a social innovation result from a cumulative satisfaction/dissatisfaction of needs/motives weighed by importance of each of those needs/motives.

2.19 To benchmark the performance of the model and reproduce social dynamics in the Groninger community as closely as possible, we used empirical data to calibrate and initialise the model (for details see Antosz et al. 2020). The design allows for simultaneous integration of methods, because the agent-based modelling serves as a conceptual and formal framework for merging findings from other methods and data collection techniques, showcasing a holistic integrated mixed-method design (Caracelli & Greene 1997).

2.20 To validate the behaviour of agents in their opinion formation and decision-making processes regarding their preferred vote, we drew random samples from the simulated data to track opinions over time. The process validity of the model for Groningen is evaluated as positive because agent behaviour observed in the samples did not reveal agents with any illogical behaviour (e.g., changing opinions drastically after every interaction without clear indicators for the change). A considerable part of the agents who experience a strong cognitive dissonance between their different motives and remain undecided and unsatisfied. This can be explained as follows: the binary decision situation of opening or closing the park for cars does not yield a clear preference, hence no satisfaction and gratification for choosing either choice. The agents do always choose, but it leaves the agent with dissatisfaction.

ABM simulation results

2.21 Figure 3 shows the interface of the model and shows the map of Groningen. The Noorderplantsoen is the black kidney-shaped form situated northwest of the centre. Agents can appear either as green or red dots. Green dotted agents depict those in favour of closing the park for car-traffic, whereas red indicates that the agent prefers the option of car traffic through the park.

Figure 3: Interface of the model for the Groningen case.

2.22 As can be seen in the interface, in some neighbourhoods, mostly close to the park, a majority of agents is in favour of closing the park for cars, whereas in other neighbourhoods a majority is against closing the park for cars. However, it is important to realise that the network of interaction between agents is not only based on physical proximity (e.g., capturing interactions between neighbours and parents at schoolyards), but also networks of friends and colleagues (not spatially defined) are part of the plausible network being implemented (for details see Bouman et al. 2021). Socio-demographic characteristics of agents, in particular age, education and economic activity, determine the existence of links in the different networks the agents have (see Antosz et al 2020 for details). An agent may try to persuade another linked agent if it experiences a dissonance due to the other agent having a different opinion. For example, agents may have a different opinion on safety. The persuasiveness is determined by how similar and/or reputable the agents are. If the sender of the message is having the same age, and has an equal or higher education and economic activity (e.g., employed), the sender may be more persuasive than if the sender is a younger student.

2.23 The simulation results on voting behaviour in the referendum yields an average 49.54%, (Standard Deviation = 0.73, $N = 1000$) minority vote in closing the park for cars. Whereas in reality the referendum resulted in a victory for the pro-closing voters, in the simulations the majority of runs the open-voters win the referendum. This also indicates that it would have been very realistic that the referendum was won by the park-open-for-cars voters. This indicates that small events can tip the vote to either outcome of the referendum, and that the opinion of a single reputable person, spread through social interactions, may be sufficiently influential to affect the outcome of a referendum.

2.24 Given that the referendum addressed a tipping point due to the almost equal number of people voting in favour or against the closure of the park, we can imagine that small events, such as a deliberate persuasive act (e.g., informative campaigns and public debates), or a coincidental event (e.g., bike with car accident in the park), could have caused a different outcome (Bouman et al. 2021). To investigate this, we conducted several experiments that explicitly take these scenarios into account (see for more details on simulation results see Bouman et al. 2021).

2.25 First, a *bike with car* accident was simulated by increasing the importance of personal norms that prescribe the prioritisation of children's, pedestrians' and cyclists' safety over the convenience of having park-through traffic, holding other motives constant. The simulation results show that an accident leads agents to be more likely to vote pro-closure compared to a situation in which no accident happened.

2.26 Second, an *affirmative campaign casted by the municipality on the benefits of a car free park* resulted in more than 60% of the population voting for closure of the park for cars.

2.27 Third, organising *a public debate held at the townhall facilitated by the municipality* was implemented by drawing a stratified sample of 50 high-educated citizens of age 25 and older to attend the meeting in the city town hall in the centre of Groningen. Even though some agents updated their personal norms considerably due to a clear descriptive norm emerging in the town hall meeting, one meeting appeared not to be sufficient to have a significant influence on referendum results.

