Barriers to System Dynamics Deployment in Business and Policy Making: Lessons Learned in Assessing Electric Utility Restructuring Policy

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Abstract

Real-world policy analyses efforts indicate repeated behavioral patterns that inhibit systems approaches, such as the time and budget pressures, the trade-off of detail vs. high-level insights, and the tendency to dwell in the familiar rather than delve into the unrevealed. Examining "mainstream" (non System Dynamic) business and policy processes issues such as these seems critical to increasing the introduction of systems approaches. However, the perspective we as a community of modelers takes is critical to reinventing business and policy analyses. To the extent the barriers are seen as circumstances of the modeling environments there is little leverage towards resolution; if we can see the impediments as being a result of our behavior as analysts, the nature of the barriers change and there is much more opportunity for improvement. The paper examines a non–System Dynamics policy analysis for the electric utility industry from both these points of view.

Introduction

This paper examines barriers to applying systems approaches in large-scale business or policy analyses. It is motivated by the author's experience with real-world policy analysis efforts that suffered from repeated patterns of behavior that inhibit the application of a robust systems approach. The paper's goal is to encourage a shift in perspective on the part of analysis professionals to further realize the benefits of systems approaches in business/policy[2] analyses. In this context, a focus on System Dynamics (SD) per se is probably too narrow. Rather, the focus should be on analytical approaches of whatever sort that lend themselves to finding feedback, dynamic relationships, leverage points or other system behavior relevant to good policy making. Further, rather than advocating for a particular modeling platform or formulation, this paper points to analysis *processes* that support the application of systems approaches.

[1] This paper reflects the views of the author only and does not represent the views of Charles River Associates or any other organization.
[2] The discussion in this paper seems applicable to both business and policy efforts. The focus is especially toward analyses that involve disparate stakeholder sets. For simplicity, and because the case study concerns a policy assessment, the term "policy" is used throughout the paper rather than "business and policy."

This paper addresses two questions:

(1) Why is it so hard to implement systems techniques and perspectives in business and policy analyses?[3]
(2) How can we as modelers[4] approach the problem so as to have more success in the deployment of systems approaches?

Among the SD community there is general acceptance of the merits of SD approaches. What is needed beyond further reports on SD successes is a critical evaluation of the barriers to the application of systems approaches in mainstream policy making, with the obvious goal of overcoming those barriers.

To this end the paper explores a real-life, "mainstream" policy assessment process (not one developed with an SD framework in mind): the analysis of the costs and benefits of a major policy choice for the wholesale electric market in Texas. A case study is presented for three reasons:

- First, it grounds the discussion of barriers with real-world examples of process barriers; perhaps real-world people with real-world issues may generate the passion to progress past those barriers.
- Second, it offers a look into the ways in which modelers who are not system dynamics practitioners[5] can, and do, bring systems approaches to traditional policy assessments. Doing this seems important given that the great majority of mainstream business and policy assessments do not strictly use an SD approach. Given the significant difference in the installed bases of "mainstream" vs. non-mainstream initiatives, a marginal increase in the deployment of SD in mainstream policy analyses could have a strong impact on the general acceptance and deployment of systems approaches.
- Third, this real-life example may spark interest among those who believe they are more interested in electric utility policy than in process questions, and this may have the side effect of creating a larger potential audience for process considerations.

While the presentation of this case study is meant to be illustrative of the application of SD to a mainstream—or non SD—modeling project, the challenges that are noted do not indicate "failures" of the policy process that was conducted. Rather, the study performed is seen as a world-class, rigorous policy analysis and an analysis that was appropriately designed and conducted given the original project intentions. Given this, the study provides a very opportune basis for considering what would have been required to conduct the study's analysis with more of systems approach; what are the challenges of integrating systems modeling approaches with necessary detailed linear models, what are the process timeline challenges and what are the challenges given stakeholders motives? These are the questions believed to be interesting.

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[3] Note that while there have been significant works published addressing policy issues within - and outside of - the electric utility industry, often these works are academic based, and few business initiative policy analyses seem to employ SD approaches.
[4] The term "modelers" should be interpreted broadly as analysts, stakeholder facilitators, etc.
[5] The author's unstated assumption is that SD academics and recognized SD consulting firms may tend to be "sought after" when a policy analysis recognizes the need for SD, whereas others (those not strictly practicing system dynamics) tend to perform mainstream analyses.

