

Social Need versus Local Opposition: Simulating Energy Infrastructure Siting Outcomes Using a Multi-Agent Decision Support System^{☆,☆☆}

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Abstract

Siting new energy infrastructure projects to meet growing demand is becoming increasingly contentious and costly. This paper explicates the design and results of the Sustainable Energy Modeling Program (SEMP_{ro}), a decision support system for energy infrastructure siting. SEMP_{ro} makes two contributions to planning decision support: first, SEMP_{ro} fuses geographical information system data with a multi agent-based model (ABM) of citizen attitude and behavior diffusion, a powerful tool in predicting the outcome of planning decisions and explaining emergent opposition behavior. Second, it is the only planning model we are aware of that integrates an ABM with spatial bargaining models of stakeholder and regulatory decision making to simulate the real world complexity of infrastructure siting. Using a high voltage transmission line project in California for model development and validation, we find emergent citizen interactions affects stakeholder and regulator decision making in siting processes. Monte Carlo simulations show that higher levels of project disruption result in a greater number of citizen comments sent to regulators. These messages have a greater impact on the preferences of regulators simulated in the spatial bargaining module than they do on stakeholder preferences. Stakeholder preferences are strongly influenced by the community based organizations that arise to oppose the project. We also find that risk communication efforts by project proponents need to be carefully tailored to the attributes of the project and the impacted communities.

1. INTRODUCTION

Growing populations and economic demands are driving investments in new energy infrastructure. Several large oil pipeline projects have recently become prominent, including

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the Keystone XL project in the US and the Northern Gateway project in Canada. In addition, massive structural changes are occurring in the energy sector from laws requiring new renewable energy sources. In the US, 27 states have renewable energy requirements while the EU is requiring 20 percent renewables by 2020. Renewable energy projects typically also require new, large transmission and distribution infrastructure projects to move the electricity into demand centers.

However, citizen advocacy and interest groups can raise ferocious opposition to new projects. Infrastructure projects increasingly result in legal battles, civil conflict, and long delays in getting the projects approved and constructed. A great deal of research has gone into this not-in-my-backyard (NIMBY) phenomenon (Schively, 2007). A project that raises NIMBY concerns, otherwise described as a locally unwanted land-use (LULU), is infrastructure that is typically socially needed, but unwanted by the community in which it is proposed to be sited. Most energy infrastructure projects are coercive, in that they are not invited by the community, and sponsors can use eminent domain to complete the project. Community opposition can stem from local quality-of life-concerns, not trusting the project sponsors, or from opposition to the perceived flaws in the proposed technology, such as nuclear power or waste incineration projects (Sandman, 2010).

To the extent that community opposition strongly influences stakeholder and regulatory decision making, then a small percentage of the population can block or delay infrastructure siting projects that are critical to larger social goals including economic development and energy system reliability. This is the classic social dilemma that we attempt to address in this research.

Our research question focuses on whether it is possible to mitigate the seemingly intractable socio-political conflicts facing public and private managers who are trying to balance legitimate citizen concerns with achieving public policy goals. Ideally, citizen and other stakeholder concerns would be integrated into the project design early in the planning process (Stern and Fineberg, 1996). Devine-Wright (2005) and Cain and Nelson (2013) make forceful calls for a more interdisciplinary approach to understanding stakeholder opposition; one that requires not only citizen preferences, but also project attributes, as well as political and institutional factors to better understand and predict project outcomes.

Our approach responds to these calls for interdisciplinary analysis by simulating citizen participation and stakeholder and regulator decision making processes simultaneously in an inherently interdisciplinary modeling framework. In the following sections, we first discuss the Sustainable Energy Modeling Project (SEMPro) decision support system designed to simulate the infrastructure siting process. Then based on SEMPro Monte Carlo simulations, we perform several econometric analyses to explore what factors influence citizens, stakeholders and regulators preferences about the project and how they might interact to determine the project outcome. We conclude with policy and theoretical implications.

2. SIMULATING THE SOCIO-TECHNICAL SYSTEM

SEMPro is part of a new class of techno-social (Vespignani, 2009) and complex adaptive systems models (Abdollahian, Yang, Coan, and Yesilada, 2013a; Quek, Tan, and Abbass,

2009), simulating the interactive effects and feedbacks between human and institutional agency, engineered physical elements, and geophysical systems. SEMPro makes two contributions to planning decision support. First, SEMPro is one of only a handful of agent based models (ABMs) that can be used for planning decision support (Ligmann-Zielinska and Jankowski, 2007), in part because of its use of geographical information system (GIS) and detailed census survey data. Second, SEMPro is the first planning model we are aware of that integrates an ABM with cooperative and non-cooperative game theory models of stakeholder and regulatory decision making.

SEMPro utilizes the ABM approach as it generates emergent, large-scale system phenomena from the micro-motivations and behavioral interactions of multiple agents. ABM results can then be validated against observed patterns of behavior to analyze what percent of the variation in real-life events that can be explained by the modelling. ABMs are used in techno-social modeling for three primary reasons. First, agents can be assigned attributes based on stochastic distributions to represent noise or errors in human communication in the model that is reflective of the dynamic, adaptive and strategic nature of human behavior, especially in real-world political and social processes (Axelrod, 1997). Introducing stochasticity in agent relationships can dramatically affect networks structures that in turn drive different behaviors (Pujol et al., 2005). Second, unlike most top-down economic models, agents in ABMs can be assigned heterogeneity in preferences, attributes, or goal-orientation objectives. Brown and Robinson (2006) have shown how variations in preferences predict divergent land use outcomes. Finally, the interaction of these heterogeneous agents can lead to non-monotonic outcomes stemming from social mimicry, cooperation and competition in human systems (Ligmann-Zielinska and Jankowski, 2007). Thus, ABMs can represent, anticipate and shape the complexity of socio-technical systems better than equation-based models and are more transparent (Axtell, 2003).

