Social Need versus Local Opposition: Simulating Energy Infrastructure Siting Outcomes Using a Multi-Agent Decision Support System

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21 October 2013

Abstract: This paper explicates the design and results of the Sustainable Energy Modeling Program, a decision support system for energy infrastructure siting. The model fuses geographical information system data, an agent-based model of citizen attitude and behavior diffusion with spatial bargaining models of stakeholder and regulatory decision making to simulate the complexity of infrastructure siting. We find that citizen interactions result in emergent behavior that affects stakeholder and regulator decision making in highly institutionalized Environmental Impact Assessment (EIA) 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. In fact, citizen messages and stakeholder preferences have a similar impact on regulator preferences. Stakeholders are strongly influenced by the community based organizations that arise to oppose the project. The SEMPro model fills a much needed void for public and private managers who are trying to balance citizen concerns with achieving public policy goals in the energy infrastructure siting domain. 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 economies are driving investments in new energy infrastructure. Several large pipeline projects have recently become prominent, including 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 transmission and distribution infrastructure to move the energy into demand centers. Many of these infrastructure projects are resulting in legal battles, civil conflict, and long delays in getting the projects approved and constructed.

The goal of the paper is to explicate the design and results of the Sustainable Energy Modeling Program (SEMPro), a multi-agent decision support model designed to improve infrastructure siting outcomes. SEMPro simulates socio-political behavior during the siting process. In this case study we focus on Environmental Impact Assessment (EIA) processes for siting a large energy infrastructure project, as EIA's are typically required for these large infrastructure projects involving federal funds or lands. EIA's 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 (European Commission, 2012). Most nations in Asia, including China, Korea, Japan, Indonesia and India require some form of EIA before major projects can proceed.

Although the exact structure of EIA processes varies, 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). However, empirical research indicates that citizen advocacy behavior will largely be limited to those in close proximity to the disruptive project. To the extent that citizen advocacy influences stakeholder and regulatory decision making, then a small percentage of the population can block or delay infrastructure siting projects that are critical to economic growth. A great deal of research has gone into this not-in-my-backyard (NIMBY) phenomena. See, among others, Shively, (2007) and Wolsink (2000). Divine-Wright (2005) and Cain and Nelson (2013) make forceful calls that a more interdisciplinary approach is needed; one that requires not only citizen preferences, but also project attributes as well as political an institutional considerations to better understand and predict siting project outcomes.

2 SIMULATING THE SOCIO-TECHNICAL SYSTEM

SEMPro responds to these calls for interdisciplinary analysis by simulating EIA citizen participation and stakeholder decision making processes simultaneously. The SEMPro model fills a much needed void for public and private managers who are trying to balance citizen concerns with achieving public policy goals. The simulation tool has been designed and evaluated to validly reflect actual citizen, agency, and regulator behavior (Abdollahian et al, 2013). SEMPro is part of a new class of techno-social models, fusing geophysical, social and political elements to understand the interactive effects and feedbacks between human and institutional agency, engineered physical elements, and the geophysical environment. SEMPro was developed using a system's 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 decisionmaking and need to be generalizable to a wide range of cases (Kersten et al, 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. The approach also allows the estimation of the effects of increased, or alternatively reduced, public participation on project outcomes. Public participation can have many important benefits including building trust, developing "buy-in", provide objectively superior decisions, and lead to a more healthy democratic society (Beirle and Crayford, 2002).

2.1 Citizen Impact in Planning Outcomes

The rationale for public participation is to "level the playing field in the sense that everyone should have equal voice in the process" (Deitz and Stern, 2008, 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 participation practices reduce conflict and develop accountability (Beierle & Cayford, 2002). Research focusing on collaborative stakeholder practices finds that they facilitate shared understanding of problems and policy solutions (Weible & Sabatier, 2009). Based on experience within the environmental arena, there is empirical evidence that when stakeholder participation is intensive and diverse, environmental planning efforts can be more successful (Leach, 2006; Lubell, 2004; Reed, 2008).

However, the effect of citizen input on environmental 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 nor resources needed to participate in technical siting decisions (Doelle and Sinclair, 2006, 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 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).