The balance of the paper is organized as follows:

- Case Study: An electric utility case study is presented, including a discussion of the process leading to the formulation of the model, of the model itself, and of relevant results. The case study is an example of a mainstream policy effort and not a case-in-point per se.
- Postmortem: The outcomes of the case study are discussed from a process perspective, asking "what were the barriers and pitfalls?" The answer is considered from two perspectives:
    - "Victim of Circumstance": The barrier/pitfall problem is presented from the perspective of the modeler/facilitator being acted upon by the process, a perspective that the author commonly experiences.
    - "Master of my Fate" In this view the modeler/facilitator is part of the process system. This perspective may be the only one that offers significant opportunity for transforming policy analysis processes.

Policy Analysis of the Texas Electric Transmission System: Process, Model, and Results

Purpose of Study

In 2004, electric-power generation, transmission, and delivery stakeholders in Texas initiated a study to assess the costs and benefits of moving to an alternative structure for the wholesale pricing of electricity.[6] In particular, the study concerned a proposed change in the method of pricing the short-run[7] use of transmission lines by electrical load-serving entities and electrical generators.

Electrically speaking, the region considered is essentially a self-contained part of the entire Texas transmission system.

In the existing pricing system, electricity is priced on the basis of the marginal value of a few major transmission corridors, which divide the region into a few zones. In this "Zonal" case, the costs of managing transmission within the zones are accumulated and essentially socialized across all users ("loads") within the region, rather than being applied directly to specific localized users.

> **Short-run (Congestion) Cost**
>
> It is not unusual for specific lines in an electrical transmission system to become oversubscribed or "congested": the desired use of the transmission system would exceed the physical capacity of the system, as adjusted for reliability margins of error. In these cases system operators are required to "redispatch" certain generating units to ensure that actual electricity flows are within the capacity of the system. The costs of the redispatching are what set the value or "cost" of the short-run use of a particular transmission path.

[6] A complete description of the study and its results can be found at <http://www.ercot.com/TNT>.
[7] Short run meaning hour-by-hour subscription of the transmission lines rather than the recovery, for example, of the embedded cost of building and maintaining the transmission lines.

The proposed new transmission pricing system would apply the marginal value of the use of individual transmission busses; this approach is known as locational marginal pricing (LMP), or nodal pricing. This was called the "Nodal" case.

Study Process

The decision maker—the Public Utility Commission of Texas—and the Electric Reliability Council of Texas (ERCOT), which operates the transmission system, sought an independent consultant to perform the assessment of costs and benefits and laid out the requirements for the study. These requirements included the following:

- The study horizon would be at least 10 years;
- The simulation of electricity generation costs was to include the use of a model embodying the concepts of "security-constrained unit commitment" and "security-constrained economic dispatch"[8];
    - All generating units in ERCOT area were to be modeled;
    - The model was to produce locational and zonal prices on an hourly basis for every year of the study;
    - Cost structures of generating plants (including fuel, start-up cost, minimum load operating costs, and variable O&M) were to be captured;
    - The model used was to be capable of modeling the entire transmission system (transmission lines operating at 69 kV and above);
- The model was to include environmental regulations and air quality limits associated with Environmental Protection Agency (EPA) non-attainment areas within the study region;
- The analysis was to evaluate the impacts of the proposed changes on a number of market segments, such as utility generators, independent generators such as municipalities, and load-serving entities such as a utility provider or an independent retail energy provider.

A study group was designated to work with the consultant to refine the study approach and assumptions, but those outlined above were to be taken as givens. Significantly, and not unexpectedly, the consultant was asked to use a well-known traditional security-constrained[9] linear production cost model. Such a model (GE-MAPS[10]) was proposed by the consultant, and accepted by the study group as part of the consultant selection process. The study group members seemed to take considerable comfort in the selection of a well-known model.

Following the selection process, the consultant worked with the study group to obtain and develop the detailed data necessary to flesh out the production-cost model and to identify the modeling simulations that would provide the insights useful to the study group. The consultant

[8] Security-constrained refers to the need to ensure that there is a high level of assurance that load can be met in the model if a single transmission path or a single generator goes out of service. A security-constrained unit commitment process selects the resources be scheduled to be available to operate, and a security-constrained economic dispatch program selects the resources that will be generating at some substantial level to produce energy.

[9] Security-Constrained refers to the need to ensure that there is a high level of assurance that load can be met in the model under the condition where a single transmission path or single generator becomes out of service.

[10] Developed by General Electric Company: see <http://www.gepower.com/prod_serv/products/utility_software/en/downloads/10320.pdf>

maintains a detailed database of generating plant parameters, so much of this "Assumptions Phase" of the processes entailed building confidence with the client group that the consultant's database was appropriate and correct.