SEMPro was developed using a systems perspective and parameterizes the project and policy levers that enable scenario analyses required of an effective decision support system (Lempert, 2002). Decision support systems (DSSs) like SEMPro allow users to simulate trade-offs and alternatives to improve energy planning outcomes (Pohekar and Ramachandran, 2004). DSSs are intended to improve the quality of decision making and need to be generalizable to a wide range of cases (Kersten, 2000). SEMPro can be applied to a wide range of infrastructure siting technologies such as oil pipelines, highways, high speed rail, electricity generation stations, and the subject of this paper, electricity transmission lines. In addition to varying project level variables such as engineering attributes in SEMPro, we can also estimate the impacts of changes in risk communication strategies by project stakeholders.

2.1. The Institutional Arena for Infrastructure Siting

Although our approach is generalizable to a wide range of institutional infrastructure frameworks, here we focus on the Environmental Impact Assessment (EIA) process. EIAs are typically required for these large infrastructure projects involving government funds or lands. EIAs involve analyzing the likely environmental impacts of a project in a multidisciplinary fashion, presenting the information to the public and decision makers, and taking public and

stakeholder comments into account in the final decision. After the US systematized EIAs in the National Environmental Policy Act (NEPA) of 1969, some form of assessment has been required by all US states, and in a growing number of nations around the world (Wathern, 1988, p. 3). The European Union requires EIA for public and private infrastructure projects that are thought to have significant environmental impacts (EU, 2012). Most nations in Asia, including China, Korea, Japan, Indonesia and India require some form of EIA before major projects can proceed. The siting of an energy project usually begins with the project sponsor developing a detailed and substantial review of social and environmental impacts. The process involves public notification of the project proposal, public involvement in scoping, preparation of a draft EIA, public review and comment on the draft EIA, and the preparation of a final EIA that takes public comments into account (NEPA, 1969).

2.2. Citizen Impact in Planning Outcomes

Most planning frameworks are designed to include public comments in the decision process to varying degrees. Public participation in decision making can have many important benefits including building trust, developing buy-in, provide objectively superior decisions, and lead to a more healthy democratic society (Beierle and Cayford, 2002). The rationale for public participation is to level the playing field in the sense that everyone should have equal voice in the process (Dietz and Stern, 2008, p. 207). There is substantial evidence in the planning and political science literature that ensuring robust public participation and making use of collaborative planning approaches can significantly reduce conflict. Beierle and Konisky (1999), in a study of planning in the Great Lakes region, find that an open and fair participatory process is associated with greater trust and better policy outcomes. Many public participation practices reduce conflict and develop accountability (Beierle and Cayford, 2002). Based on experience within the environmental arena, there is empirical evidence that when public participation is intensive and diverse, environmental planning efforts can be more successful in terms of improved trust, support for local policy change and willingness to pay for environmental protection (Lubell, 2004). Stakeholder trust in the project sponsors can reduce perceived risks from the proposed project (Baxter et al., 1999).

However, the magnitude of citizen influence in infrastructure planning outcomes is subject to considerable debate. Scholars and practitioners have found significant problems with EIAs. Doelle and Sinclair (2006) argue that the process-based approach of EIA lacks standards and neglects outcomes. In many cases, members of the public may not have the time or the resources needed to participate in technical decisions (p. 187). Jay et al. (2007) find that although the creation of a full EIA can result in modest fine tuning of projects, EIAs usually fail to substantially change the scope and nature of the projects development. Research shows that project outcomes are typically not directly influenced by explicit environmental or social variables, but rather by political concerns as well as elite preferences (Wood, 2003).

Although individual citizens may not have measurable influence on project outcomes, organized opposition groups can successfully alter policy decisions. Community based organization (CBO) collective action has generally been in the form of social movements, whose strategies have included protests, political lobbying, and legal challenges (Halebsky, 2009).

While an in-depth review of this voluminous literature is beyond the scope of this paper, Amenta et al. (2010) reviewed five top sociological journals from 2001 to 2009 and they found that only 3 of 54 articles reported no political or social effects of social movement activity.

However, many of these studies can be challenged as they tend to select on the dependent variable by focusing on only success cases while neglecting community collective actions that social movements did not arise, nor were a causal factor in determining policy outcomes. Walder (2009) provides a critical review of the literature on political sociology and social movements that shows strong effects of social movements on political change. Similarly, McAdam and Boudet (2012) identified twenty at-risk communities and studied whether their mobilization or non-mobilization led to the rejection of energy projects. They found community mobilization to be one factor in determining project outcomes, but political economy and stakeholder preferences were also important.

2.3. Elite Impact in Planning Outcomes

Empirical research outside political sociology also show that elite preferences strongly shape planning outcomes. Maggioni et al. (2012) find that energy sector elites have considerable influence in planning outcomes and this section is derived from their review. Although stakeholder participation in general has elicited great expectations for power sharing among diverse interests and individuals (Fiorino, 1990), other researchers have been concerned that stakeholder processes simply reproduce the power relations already present in a jurisdiction (Ansell and Gash, 2007). Other studies suggest that powerful industry groups manage to manipulate state energy policies (Rabe and Mundo, 2007). Evidence suggests that environmental groups have been skeptical of participation mechanisms because of the perceived power of pro-development interests to influence the outcomes (Echeverria, 2001; McCloskey, 2000).

3. DATA AND METHODS

Given this review of elite influence in planning outcomes, a planning decision support tool needs to systematically integrate elite preferences into modeling efforts. SEMPro is the first planning tool that we are aware of that simulates bargaining dynamics amongst stakeholders as well as decision makers in the decision process using a spatial bargaining model. Bargaining models date back to Condorcets voting paradox (1785), and Black (1958) and Downs (1957) trying to frame a positivist approach to analytical politics. More recently, McKelvey and Ordeshook (1990) as well as Feldman (1996) outline four fundamental assumptions for spatial stakeholder bargaining models: actors are instrumentally rational, with the choice set of feasible political alternatives modeled as a space with complete, ordered and transitive properties. The spatial bargaining approach naturally lends itself to agent-based modeling as stakeholders possess decision agency as well as attributes of preferences over issue spaces, with varying influence and salience (Hinich and Munger, 1997). ABM instantiations of spatial bargaining models include Abdollahian and Alsharabati (2003) and Abdollahian, Baranick, Efir, and Kugler (2006).