2.28 Fourth, we simulated *a meeting where inhabitants of neighbourhoods around the park could voice their concern on the additional car-traffic that will now go through their streets*. In the model we draw a stratified sample of 50 citizens of age 18 and older living in districts located directly adjacent to the park that can attend the meeting in a community centre in the park. Because already a majority was in favour of closing the park, no significant effect was found.

2.29 Overall, it seems that unexpected events can drive a revaluation of descriptive norms resulting in a change in voting behaviour. Regarding communication policy interventions, only the affirmative campaign of the municipality had a significant effect. This is perhaps not entirely surprising as this is the only top-down policy intervention where a descriptive norm is displayed and underlined by the local government, which has legitimate persuasive power and thereby puts a heavier weight on the descriptive norm compared to the other policy interventions. In reference to the policy reports from the field, both policy makers and citizens indicate that for communicative policies to be effective, citizens should be motivated to be involved from the onset and repeatedly be inquired with to reach a significant result and truly gain sustainable and long-term civic engagement (Dumitru et al. 2021).

2.30 In 2019, we conducted a survey ($N = 703$)[2] inquiring how Groningen citizens would vote nowadays in the referendum (Antosz et al. 2021). Almost 94% of the respondents indicated they preferred the status quo. This is a significant change compared to the referendum results in 1994, where only 51% voted for the closure of Noorderplantsoen for car traffic. It seems that over the course of 25 years, Groninger citizens have adapted to the Noorderplantsoen being a car-free park and fully internalised the emerging personal norm into a clear injunctive norm.

The El Hierro case: An island transitioning towards sustainable energy

2.31 El Hierro is the smallest of the Canary Islands in Spain, covering an area of 278 km^2 with a population of around 10,000. Historically, the island maintained total external dependence on energy supply, but in 1997 a Sustainability Plan was approved, whose main objective was to reduce dependence on fossil fuels. The island's conditions, such as a unique landscape with steep slopes permanently exposed to the wind, led the island government to set up the energy company '*Gorona del Viento*', an experimental wind-pumped hydroelectric plant that has been operating since 2015. On average, El Hierro achieved almost 50% renewable electricity in 2017. In the first half of 2018, Gorona del Viento generated 100% of the island's electricity for 1,450 hours, saving tons of diesel and CO_2 emissions, a particularly relevant milestone that turned the island into one of the first isolated territories in the world capable of covering its electricity demand, at certain times of the year, using 100% renewable sources.

2.32 Challenges remain to gain resilience and autonomy in energy supply and become a sustainable island by replacing energy based on fossil fuels with renewable energy sources, challenges that are addressed throughout the project "El Hierro 100% renewable energy island". Despite the apparent success of the project, there is still some resistance from part of the population for various reasons, among them, the cost of the project, which is not reflected in the reduction of prices that citizens must pay for energy.

2.33 In this case, the agent-based model aims to simulate the time evolution of citizens' opinion about the project from the very beginning up to the present, once they experienced the first phase of the project. Specifically, we are interested in studying the acceptability of the project and the factors that influence this acceptability in order to answer the following question regarding the future of the project: "What percentage of citizens will be in favour and what percentage will be against the expansion of the "El Hierro 100% renewable" project?". As was demonstrated (Bouman et al. 2021) and will explained later on, the acceptability will be related with the personal norms or values of the citizens, as well as with their understanding of social (injunctive) norms (e.g., opinions and behaviour of their friends, family members, neighbours, etc.).

2.34 As in the Groningen case, the main entity (agent) of this model is the citizen, who follows the general HUMAT architecture (Antosz et al. 2019), already described, to decide between two behavioural alternatives: accepting or rejecting the expansion of the project. The model also includes several critical nodes, key actors that played a relevant role during the execution of the El Hierro project, such as the *Cabildo* (city council) or, *Gorona del Viento* (the company responsible for managing the "Wind Power- Pumping Hydroelectric Plant"). Representing these critical nodes is fundamental since their opinions (for or against the social innovation) influence the citizens and, therefore, their possible transitions towards one behaviour or another.

2.35 In order to feed the model with specific data on the case, different quantitative and qualitative procedures were used to collect information on the actions carried out by these critical nodes over time (details in Dumitru et al. 2021). Additionally, a survey was conducted to collect socio-demographic data directly from citizens. It also includes all relevant aspects to model the process of creation of social networks (friends, neighbours), such as the number of persons a citizen usually interacts with or the trust s/he has in the different key actors.