2.2 Elite Impact in Planning Outcomes

While citizen impacts on EIA outcomes are subject to debate, one empirical consensus in EIA research is that elite preferences strongly shape EIA outcomes. 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 & Gash, 2007; Cooke & Kothari, 2001), and have underscored the importance of structural characteristics of stakeholder groups (Bidwell & Ryan, 2006) and context (Koontz, 2005; Lubell et al., 2009). Power imbalances are a known problem of stakeholder collaboratives (Ansell & Gash, 2007). Bidwell and Ryan (2006) point out that, when not diverse, stakeholder partnerships provide venues for powerful groups to skew policies to their own advantage. Other studies suggest that powerful industry groups manage to manipulate state energy policy processes (Rabe & Mundo, 2007). Evidence suggests that environmental groups have been skeptical of collaborative governance mechanisms because of the perceived power of pro-development interests to influence the outcomes (Echeverria, 2001; McCloskey, 2000). However, the literature seldom addresses how and to what extent stakeholder participation influences actual policy design (with the notable exceptions of Lynn & Busenberg, 1995, and Koontz, 2005). Maggioni, et al (2012) find that energy sector elites have considerable influence in planning outcomes.

Unlike most DSSs, SEMPro also simulates bargaining dynamics amongst stakeholders in the decision process. Precursors to stakeholder bargaining models date back to Black (1958) and Downs (1957), in trying to frame a positivist approach to analytical politics, yet the intellectual foundations go back much further including Condorcet's voting paradox (1785). More recently, McKelvey and Ordeshook (1987) 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 model (ABM) instantiation as stakeholders posses agency and multi-attributes of preferences over issue spaces, with varying influence, salience and positive or negative complementarity across *n* issues (Hinich and Munger 1997). When dealing with more than one bargaining issue at a time, winsets are identified as the Pareto-set of potential agreement where no single stakeholder is made worse off than the current status quo (McKelvey 1986, Hinich and Munger 1997). ABM instantiations of spatial bargaining models include Abdollahian and Alsharabati (2003) and Abdollahian et al (2006).

3 DATA AND METHODS

The SEMPro model simulates individuals, organizations, and agencies all interacting on a geophysical substrate. The individual citizen agents are created randomly based on distributions of characteristics based on census data. These agents interact with on another and are subject to influence from anti-development Non-Government Organizations (NGOs), like the Sierra Club, and the pro-development sponsoring utility company. The individual agents also have the ability to organize into Community Based Organizations (CBOs) to increase their influence. The individual agents and a set of stakeholder organizations and agencies then influence the regulatory body to influence the outcome of the citing decision. The technical foundations of SEMPro are described in greater detail in Abdollahian et al (2013).

3.1 Process Overview and Scheduling

SEMPro model has three different sequential submodels, a citizen/CBO formation module, a stakeholder lobbying module and a regulatory decision making module. Figure 1 depicts the high level process and multi-module architecture.

<<Figure 1 about here>>

In the first module, 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 level data on population density is used to locate citizen agents in the ABM. Citizen agents are instantiated in the model's "space" at a rate consistent with their census population (ie 1 agent per 1000 census population). Census data on education and income by block-group are included as attributes of the agents that are instantiated in the model. Education and income provide some of the variation in citizen behavior in the simulations. Higher values are associated with greater levels of influence in affecting project outcomes and imbue citizens with "power." Wealthier and more educated individuals have a stronger sense of self-efficacy and more resources available to advocate against the project (Nishishiba, Nelson and Shinn, 2005).

SEMPro simulates the technical aspects of the decision process using project engineering GIS data. This data can take the form of lines or polygons (power lines) or points (waste incinerators or power plants). Overlaying GIS project data onto the census data is critical as the project then follows, or is placed, into the real-life attributes of the community.

This is critical when the infrastructure project is sited in existing right-of-ways through the region. These right-of-ways represent the setback between the project and the houses along the route. The proximity of the citizen agents to the project is a key driver of attitudes the project. We assume that the importance (salience) of the project to citizens is relative to 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.

Intuitively, citizens react to transmission siting projects forming opinions and shaping those of others. Citizens send out messages supporting or opposing the project based on their own attributes. utility and NGO messaging, and the project's attributes. These citizen interactions can result in the formation of Community Based Organizations (CBOs) that either support or oppose such projects.

In the second module of stakeholder bargaining, against this backdrop of political and social opinion formation and transmission processes, organized stakeholders seek to lobby not only citizen opinions and 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.