The SEMPro model is implemented in the popular NetLogo ABM modeling environment (Wilensky, 1999), simulating individuals, organizations, and agencies all interacting on a geophysical substrate. SEMPro model has three different sequential submodels built on different game theoretic assumptions, a cooperative citizen/CBO formation module to maximize joint interests, a non-cooperative stakeholder lobbying module and a regulatory decision making module that maximize individual stakeholder and regulator interests. Figure 1 depicts the high level process and multi-module architecture.

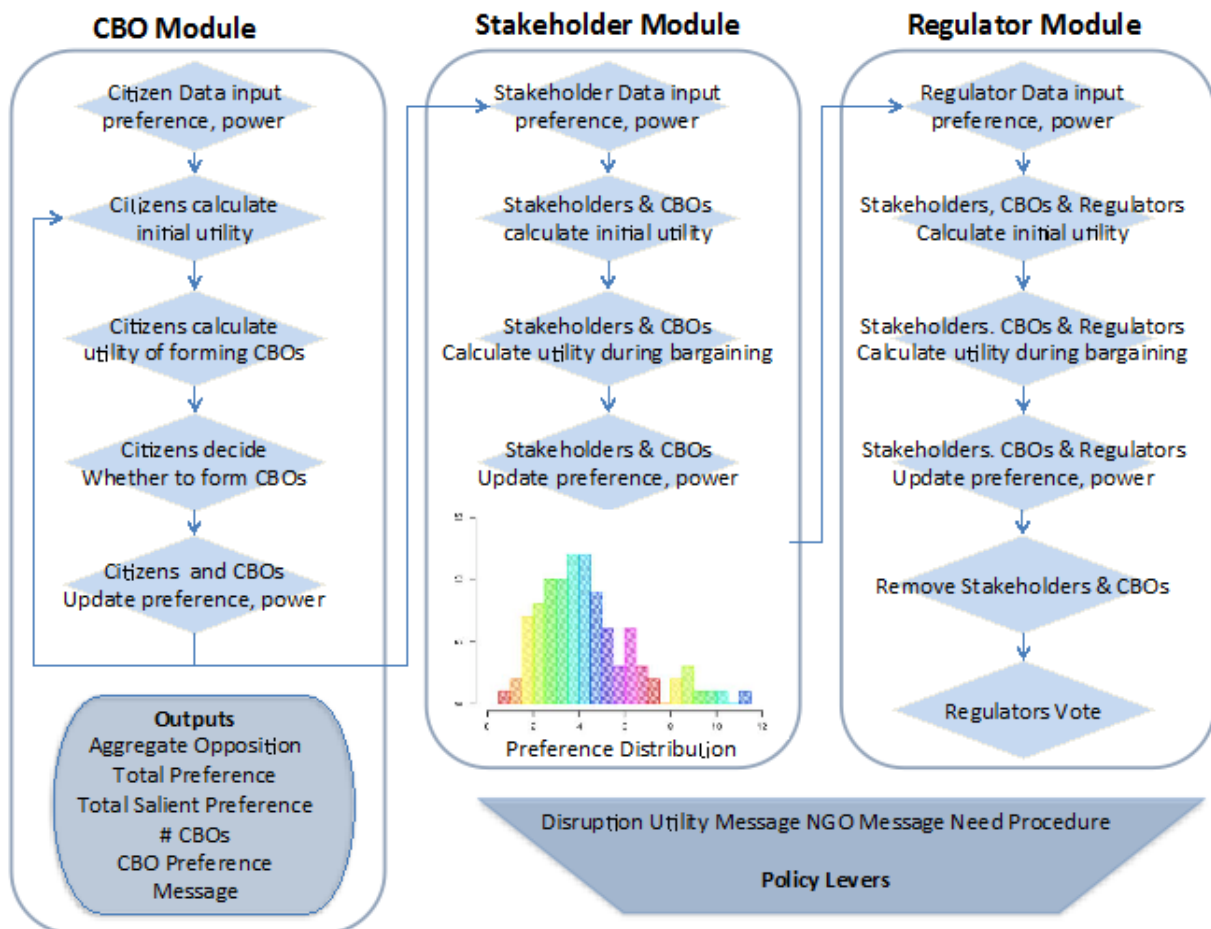


Figure 1: SEMPro Modules (online color)

Source: Abdollahian, Mark, Yang, Zining and Nelson, Hal (2013). Reprinted with permission.

The individual citizen agents are instantiated in the model and interact with one another and are subject to influence from anti-development Non-Government Organizations (NGOs), such as the Sierra Club, and the pro-development sponsoring utility company. The citizen agents also have the ability to organize into CBOs to increase their influence. The CBOs and a set of stakeholders then bargain amongst each other about the project, trying to influence the regulatory body over the outcome of the siting decision.

3.1. SEMPro Overview and Scheduling

In the first module, citizens react to infrastructure siting projects forming opinions and shaping those of others. Citizens send out messages supporting or opposing the project based on their own attributes and proximity to planned infrastructure siting. These citizen interactions can result in the formation of CBOs that either support or oppose such projects. To simulate this process, after we load GIS data and initialize the model, citizen agents are queued and processed according to their patch or grid location. US Census block-group population density data is used to locate citizen agents in the ABM. Citizen agents are instantiated in the model space at a sampled rate consistent with their census population (i.e. 1 agent per 1000 census population). Census data on education and income by block-group are instantiated as attributes of the agents in the model and provide initial heterogeneity for simulated citizen behavior. Higher values are associated with greater levels of influence in affecting project outcomes and imbue citizens with power. Wealthier and more educated individuals tend to have a stronger sense of self-efficacy and more resources available for advocacy. Each citizen agent is assumed to be autonomous, with bounded rationality, maximizing its own utility subject to the geophysical, engineering and social constraints of its environment (Yeung et al., 1999).

SEMPro simulates the technical aspects of the decision process using project engineering and GIS data. This data can take the form of lines or polygons, the power lines, or points, such as waste incinerators or power plants. Overlaying GIS project data onto the census data is critical as the project is placed into the real-world political and social community attributes. This is critical as infrastructure projects are often sited in existing right-of-ways. These right-of-ways represent the setback between the project and built environment. This drives model behavior as the proximity of the citizen agents to the project is a key parameter in the model. Citizen importance or salience attached to the project is the inverse of its distance. On average, less proximate citizens don't get involved in the siting process because it is not that important to them.