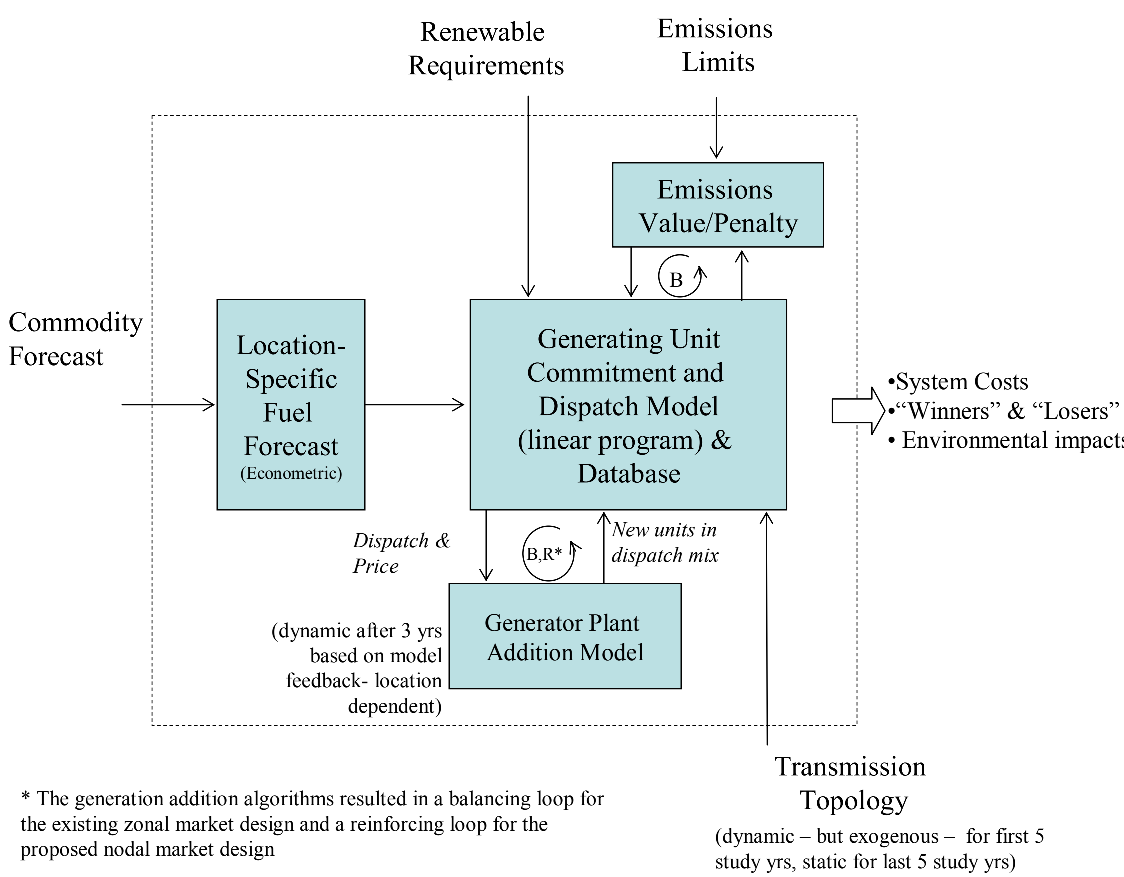
The consultant customized the model to provide results useful to the policy decision at hand. The study was considered to be a "Cost-Benefit" study, and two scenarios, one for each of the alternative market designs, were generated.

Given that the study called for a 10-year time horizon, long-range behaviors and interrelationships were viewed by the study group as important. As consultants, we recommended treatment of long-term effects, and began the modeling process.

Model Employed

Figure 1 provides a schematic of the model used in this study. The description below is presented from a System Dynamics perspective, but the actual study was conducted without any such representations or language. To the study group we were simply simulating, with a familiar algorithm, the hourly dispatch of electricity within the system during each year of the study. No distinction was made between static and dynamic representations or between exogenous and endogenous variables. For reasons discussed below in the Postmortem section, the study group did not focus on such conceptual modeling distinctions—at least not during the course of the analysis.

Figure 1. Model Processes



While the core of the modeling analysis was the traditional production-cost model linear program, two dynamic effects were reflected through the customization of the model for the specific policy assessment:

- Emissions limitations feedback
- Generation siting feedback

The emissions limitation feedback loop reflected a straightforward effect of EPA-imposed emissions limitations. In order to treat those limitations in the monetary cost-benefit model, the consultant translated them into economic impacts.