In the third module, Regulators join the bargaining process in the end of the stakeholder module and bargain only among themselves in the regulator module, then vote either to support or oppose the project. The policy levers that can impact the citizen module include utility outreach and messaging, NGO messaging, trust in sponsors, citizen perceptions of procedural justice, as well as the project disruption.

Each module updates the following module at each time step. Regulators join the process in tick 15. This parallel, linked module processing sequence then iterates. After tick 20, CBOs and stakeholders stop bargaining and regulators bargain among themselves through the end of each simulation. At final tick, regulators vote to either support or oppose based on their final preference. In two continuous ticks, if no new coalition is formed, or no CBOs, stakeholders and regulators change their preference, then the model reaches the steady state and will stop.

Actionable policy levers for shaping the transmission siting process include the disruption engineering of the project, utility and NGO messaging outreach, as well as perceived project need and procedure surrounding the process. These policy lever inputs condition relevant the data and model's processes at each time step.
Data for the validation of the SEMPro model came from two primary sources. The citizen comment model was calibrated against the number and location of the approximate actual comments received during the EIA process for the Tehachapi Renewable Transmission Project between 2007-2009 (California Public Utilities Commission 2012).

Figure 2 shows validation of model's outputs and predictions for the spatial location of citizen messages in high population density census tracts. The black line represents the powerline 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 model's predictions of the location of citizen comments opposing the project. These locations are representative of the comments submitted by citizens of Chino Hills and slightly over predicts comments from the Pasadena / Alta Dena area (CPUC, 2009). One agency stakeholder interviewed as part of the data collection described below stated that they were surprised by the lack of opposition in this area which is also supportive of the SEMPro simulations (Nelson, 2012b).

<<Figure 2 about here>>

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 gave a formal comment on either the Tehachapi Renewable Transmission Project (TRTP) or Sunrise Powerlink projects in Southern California. We received 38 usable responses from our 122 invitations. The high response rate (31%) was achieved because invitees were incentivized to participate with an offer of a $20 Starbuck's gift card upon completing the survey.

3.2 Simulation Experiments

We conducted a quasi-global sensitivity analysis by varying all input parameters across their entire range in three steps (min, mean, max) for 25 time steps, which resulted in 729 runs. All state variables and model attributes were recorded. Specific output variables captured besides the ones detailed above include both stakeholder and CBO preference variance.

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. Pooled OLS estimation was used to create standardized β coefficients for input parameter comparability and model performance. The discussion in the text refers to the standardized beta coefficients presented in the furthest right column of the regression tables. A table of descriptive statistics is presented in Appendix A to further aid results interpretation. 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. R^2 indicates that more than 80% of the variation in the dependent variable is explained. Variables are reported with standardized coefficients which facilitates comparisons in effect size.

First, let us examine the effect of project attributes on citizen opposition. In our simulations, disruption posed by the project has a very large impact on citizen messages (β = .08) as expected. A one standard deviation decrease in disruption results in a decrease of .08 standard deviations in negative citizen messages. On other words, modifying the project engineering design to reduce disruption by 35% by increasing the width of the right of way could result in 8% less citizen opposition.

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

	Model 1	Model 2	Model 3	Model 4
Dep. Var.	negativemessage	cbopref	cbopref	cbopref
disruption	0.082***	0.003	0.003	0.010*
	(0.000)	(0.247)	(0.246)	(0.049)
talkspan	0.623***	0.909***	0.909***	0.909***
	(0.000)	(0.000)	(0.000)	(0.000)
ngomessage	0.011**	0.010***	0.010***	0.010***
	(0.002)	(0.000)	(0.000)	(0.000)
utilitymessage	-0.005	-0.002	0.052***	0.005
	(0.141)	(0.474)	(0.000)	(0.347)
need	-0.013***	-0.013***	-0.013***	-0.013***
	(0.001)	(0.000)	(0.000)	(0.000)
procedure	-0.002	-0.003	-0.003	-0.003
	(0.547)	(0.221)	(0.22)	(0.221)
step	0.637***	0.245***	0.245***	0.245***
	(0.000)	(0.000)	(0.000)	(0.000)
utilitymessage2			-0.056***	
			(0.000)	
utilitydisruption				-0.01
				(0.096)
N	14576	14576	14576	14576
adj. R-sq	0.801	0.886	0.886	0.886

Standardized beta coefficients; p-values in parentheses
* p<0.05 ** p<0.01 *** p<0.001

Project need in model 1 is negative and significant (β = -.01), consistent with observation that citizens express less opposition when the project siting brings significant benefit to local community and is perceived as legitimately needed by the community. 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 (β = .636) is positive and significant as the number of messages increases as over time.