Risk communications are also instantiated in the model design, defined as a purposeful exchange of information about health or environmental risks between interested parties (Covello et al., 1987, p. 172). Risk communications by project proponents and opponents can serve multiple functions. They can attempt to educate target groups, disclose potential hazard information to exposed groups, or they can attempt an attitude modification role to increase the acceptance of a specific source of risk (Renn and Levine, 1991).

In the second module of stakeholder bargaining, against this backdrop of political and social opinion formation and risk communication processes, organized stakeholders seek to lobby not only citizen opinions but also other stakeholders to maximize their specific, organizational interests. The stakeholder bargaining module takes the emergent CBO formation into consideration in determining stakeholder bargaining outcomes using non-cooperative game theory.

In the third module, regulators join the bargaining process in the end of the stakeholder module, taking into account CBO formation and public opinion, then bargain among themselves in the regulator module to vote either in support or opposition to the project. Each module updates at each time step. This parallel, linked module processing sequence then it-

erates. In two continuous time steps, if no new coalition is formed, or no CBOs, stakeholders and regulators change their preference, then the model reaches its steady state equilibrium and will stop.

SEMPPro users can simulate changes in the engineering, social, and political attributes of each project as explained in Abdollahian, Yang, and Nelson (2013b). Actionable policy levers for shaping the siting process condition relevant the data and models processes at each time step. Each policy lever parameter is normalized along Downsian issue continuum on a 1-10 scale to calibrate the models internal validity.

- The most important project variable in the model is the level of *disruption* that the project imposes on the community. Disruption is defined as impacts to public health and safety, viewshed impairment, impacts to property values, or other externalities from the infrastructure project (0-1 scale).
- *Perceived Need* is another project variable. The highest value is when the project has been approved by the state regulator and is perceived to provide local system reliability or economic benefits.
- *Utility-Message* represents the number of pro-development messages the project sponsor sends to citizens to shape public attitudes in each time step. SEMPro propagates utility and NGO messages according to the parameter settings for each simulation in each time step.
- *NGO-Message* is the final project level variable that represents the number of anti-development outreach risk communications that non-governmental organizations (NGO) such as the Sierra Club sends in each time step.
- Two institutional level variables are included in the model:
 - *Procedure* is an indicator of procedural justice, or to what extent the citizens think their preferences will be included in regulatory decision-making.
 - *Trust* is citizen perceptions of how well the project sponsors can be trusted to follow through on what they say they will do.
- The primary community level variable is *Talk-Span*, defined as is the distance across which citizen agents talk to each other and make decisions on whether to form CBOs. This can be conceived as the social connectivity of citizens (Putnam, 2001).

3.2. SEMPro Case Study

The SEMPro model was validated with data on the Tehachapi Renewable Transmission Project (TRTP) in Southern California. Southern California Edison (Edison) is building the TRTP to connect renewable generation facilities in Kern County with customers in Los Angeles and San Bernardino Counties. The 250-mile, \$2.1 billion project includes both the construction of a new 500-kilovolt transmission lines as well as upgrades of existing transmission lines and substations (CPUC, 2013).

This study area was selected in 2010 because of the rich, publicly-available data on citizen and stakeholder preferences, but has become an opportunity to showcase the power of SEM-Pro to predict socio-political conflict. After winning final approval in 2009 and beginning construction, the California Public Utilities Commission (CPUC) reversed its decision. It has ordered Edison to underground the large power line through the wealthy community of Chino Hills. The CPUC's reversal was due to turnover in its internal membership, a change in the California Governorship, as well as a protracted political campaign by a Chino Hills community-based-organization opposed to the project.

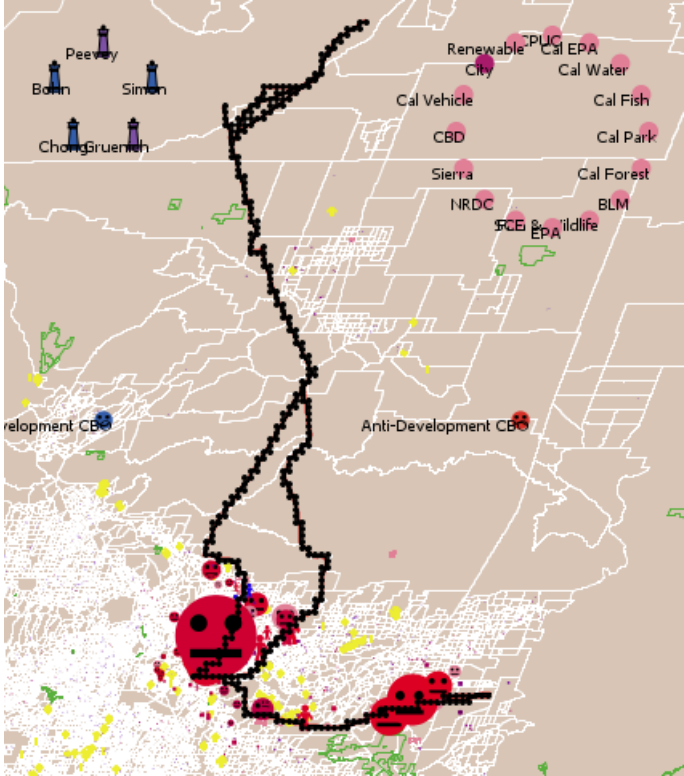


Figure 2: SEMPro Dashboard (online color)

Figure 2 shows the SEMPro dashboard and its data visualization for the case study. The black line represents the TRTP power line as it goes south from the wind-rich Tehachapi region in Southern California, across the San Gabriel mountains, into the populated Los Angeles basin. The white lines represent US census block groups where small polygons have higher population densities. The red faces represent the models predictions of the location of CBOs that oppose the project and are discussed below. The regulators and their preferences are represented as chess pieces in the upper left of Figure 2. The circle of stakeholders and their preferences are represented in the upper right of Figure 2 details the bargaining and proposal networks created throughout the influencing process.