2.36 These data also allow us to identify the needs required to apply the HUMAT model (see Section 2.2), in this case: experiential needs, values (such as environmental values and island independency) and social needs. These needs refer to the opinions that each citizen has regarding the project. In addition, the importance that each individual gives to each of these aspects was also obtained, which reflects their personal values and norms. The importance given to social needs determines to a large extent the diffusion of the norms since, as has already been explained, the level of satisfaction achieved in social needs compared to others, is what triggers communication between citizens in order to overcome their cognitive dissonances, either by inquiring (asking for their opinion), or signalling (explaining their opinion to their social network). Citizen agents are part of different social networks: friends (modelled on a homophily principle in age and level of studies) and neighbours (based on physical proximity). Thus, as in the Groningen case, the former allows for interactions between agents not close to each other physically. When dissonance appears in an agent, it might try to convince other agents in its networks that have different opinions on the matter. The degree to which they influence one another depends on their mutual trust, which is not necessarily symmetric, together with the similarity of their personal norms and values. In addition, another type of communication is unidirectional from critical nodes (local authorities, press) to citizen agents, where the former tries to convince the latter, their success depends on the trust citizens have in them. In the end, it is these communications that help individual opinions to become social norms.

2.37 The behaviour of citizens, guided by the HUMAT model, can evolve through three states (in favour, against or undecided about the project), although they finally have to make a decision. The individual's ultimate goal is to obtain the maximum global satisfaction with one of the behavioural alternatives, depending on how this alternative allows him to partially satisfy his personal norms and values.

2.38 As stated, agents do not live in a vacuum and communications received from critical nodes can also alter citizens' behaviour depending on the trust they have in these nodes. Some of these critical nodes could be seen as innovators/pioneers of the project. Besides, interaction with his social network also influences the behaviour of an agent, due to the need for citizens to feel part of it. However, these influences can be mitigated by the importance that each agent gives to each type of norm, thus allowing personal norms or values to determine the agent's decision over the social normative influence expressed as the thoughts of his neighbours or friends. In this model, the communicative acts carried out by the key actors were extracted from the documentary analysis to reflect the dynamics that they followed in the timeline that covered the three stages of the implementation of "El Hierro 100% renewable" (years 2006 to 2020).

2.39 Finally, the model allowed us to understand which norms and factors influence the dynamics of public opinion formation, to reach positive or negative tipping points. In conclusion, it was observed that the dynamics of reputation, as well as the tactics and strategies used by promoters to involve citizens more in the definition of the project, were the most influential aspects to achieve the objective of increasing the acceptability of such a project, which was imposed as a government strategy and that initially did not respond much to the particular concerns of citizens.

ABM simulations results

2.40 The interface of the model is presented in Figure 4. In the centre, the map of El Hierro island is shown with citizen agents placed in their corresponding census section, those in favour of the social innovation coloured in green, those against in red and undecided citizens in blue colour. As the model evolves, and citizen agents change their position towards the El Hierro project, their colour is appropriately varied. In addition, there are eight graphics showing the evolution of agents' opinions of the project, the number of communications with other citizens and the satisfaction of specific needs.
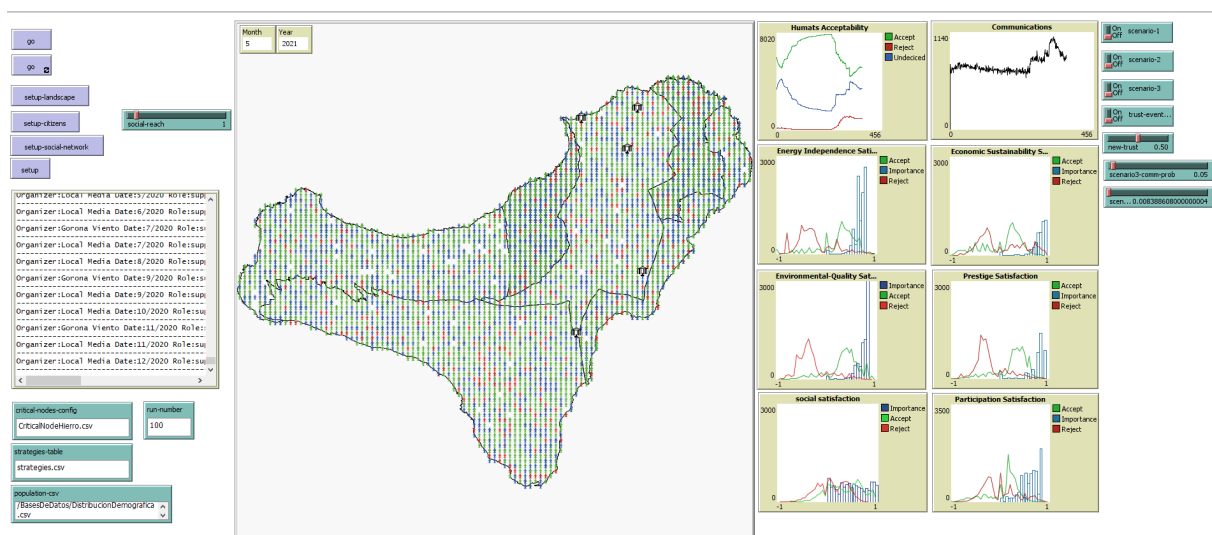