Community attributes also have a large impact on citizen advocacy and activism. Talkspan has a large positive impact (β = .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 as expected since credible NGO messaging can enhance citizen activism. However the impact of NGO messages is only modest (β = .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 2-5 (model 5 results are shown in Table 2) we look at the impact of input parameters on CBOs preferences, a key emergent output variable from the first module. CBO preference is the weighted average of the number of CBOs and 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 adequately. We can see that talkspan is not only highly significant but has the largest impact (β = .91) on CBO preferences. As citizens are able to communicate and exchange opinions across greater distances with more neighbors, the number of citizens opposed to the project in CBO increases. The time variable also shows a large and significant impact on CBO formation (β = .24), indicating CBOs opposition increases as time passes. The magnitude of this variable is significantly smaller than for citizen messages, indicating that CBO preferences are much less time dependent.

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 affect have a positive impact on CBO preferences.

The Differential Impacts of Risk Communication Strategies

In model 3 we explore the effects of risk communications found in the main regression results. Model 3 uses the square of the utility messages. Figure 3 plots the marginal effects of utility messages on CBO preferences at different levels of utility messages. The figure 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. Several implications follow. One, utility message effects are nonlinear and not captured by the linear OLS estimation in models 1 and 2.

<<Figure 3 about here>>

Second, utility outreach programs could be less effective at shaping citizen opposition in project siting than previously thought. In alignment with social psychological findings, SEMPro incorporates Social Judgment Theory in each citizen agent's objective function. This theory describes how the positions of two agents can be conceived along a Downsian continuum and distance between these positions affects the likelihood of one accepting the other's position. A message that is far from a receiver's position is likely to be rejected (Siero and Doosje 2006). Since the utility position is far from citizens' positions, more frequent messages (at 10) are rejected, and they reinforce citizen opposition. Fewer utility messages fail to 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 the messaging. Thus, in a conflictual environment, NGOs will inherently more effective in influencing citizen attitudes that project sponsors.

<<Figure 4 about here>>

Figure 4 shows the marginal effects of utility messages times disruption on CBO preferences. The graph shows that on balance, the effects of utility messages decline as utility messages get stronger. Low levels of utility messages are more effective with a medium level of project disruption than at other levels.

Stakeholder Preferences

Next, we turn to an analysis of stakeholder preferences in Table 2. We employ a two stage least square (2SLS) regression technique for the model outputs for timesteps 1-20. The instrumental variable technique uses the predicted value of CBO preferences in stage one to predict stakeholder preferences in the second stage regression, controlling for the simultaneous impact of CBOs on stakeholder preferences. The R^2 shows that 90% of the variation in stakeholder preferences is explained. Stage 1 in model 5 is very similar to model 2, but also includes negative messages. The inclusion of negative citizen messages truncates the coefficients for time step and talkspan and makes the need coefficient negative (and consistent with model 1 and our theoretical priors). Higher disruption has a small negative impact on stakeholder preferences.

The second stage regression results indicate 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.

Table 2: Two Stage Least Squares Stakeholder Model

Stage 1	**Model 5**
	cbopref
disruption	-0.021***
	(0.000)
talkspan	0.724***
	(0.000)
ngomessage	0.007**
	(0.007)
utilitymessage	-0.000
	(0.880)
need	-0.009***
	(0.000)
procedure	-0.003
	(0.288)
step	0.056***
	(0.000)
negativemessage	0.296***
	(0.000)
N	14576
adj. R-sq	0.904
Stage 2	stakeholderpref
cbopref	0.929***

	(0.000)
negativemessage	0.094***
	(0.000)
N	14576
adj. R-sq	0.976

Standardized beta coefficients; p-values in parentheses
* p<0.05 ** p<0.01 *** p<0.001"

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. Stage 1 is slightly different from Stage 2 in Table 2 above because, we only use time steps 16-20 when stakeholders and regulators are bargaining with each other in the model. 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 tick 16 to 20, and then decide amongst themselves from tick 21-25.

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 (β=.28) increase in regulator oppositional preferences. Stakeholder preferences smaller coefficient (β = 0.24), indicating that stakeholder preferences influence regulators' preferences less relative to citizen messages.