Data for citizen preferences comes from the EIA documents (CPUC, 2013). Data for stakeholder preferences comes from a mail and web-based survey administered between

August 2011 to March 2013 to 122 government agency, industry, and NGO stakeholders who submitted formal comments on either the TRTP or Sunrise Powerlink projects in Southern California. We received 38 usable responses from 122 invitations. The high response rate (31%) was achieved because invitees were incentivized to participate with an offer of a \$20 Starbucks gift card upon completion of the survey.

3.3. Model Verification and Validation

The SEMPro software code was verified using several standard modeling techniques. Verification is the process of ensuring the model functions as it is intended to. Comments were included in the model code to identify functions, objects and procedures. Unit tests were employed in the development of the three modules. Finally, SEMPro outputs include multiple output diagnostics to track intermediate as well as final values to identify potential programming errors.

Next, the model outputs were validated against what it claims to be representing. The general goal of validating ABMs is to assess whether the micro-level behavior of the agents generate the expected macro-level patterns (Gilbert, 2008). Following Taber and Timpone (1996) we employed a two-step validation process. The first was a process validation assessment that tests the models mechanisms against real-world processes. Our process validity assurance began with selection of appropriate micro-level theories about attitude and behavior diffusion, including social judgment theory (Siero and Doosje, 2006) and spatially structured (rather than random) interactions (McPherson et al., 2001). Subsequently, the models assumptions underlying the models algorithms were validated against survey data of citizens of Chino Hills. The analysis of the survey data indicated that citizen preferences are moderated by their proximity to the project, their communication networks, and the disruption posed by the project. The effect of trust in the project sponsor on citizen preferences is moderated by distance (Nelson et al., 2014). In sum, the strong theory and survey data support the models internal structure.

Next, model output validity tests were performed by correlating citizen module outputs against the number and location of the actual comments received during the EIA process for the TRTP between 2007-2009 (CPUC, 2013).

Figure 3(a) shows the geo-located citizen comment sentiment taken from public records. The red patches in the circle of Figure 3(b) show the areas of predicted opposition from the SEMPro model. As discussed in detail below, the SEMPro model consistently predicts the strong citizen opposition from Chino Hills, an educated and wealthy community. The models predictions align with the actual number of comments submitted by citizens of Chino Hills, although it slightly overpredicts comments from the Pasadena area. One agency stakeholder interviewed as part of the data collection process stated that they were surprised by the lack of opposition in Pasadena area (Nelson, 2012b), which anecdotally supports our simulation results. Abdollahian et al (2013) report other validation tests performed on the SEMPro outputs.

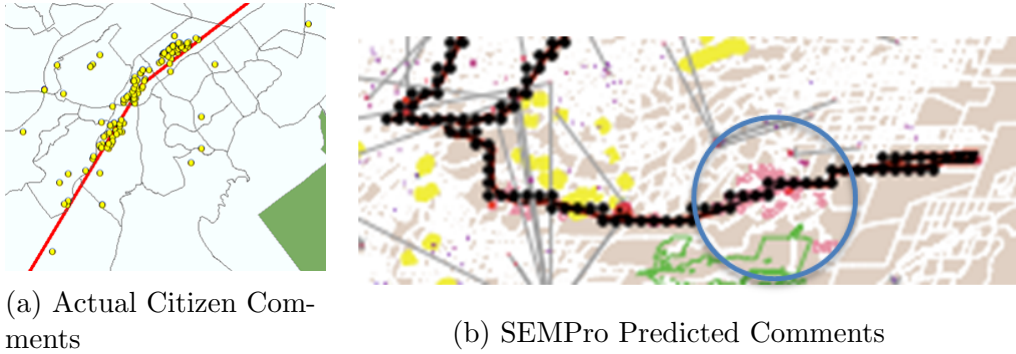


Figure 3: Citizen Comments for Chino Hills, California (online color)

3.4. Simulation Experiments

We conducted a quasi-global sensitivity analysis by varying all input parameters across their entire range in three steps (min, mean, max) resulting in 729 runs with up to 25 time steps each, for a total of 14,576 observations. We then pool all the simulations together for a pooled time series regression design estimated with ordinary least squares (OLS) regression with standardized β coefficients for input parameter comparability and model performance. The discussion in the text refers to the standardized beta coefficients which facilitates comparisons in effect size. Although King (1986) cautions against the use of standardized coefficients, we present them here since many of the variables are measured on comparable scales that allows meaningful interpretations. A table of descriptive statistics is presented in Appendix A to further aid results interpretation of the standardized coefficients.

4. RESULTS

Table 1 contains the results of the OLS modeling of the simulation results. Each model has a different dependent (endogenous) variable that is explained by a set of input exogenous parameters, as described above in section 3.1. Model 1 in Table 1 is our baseline model for detailing the impact of input parameters on number of citizen messages sent to regulators regarding the siting project. The dependent variable is the interaction term of total messages and median preferences of citizens, which captures not only the number of messages but also the direction of messages opposition or support for the project. The R^2 indicates that 80% of the variation in the dependent variable is explained.

First, let us examine the effect of project attributes on citizen opposition. In our simulations, the disruption posed by the project has a very large impact on citizen messages ($\beta = 0.8$) as expected. A one standard deviation decrease in disruption results in a decrease of .08 standard deviations in negative citizen messages. Modifying the project engineering design to reduce disruption by 35%, for instance by increasing the width of the right-of-way, is predicted to result in 8% less citizen opposition.

Project need in model 1 is negative and significant ($\beta = -.01$), but is much less important than disruption in explaining outcomes. The results are consistent with observation that citizens express less opposition when the project siting brings significant benefits and is

Table 1: Pooled OLS Estimations of Citizen Messages and CBO Preferences

	Model 1 <i>negativemessage</i>	Model 2 <i>cbopref</i>	Model 3 <i>cbopref</i>
<i>disruption</i>	0.082*** (0.000)	0.003 (0.247)	0.003 (0.246)
<i>talkspan</i>	0.623*** (0.000)	0.909*** (0.000)	0.909*** (0.000)
<i>ngomessage</i>	0.011** (0.002)	0.010*** (0.000)	0.010*** (0.000)
<i>utilitymessage</i>	-0.005 (0.141)	-0.002 (0.474)	0.052*** (0.000)
<i>need</i>	-0.013*** (0.001)	-0.013*** (0.000)	-0.013*** (0.000)
<i>procedure</i>	-0.002 (0.547)	-0.003 (0.221)	-0.003 (0.220)
<i>step</i>	0.637*** (0.000)	0.245*** (0.000)	0.245*** (0.000)
<i>utilitymessage2</i>			-0.056*** (0.000)
N	14576	14576	14576
adj. <i>R</i> ²	0.801	0.886	0.886

Note: Standardized beta coefficients; p-values in parentheses.

p* < 0.05 *p* < 0.01 ****p* < 0.001

needed by the community. Similarly, perceptions of the procedural justice of the project are negative but not significantly different from zero, suggesting that in these simulations, increasing citizens perceptions of the procedural fairness of the EIA process is not likely to have an impact on citizen opposition. As expected from the model design, time ($\beta = .636$) is positive and significant as the number of messages grows over time.