Figure 4: Interface of the model for the El Hierro social innovation case.

2.41 The calibration of the model tested its coherence with the real situation, from the period in which the "100% renewable El Hierro" project was launched (2006-2008) till it came into operation (2015-2020). Exhaustive documentary analysis of the case and validation through experts confirm that the model is able to reproduce the pattern of acceptability of the project. The validation was carried out using different workshops to consider the opinion of relevant promoters and stakeholders (Dumitru et al. 2021). This acceptability pattern is reflected in the blue curve of Figure 5 that depicts the evolution of the number of agents accepting the project from 2006 to 2021. As can be observed, initially it takes a while until this acceptance is imposed as the general norm, but a decrease in the acceptability started around 2016 that barely recovers at the end of the project in 2020. According to the stakeholders, the main reason for the population's disenchantment with the project was due to a misunderstanding, since the majority of the population assumed that, once Gorona del Viento came into operation, it would mean a reduction in electricity bills. This lack of communication between the promoters of the project and citizens, in which the financial consequences for the citizens were not communicated clearly enough, resulted in a difference between expectations and reality. One of the most important values was the individual

economic sustainability, which was not satisfied with the implementation of the project. In addition, the high cost of the project was also criticised in the press at that time. As a consequence, there was a change in the descriptive norm, a tipping point, with the majority of the population positioned against the project because of this coincidental event.
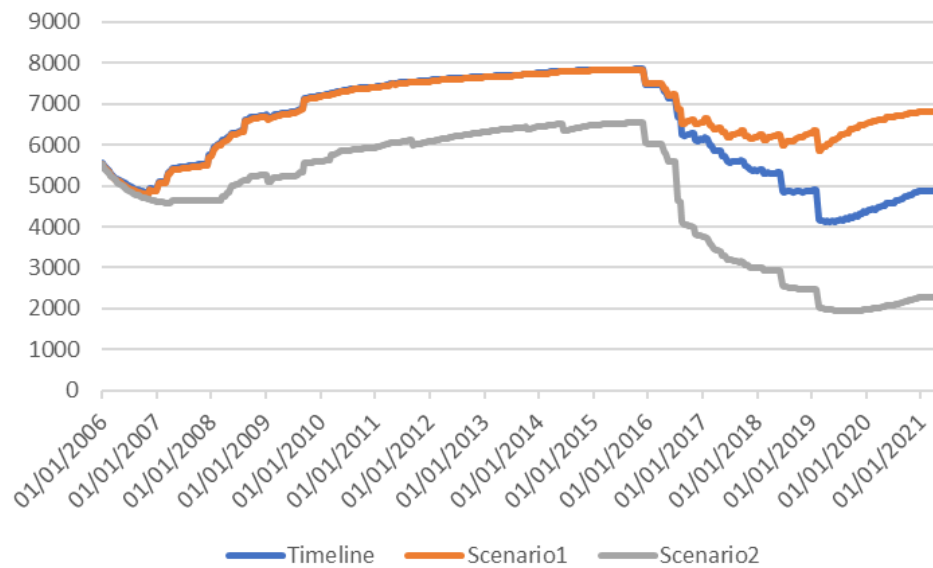

Figure 5: Evolution of the number of agents accepting the project from 2006 to 2021. Comparison between the basic Timeline and Scenarios 1 and 2.