Table 3: Two Stage Least Squares Regulator Model

Stage 1	**Model 6**
	stakeholderpref
cbopref	0.858***
	(0.000)
negativemessage	0.142***
	(0.000)
N	2912
adj. R-sq	0.982
Stage 2	regulatorpref
stakeholderpref	0.247***
	(0.000)
negativemessage	0.284***
	(0.000)
N	2912
adj. R-sq	0.273

Standardized beta coefficients; p-values in parentheses
* p<0.05 ** p<0.01 *** p<0.001"

The differential impact of citizen activism on stakeholder and regulator modules is critical. The impact of citizen messages on regulator preferences is over three times larger than their impact on stakeholder preferences (Table 2). Citizen preferences impact stakeholder preferences directly or, more likely, through the efficacy of CBOs who bargain with other stakeholders. On the other hand, as political appointees (or directly elected), regulators are more balanced in their response to citizens and stakeholders' demands.

5 DISCUSSION

The results from the SEMPro simulations show important insights for managing EIA processes. 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. Decision support systems like SEMPro allows the estimation of the cost effectiveness of project design changes on social sustainability. For example, if increasing the right of way to reduce project disruption is estimated to cost $500M, then this cost can be normalized by the simulated reduction in citizen and CBO opposition.

Second, emergent citizen behavior is likely to 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 large positive shift across all three levels of analysis.

<<Figure 5 about here>>

For public managers, this indicates the need for conflict resolution mechanisms as the EIA moves from the scoping phase to draft EIA to final EIA phases, and beyond. Citizen anger can manifest itself after the EIA is complete and construction has begun, and in such instances utility equipment has been stolen or vandalized in high conflict areas (Nelson, 2012a). Stakeholder conflict arises as expensive legal challenges to regulatory decisions.

Another important finding is communities with more well-connected citizens (larger talkspan) are more likely to be effective in advocacy. In many cases, this entails blocking or delaying 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. We refer interested readers to Abdollahian et al (2013) that analyzed the betweenness and eigenvector centrality of SEMPro's social network outputs.

Another way to conceptualize talkspan is the level and type of social capital of the community. Robert Putnam (2001, pp. 22-23) contrasts bridging (inclusive) social capital that encompasses citizens across groups, with bonding (exclusive) social capital that reinforces 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) and for information diffusion (Putnam, 2001, pp. 23). Schussman and Soule (2005) find that the strongest predictor of protest actions is being asked by a peer to protest.

6 CONCLUSION

SEMPro's results show that given the model structure a key emergent behavior from citizen interaction via CBO formation is critical. In simulating EIA process, these CBOs are effective in aggregating citizen preferences and altering stakeholders' bargaining 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 the supports the efficacy of institutionalized EIA processes. At the same time, we also find that the importance of stakeholders' positions, including CBOs, in determining regulators' preferences. The SEMPro platform combining an 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 question" in the social sciences (Schelling, 1978; Helbing, et al, 177).

While our results apply to only one siting case, the SEMPro simulation approach does promise multiple benefits for policymakers in siting processes. It provides sustainable energy policy leaders with strategic guidance on building stakeholder consensus to move from stewardship to sustainability, identifying the promise and pitfalls along the way in achieving policy outcomes. It can serve as a platform for exploring successful policy dialogues. The DSS can offer scenarios analyses for policymakers to explore key political, environmental, and regulatory uncertainties and to identify which solutions resonate with communities. Perhaps more interestingly, SEMPro and other techno-social simulation approaches can yield insights on the non-monotonic, nonlinear effects, as well the potentially harmful assumptions of linear, additive policy actions such as risk communications. We see this particularly clearly in the model's non-linear response to utility messages. Given the importance and increasing tempo of mandated renewable energy targets, policy makers would be remiss not to leverage such DSS approaches to help mitigate risk in siting large infrastructure projects.