Community attributes also have a large impact on citizen advocacy and activism. Talk span has a large positive impact ($\beta = .62$) on citizen comments, suggesting that citizens express their opinion more frequently in well-connected communities. The implications of this finding are discussed in more detail below.

Turning to the effects of risk communications strategies by project proponents and opponents, NGO message is significant since credible NGO messaging can enhance citizen activism. However the impact of NGO messages is only modest ($\beta = .01$) showing effects on activism of about the same magnitude as perceived project need. Although utility risk communications reduce the number of negative messages sent to regulators, the average effect of this variable is not significant. The implications of this finding are discussed in more detail below.

In models 2 through 5 (Tables 1 through 3) we look at the impact of input parameters on CBO preferences, a key emergent behavior from the first module. CBO preference is the

weighted average of the number of CBOs times their preferences categorized by deciles in model output. A higher value for CBO preferences indicates more CBO opposition to the project. The R^2 of 88% in model 2 shows variation in CBO preferences is explained.

We can see that *talkspan* is not only highly significant but has the largest impact ($\beta = .91$) on CBO preferences. As citizens are able to communicate and exchange opinions across greater distances with more neighbors, the number of citizens joining CBO increases. The time variable also shows a large and significant impact on CBO formation ($\beta = .24$), indicating CBOs opposition increases as time passes. The magnitude of this variable is significantly smaller than for citizen messages (model 1), indicating that CBO preferences are less time dependent than citizen messages.

Utility message and other policy levers like disruption, procedural justice and NGO message do not have significant impact on CBO preferences in the citizen module. Need is significant and positive, counter intuitively indicating greater project need increases CBO opposition. Further investigation of this finding is warranted to discover how project need is channeled through citizen preferences that might have a positive impact on CBO preferences.

In model 3 we further explore the effects of risk communications. Recall that the main effects of utility messages in models 1 and 2 were found to be non-significant. Model 3 utilizes squared utility messages to assess nonlinear effects of risk communications. Figure 4 plots the marginal effects of utility messages on CBO preferences at different levels of utility messages from regression model 3.

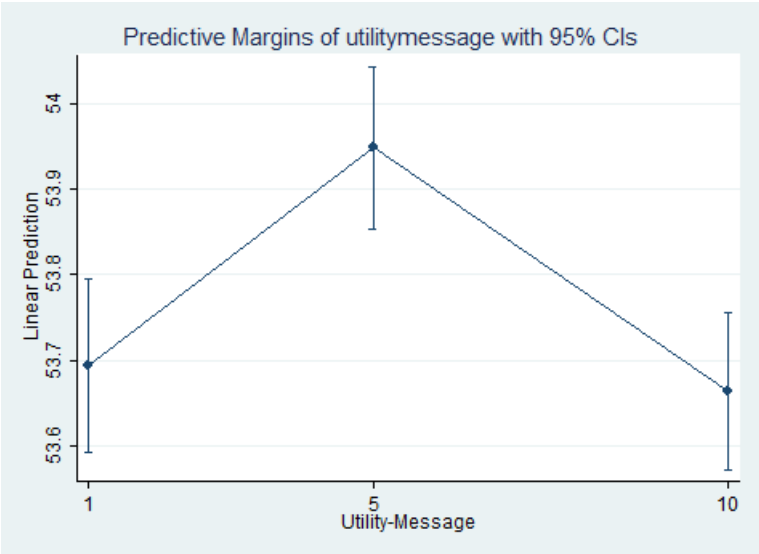


Figure 4: Marginal Effects of Utility Messages

The figure above shows that the marginal effect of utility risk communications is significantly higher at the mean level of messaging rather than at the minimum or maximum levels. The interpretation is that utility message effects are nonlinear and not captured by the linear OLS estimation in models 1 and 2. Since the utility position is far from citizens positions, more frequent utility messages are rejected and serve to further reinforce citizen

opposition.

4.1. Stakeholder Preferences

Next, we turn to an analysis of stakeholder preferences in Table 2. We employ a two stage least square (2SLS) / Instrumental Variable (IV) regression technique for the model outputs for time steps 1-20. The error termS from stakeholder preferences are likely to be correlated with CBO preferences in any given time step. 2SLS is an appropriate econometric technique that uses the predicted value of CBO preferences created in the first stage to predict stakeholder preferences in the second stage regression. This controls for the simultaneous impact of CBOs on stakeholder preferences.

Table 2: Two Stage Least Squares Stakeholder Model

Stage 1	Model 4 <i>cbopref</i>
<i>disruption</i>	-0.021*** (0.000)
<i>talkspan</i>	0.724*** (0.000)
<i>ngomessage</i>	0.007** (0.007)
<i>utilitymessage</i>	-0.000 (0.880)
<i>need</i>	-0.009*** (0.000)
<i>procedure</i>	-0.003 (0.288)
<i>step</i>	0.056*** (0.000)
<i>negativemessage</i>	0.296*** (0.000)
N	14576
adj. <i>R</i> ²	0.904
Stage 2	<i>Stakeholderpref</i>
<i>cbopref</i>	0.929*** (0.000)
<i>negativemessage</i>	0.094*** (0.000)
N	14576
adj. <i>R</i> ²	0.976

Note: Standardized beta coefficients; p-values in parentheses.

p* < 0.05 *p* < 0.01 ****p* < 0.001

The first stage in model 4 results in an R^2 of .90, indicating 90% of the variation in CBO preferences is explained. Stage 1 in model 4 is very similar to model 2, but also includes negative messages. The inclusion of negative citizen messages truncates the coefficients for both time step and talkspan and makes the need coefficient negative. This is also consistent with model 1 and our theoretical priors. The second stage regression in model 4 indicates the number of citizen messages has a much smaller impact on stakeholder preferences than CBO preferences. This is consistent with observed behavior that citizens need a seat at the table to be heard. Organizational representation is critical to influence stakeholder bargaining in the SEMPro model.