2.42   Different alternative scenarios were tested trying to analyse how several policy actions could help to smooth out this drastic drop in acceptance in 2016. The first alternative scenario consisted of improving the direct communication of the main project-promoter (*Gorona del Viento*) aimed at "ensuring that the citizens perceive the project's benefit, as this is the most effective in terms of their acceptance". Even though the electricity bill is not reduced, the objective of this direct communication is to achieve greater acceptance of the project and, thus, that the descriptive norm becomes accepting it. The communication is emphasising how the project can benefit other needs or values not related to individual economic benefit, such as environmental quality and island prestige. This scenario was simulated in the system by increasing the frequency of communicative actions from promoters (both Cabildo and Gorona del Viento), especially in the 2014-2020 period. Some citizens will be influenced by this direct communication, changing their personal norms. The alteration of these citizens can spread through their social networks, and thus influence others who, in turn, may also change their behaviour. Table 1 shows the remarkable increase in acceptance that this communication strategy has, since it achieves that 20% more citizens accept the project, resulting in accepting the project as a social norm. Similarly, Figure 5 shows how the 2016 decline slope is slightly up (orange line).

Scenarios	Initial Acceptability (%)	Final Acceptability (%)
Timeline	58.43	51.16
Scenario 1	57.70	71.45
Scenario 2	57.90	23.97

Table 1: Evolution of the number of agents (%) accepting the project at the beginning of the simulation (2006) and at the end (2021).

2.43   The relevance of social norms, and mainly of organised communication acts, is reflected in the second alternative scenario. This shows the opposite situation to scenario 1: what would happen if the promoters of the project did not exist, that is, they did not issue any communicative act and citizens make the decision to accept the project (or not), based solely on their personal norms, their experience with the project, or by the messages they receive from their closest circle (friends, neighbours). As it can be seen in both Table 1 and Figure 5, the final acceptability drops considerably below the timeline results. Consequently, comparing these two results with the original timeline in which sporadic communication campaigns were carried out, it can be concluded that a periodic information campaign not only improves the final acceptability of the project but also makes

citizens have a more robust opinion of the project and, therefore, that the descriptive norm is less vulnerable and changeable in the face of certain uncontrollable events that may occur.

● Discussion and Conclusion

3.1 Many changes in behaviour and social practices that are desirable from a sustainability and quality-of-life perspective, take place within a social context, where information, social norms and personal norms and values interact in complex ways. As the case studies presented in this paper demonstrate, it is quite possible to develop agent-based models that are capable of simulating such dynamics. This opens up possibilities to explore how policies and critical (co-incidental) events interact with social dynamics.

3.2 The key lessons we learned in modelling different cases is that (1) norms play an important role in the success or failure of social innovation projects, (2) empirical data on how susceptible people are for the social influences by other people are virtually impossible to get, and (3) using theoretical grounded rules for modelling these normative influences allows for an approximation of normative effects in processes of social innovation.

3.3 The three cases we presented differ concerning the level of detail in the modelling of social and personal norms and values. This is because the different cases also differ with respect to the context.

3.4 The Aberdeen case focussed on a street level and a decision to join the heat-network. For this, two types of agents were implemented, the visionaries that were more driven by their tech-prone values, and the pragmatists being more interested in what technology is used by people like them, so following a descriptive norm. The heat network is scheduled for installation in streets in which the majority of resident agents are in favour. The Aberdeen heat network case demonstrates that the success rate of projects can vary a lot, and that social norms can have an overall negative influence on the success rate of a project. Social norms display a basic reserve to new practices. However, once a critical mass of adopters has formed, the social norm may change and support grows. Having a cluster of people adopting the innovation can cause an innovation to spread faster and further through a community (see e.g., Delre et al. 2010). The success rate of simulated projects therefore fluctuates a lot, indicating that local social processes (here at the street level) may determine the fate of a project.

3.5 The Groningen case is larger in scale, and deals with different neighbourhoods, where interest in closing the park for traffic differs. First, the social norms in the neighbourhood of the park were stronger, the poster action being a visible demonstration of the social norm. Next, the personal norms and values differed between citizens, partly correlating with the neighbourhood. The value of having freedom to use the car was important for a relevant group of citizens, whereas environmental and safety values were emphasised by other citizens. Both policies as coincidental events can impact the outcome of the referendum. The Groningen case spans over 25 years, and we empirically observed that the support for closing the park for cars rose from 25% in the beginning, to 95% now. This highlights that social norms can be internalised as personal norms and values over a time-period. Investment in infrastructure can impact the personal norms and values that people have in the longer run. We have to be mindful of the increased importance of environmental values that have changed over the years as well. Social simulations that model long-term developments thus could benefit from a norm-internalisation process, where agents initially can adopt behaviour because of social norms, but internalise this over time into a personal norm or value. Here a connection with models addressing self-identity can prove to be of interest.