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Appendix A

Descriptive statistics

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
lnmessage	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

Figure 1: SEMPro Modules

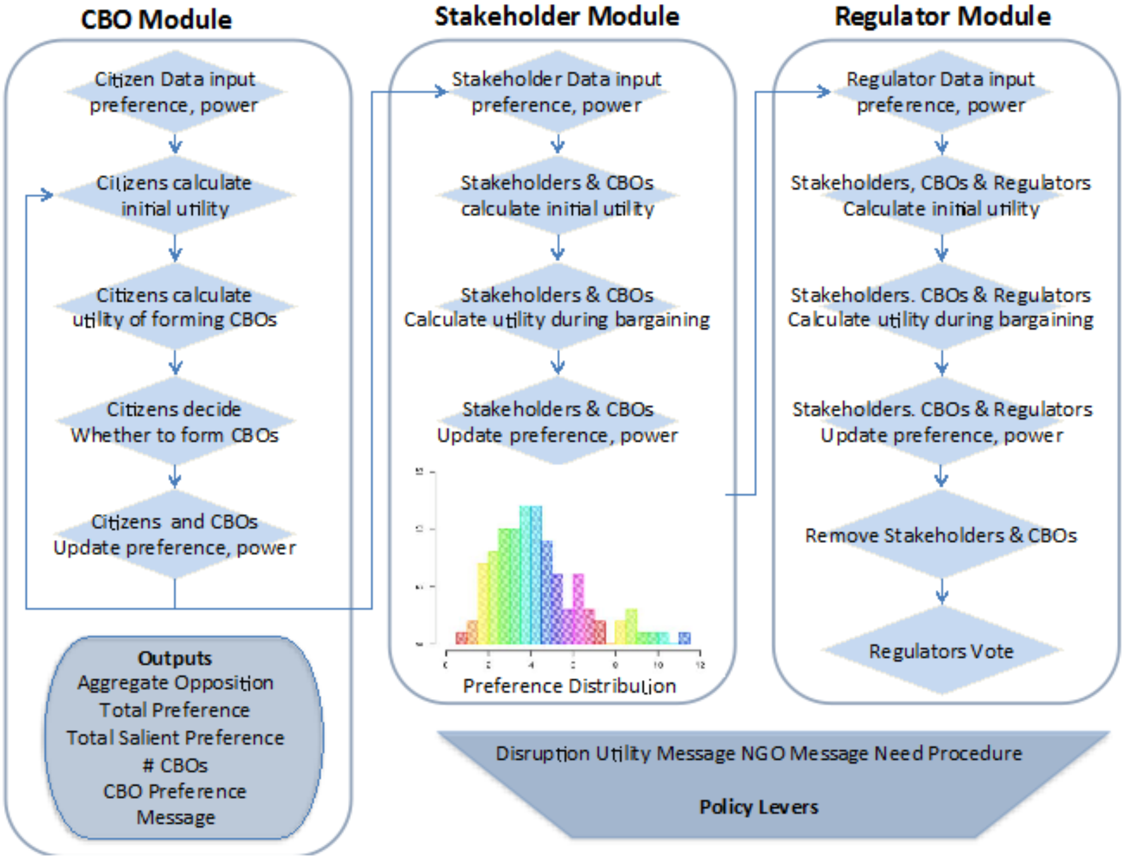