4.2. Regulator Preferences

Table 3 shows the variables that impact regulator preferences using the same instrumental variable approach where we first predict stakeholder preferences and then use that value to predict regulator preferences. The R^2 indicates that 27% of the variation in regulator preferences is explained by the stakeholder preferences and citizen messages. We expect the R^2 for regulator preferences to be lower than that of the stakeholder equation as regulators have to balance additional considerations, such as competing policy goals and political issues, in their decisions. In addition, the R^2 is lower as regulators only interact with CBOs and other stakeholder from time step 16 to 20, and then decide amongst themselves from time step 21-25.

Table 3: Two Stage Least Squares Regulator Model

Stage 1	Model 5
	<i>Stakeholderpref</i>
<i>cbopref</i>	0.858*** (0.000)
<i>negativemessage</i>	0.142*** (0.000)
N	2912
adj. R^2	0.982
Stage 2	<i>Regulatorpref</i>
<i>Stakeholderpref</i>	0.247*** (0.000)
<i>negativemessage</i>	0.284*** (0.000)
N	2912
adj. R^2	0.273

Note: Standardized beta coefficients; p-values in parentheses.

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 3 shows that negative citizen messages have a larger impact on regulator preferences than stakeholder preferences in the previous table. A one standard deviation increase in citizen messages results in a .28 standard deviation ($\beta = .28$) increase in regulator oppositional preferences.

This differential impact of citizen activism on stakeholder and regulator modules is critical. The impact of citizen messages on regulator preferences is over two times larger than their impact on stakeholder preferences (stage 1 in Table 3). Citizen preferences impact stakeholder preferences through the efficacy of CBOs who bargain with other stakeholders. On the other hand, the modeling predicts that elected or appointed regulators are more balanced in their response to citizens and stakeholders demands.

5. DISCUSSION

The results from the SEMPro simulations show important insights for planning processes as the linkages between emergent citizen behavior and stakeholder and regulator preferences are complex. First, citizen advocacy in institutional processes will be greater when threats to their communities are greater as evidenced by the positive impact of the disruption variable, which is consistent with the risk communication research.

Second, emergent citizen behavior can dramatically alter institutional outcomes over time. Figure 5 shows histograms of average citizen, stakeholder and regulator preferences in the first, middle and last time steps in all of the simulations.

What is notable across all three categories is the shift towards greater project opposition across all three levels of analysis. These results partially explain the questions posed in McAdam and Boudet (2012) about why communities that mobilize against energy projects are typically successful in getting their demands met. Successful CBOs can disrupt closed, or captured, institutional decision making processes by raising media attention and the political stakes. For public and private managers, the implication is a need for active conflict resolution mechanisms as the project moves from the scoping phase to the final impact report, and beyond. Citizen anger can even manifest itself after the EIA is complete and construction has begun as utility equipment has been stolen or vandalized in high conflict areas (Nelson, 2012a). Other social conflict also arises as NGOs and other stakeholders mount expensive legal challenges to regulatory decisions.

The third finding is communities with more well-connected citizens represented in SEMPro by larger talkspan are more likely to be effective blocking or altering infrastructure projects. Talkspan implies citizens talking across a greater geographical distance in the model and predicts fewer CBOs as well as more citizen opposition messages. Talkspan can be conceived of as the level of betweenness in social network terms, with larger nodes being more socially connected to other individual citizens. For details, see Abdollahian, Yang, and Nelson (2013b) analysis on betweenness and eigenvector centrality of SEMPros social network outputs.

Another way to conceptualize talkspan is the level and type of social capital of the community. Putnam (2001, p. 22-23) contrasts bridging (inclusive) social capital that encompasses citizens across groups, with bonding (exclusive) social capital that reinforces