3.6 In the El Hierro case, island prestige was an important value, which can be interpreted as a shared identity value that people cherish. This indicates that a shared identity can be coupled with shared practices in a community, which adds to the social dynamics of innovative projects. The social identity that people have can be multi-layered, perhaps even starting from the street level (e.g., the Aberdeen case), and range to the neighbourhoods, cities, islands and countries. In the El Hierro case multiple needs were implemented, ranging from value driven needs such as energy independence and island prestige, to following norms, referring to belongingness, social safety and status in the social network composed of friends and family. Here the whole island population could be more or less supportive of the "El Hierro 100% renewable" project, which was more complicated than the aforementioned joining a heat-network or voting on a car-free park. Informative policy had an important impact on the support for the El Hierro project. This shows that informational strategies addressing for example personal values of people (island prestige) may create support for the project, which in turn also influences the social norm concerning the project. In this sense, simulations can reveal second order social effects of informational strategies.

3.7 The results obtained with the three simulated cases highlight the fact that normative influences and values affecting opinions and behaviours cannot be addressed in isolation when studying real cases of social innovation.

These factors are embedded in a wider behavioural and social-cognitive context, and hence require embedding in an integrated modelling framework of humans in communities. This requires a formal connection between (1) cognitive processes addressing e.g., different needs, memory, learning and cognitive dissonances, (2) social psychological processes addressing e.g., processes of persuasion and normative susceptibility, and (3) sociological notions on the structures and properties of networks connecting people in a community.

3.8 With respect to modelling the influence of norms, we suggest starting with modelling needs and cognitive processes. This allows us to address conflicts between personal interests and motivations on the one side (experiential and value needs), and the behaviour and opinions of alters on the other side (social need). When a norm conflicts with experiential and value needs, the agent experiences dissonance, which serves as a driver for persuasive processes. In more simple models that do not address persuasion, such as the Aberdeen model, it might be sufficient to make a distinction between the visionaries and the pragmatists, the latter following the example of visionaries if attractive enough. However, when persuasive processes are being targeted in a model, cognitive dissonance can be used as the driver for agents to try to convince other agents. Here social psychological rules come into play, because an agent will not try to influence random people. Similarity between agents is a key factor that serves as a basis for trust and relevance of information, and is important in networked communication. Status differences have an influence on who is listening to whom. Similarity and status together target the sociological level of networks, which is very difficult to get grip on using empirical data only. Getting reliable and complete data on social influences in a community regarding a particular topic is virtually impossible to do. Hence we use socio-economic data of the population to be modelled, and define rules for similarity and status affecting who is interacting with whom, and how susceptible the agents are to the influence of other agents. This allows us to model norms in a more elaborate manner in contexts of social innovation, using relative standard data sets of data that are commonly available at e.g., municipalities.

3.9 To conclude, we have argued that the modelling of normative influences in such a way that it captures the communicative processes in communities requires an integrated modelling approach. Norms do not operate in isolation, but are nested within a wider context of different needs. They relate to cognitive dissonances, which drive persuasive processes. The degree to which people are susceptible to other people depends on their similarity and reputation. This also relates to the social network that people have, but also to the personality of people. Some people are less susceptible to norms (non-conformists), and some even actively opposing norms (anti-conformists). Of course, very often people are behaving habitually, and do not really consider changing their behaviour. This means that the operation of norms can be understood only in the context of other drivers and factors, which requires an integrated modelling approach. HUMAT is being presented here as a framework that allows for such an integration.

3.10 Our case studies demonstrated how empirical data can be used in modelling normative influences. Because data on normative influences and social networks are very difficult to obtain, we used more simple socio-economic data, and used theory-informed rules to leave it to the agents themselves to form their networks and interact. This appears to be an efficient way to simulate processes of social influence in an efficient and theoretically plausible manner. Possibly this is even better than asking people after their social susceptibility and using this as an input for models, as people generally are hardly aware of the strong social forces determining their behaviour.

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⬤ Model Documentation

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Notes

[1]Often the concept of natural resources is used in this context, however, this can be interpreted as a too anthropocentric perspective on nature.

[2]Due to self-selection bias, and possibly a sampling frame bias, there is significant underrepresentation of Groningers with lower level of education and overrepresentation of young adults.

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