Figure 2: Model Output

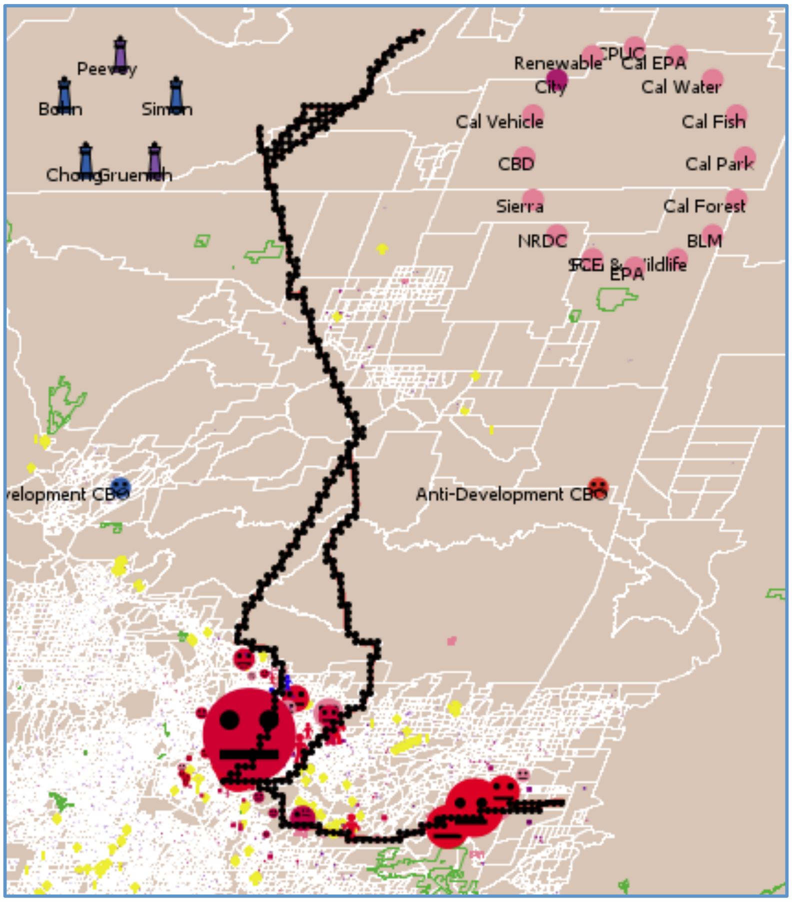

Figure 3: Marginal Effects of Utility Messages[2]

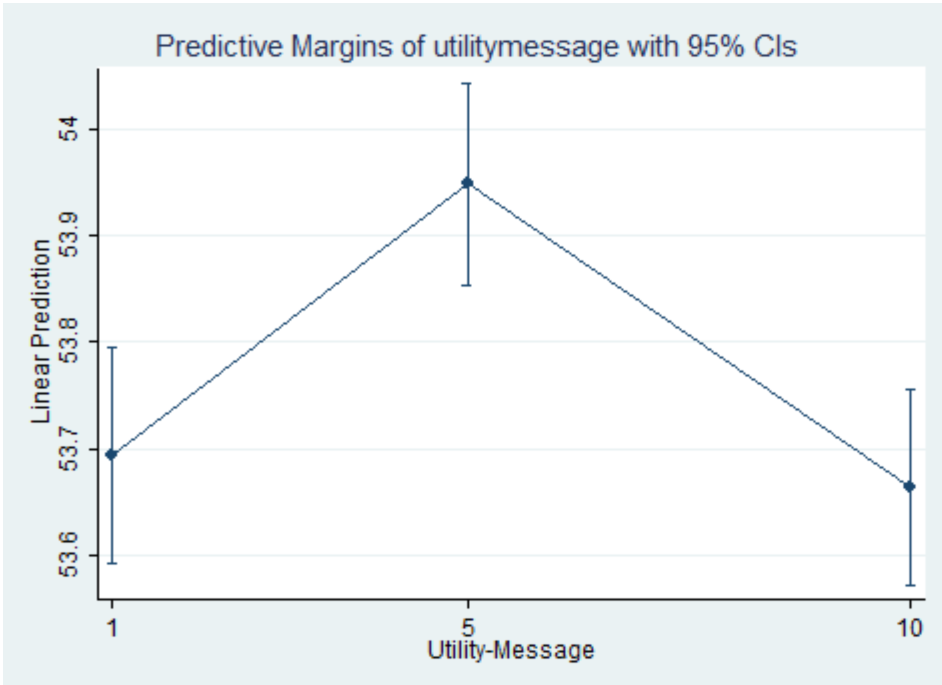

Figure 4: Marginal Effects of Utility Messages * Disruption

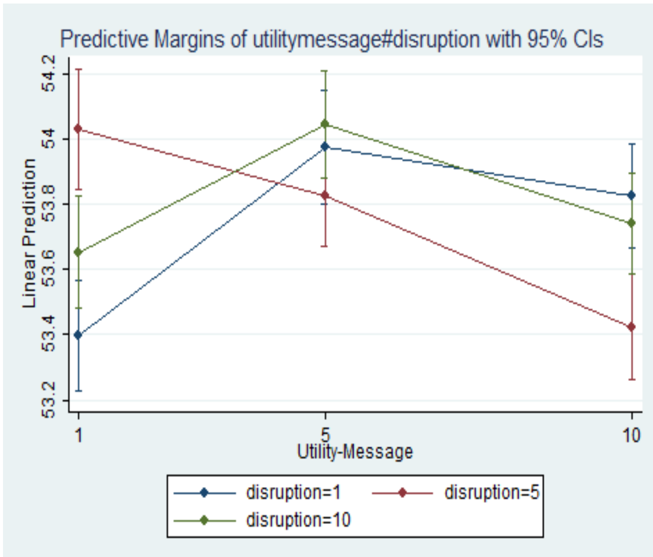

Figure 5: Preference Histograms