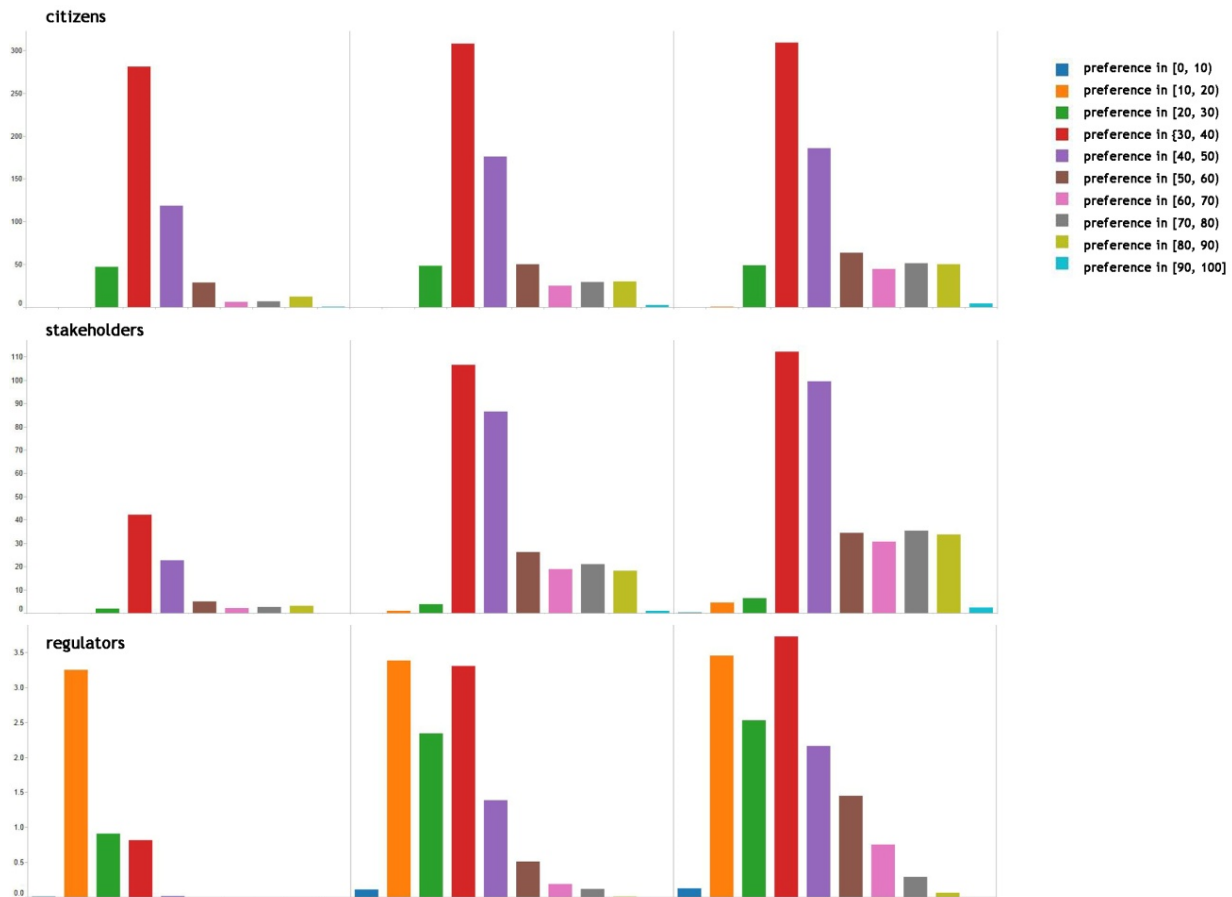


Figure 5: Preference Histograms (online color)

identities and groups. There are several potential mechanisms by which bridging capital can increase citizen activism. Bridging capital is useful for mobilizing solidarity against corporate or state actors who are perceived as threatening local conceptualization of place, as well as for information diffusion (Putnam, 2001, p. 23). Schussman and Soule (2005) find that the strongest predictor of protest actions is being asked by a peer to protest.

Finally, we posit several mechanisms to explain the nonlinear effects of risk communications. Recall from Figure 4 presented in Section 4 that the marginal effect of utility risk communications is significantly higher at the mean level of messaging rather than at the minimum or maximum levels. Utility messages can be conceptualized as frequency \times volume. At a level of 1, no one pays attention, but at 10 citizens push back because more citizens are opposed to the project than support it. Thus, fewer strong utility messages will reach citizen agents who are potentially receptive to the utility's position. In contrast, NGO messages are better received by citizens because a greater portion of citizens have positions that are closer to the NGO position and thus are receptive to its messaging. Thus, in a conflictual environment, NGOs will inherently be more effective in influencing citizen attitudes than project sponsors.

SEMPro incorporates Social Judgment Theory in each citizen agents objective function (Jager and Amblard, 2004). This theory describes how the positions of two agents can be conceived along a Downsian continuum where the distance between their positions affects the likelihood of one accepting the others position. A message that is far from a receivers position is likely to be rejected (Siero and Doosje, 2006). For decades, social psychology research has documented that not only do people resist changing their own positions in relationship to new information, but that they might also adopt even more extreme beliefs than before (Lord et al., 1979). Social judgment theory finds support in the literature on risk perceptions and social trust. Citizens are unlikely to change their preferences about the project if they distrust the source of risk communications Kasperson and Stallen (1991). In spatial bargaining, trust can be operationalized as the distance between two stakeholders positions and again is operationalized in the SEMPro model structure.

6. CONCLUSION

SEMPros results show several key emergent behaviors from infrastructure siting including citizen interaction and CBO formation. Our simulations explain why CBOs are effective in aggregating citizen preferences and altering stakeholder preferences. The finding that citizen messages are relatively more important to regulators than stakeholders is consistent with the institutionalized comment process. Our findings indicate that citizen comments are surprisingly influential in determining regulators preferences, indicating a level of political responsiveness to social sustainability issues that supports the efficacy of institutionalized planning processes. At the same time, we also find that CBOs positions are important in determining stakeholder preferences.

The SEMPro design that links an ABM with GIS data is critical for valid inferences in the planning process as citizen interactions emerge from local conditions and attributes. Linking the GIS-based ABM with spatial bargaining models permits the analysis of the interactions and linkages between citizen emergent behavior and institutionalized decision-making modalities. By linking citizen behavior with stakeholder and regulator preferences, SEMpro explicitly simulates the impact of micro-level behavior on macro-level institutional outcomes, a fundamental challenge in social policy spaces (Schelling, 1978; Helbing et al., 2011).

While the results herein apply to only one siting case, the SEMPro multi-agent simulation approach does promise benefits for policymakers in siting processes. SEMPro allows the assessment of the socio-political risks of alternate project routes or designs, and can generate specific and actionable risk management strategies. It provides sustainable energy policy leaders with strategic guidance on building stakeholder consensus and also can offer scenarios analyses for policymakers to explore key political, environmental, and regulatory uncertainties. SEMPro and other techno-social simulation approaches can yield insights on the non-monotonic, nonlinear effects of proponent risk communications. We believe that approaches like SEMPro fill a much-needed void for public and private siting managers who are trying to balance legitimate citizen concerns with achieving public policy goals in the contentious domain.

Appendix A. Appendix A

Variable	Obs	Mean	Std. Dev.	Min	Max
negativeme~e	18200	34.66672	11.31772	0	68.37575
cbo	18929	4.246902	2.84905	0	11.73333
citizenmed~f	18929	6.26863	1.783054	0	9.970166
stakeholde~f	18200	50.91351	7.649851	37.4	68.11475
regulatorp~f	7265	29.28879	8.320834	11	59.375
Inmessage	18200	5.441578	.8687049	2.855196	13.96497
disruption	18929	.53324	.3683229	.1	1
talkspan	18929	5.339056	3.680943	1	10
ngomessage	18929	5.332664	3.680801	1	10
utilitymes~e	18929	5.332189	3.683363	1	10
need	18929	5.332559	3.681514	1	10
procedure	18929	5.338	3.681614	1	10
step	18929	12.48671	7.495938	0	25

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