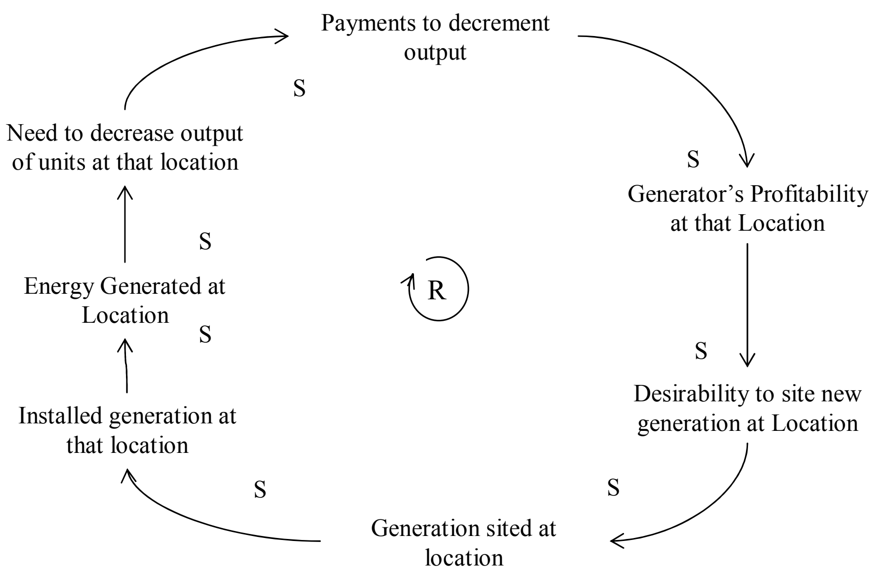
The limits apply to certain "non-attainment areas," areas within Texas in which the emission rates of, or concentration of, pollutants must be managed. These areas tend to be metropolitan areas that are also load pockets (regions in which there are a relatively high level of load relative to the level of generation available). There is thus a demand for large imports of electricity into these areas. Transmission paths surrounding these areas therefore tend to be subject to congestion, given the preference for importing inexpensive energy into the area. Representing the emissions value the model effectively limited the production of NOx and/or SOx within the attainment areas. The emissions pricing element of the model produces a balancing feedback loop that limits the production of emissions by making the import of energy more attractive relative to generation from the attainment generating units.[11] This feedback loop acts similarly in both the nodal and zonal cases.

The generation siting feedback loop was more interesting, because it was sensitive to the market design alternatives. The loop arose because, over the relatively long 10-year time horizon of the study, the siting of generating plants would be driven by energy pricing.

The two market design cases produced different outcomes in this feedback process. Under the existing zonal market design, generators of electricity are paid when management of congestion in the transmission system (see the box on page 2 describing congestion) requires that they increase or decrease their electrical output. The compensation of generators for decreasing output creates a positive feedback loop, as shown in Figure 2.

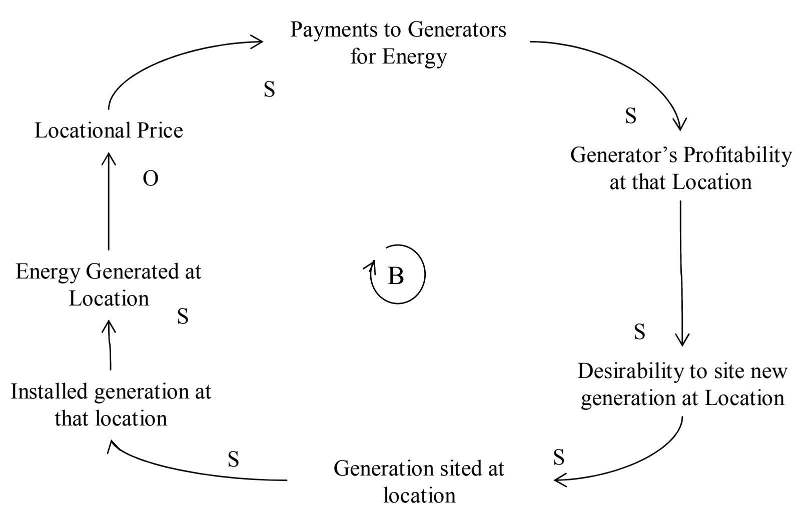
11 For example, load growth in the area creates increased demand for electricity, creating an increased incentive to generate from attainment area plants, creating increased emissions, raising the value of emission credits, raising the relative cost of the in-area energy, making it more cost-effective for outside-area generators to deliver into the area. This then displaces the need for in-area generation, thereby limiting the emissions.

Figure 2. Siting Feedback Loop, Zonal Market Design



The siting policy under the proposed nodal market design produced a different behavior, one that is balancing in nature. In this case, generating units are paid the marginal value of energy at their locations for increasing or decreasing their output. With this pricing scheme, generators that must decrease their output will be downstream from a transmission constraint, where the price is low, and generators that must increase their output will be upstream from the constraint, where prices are higher. Because the generators are priced at their marginal value, the relationship between generator prices, the transmission constraint, and the optimal generator outputs works to create a balancing system, as shown in Figure 3.

Figure 3. Siting Feedback Loop, Nodal Market Design

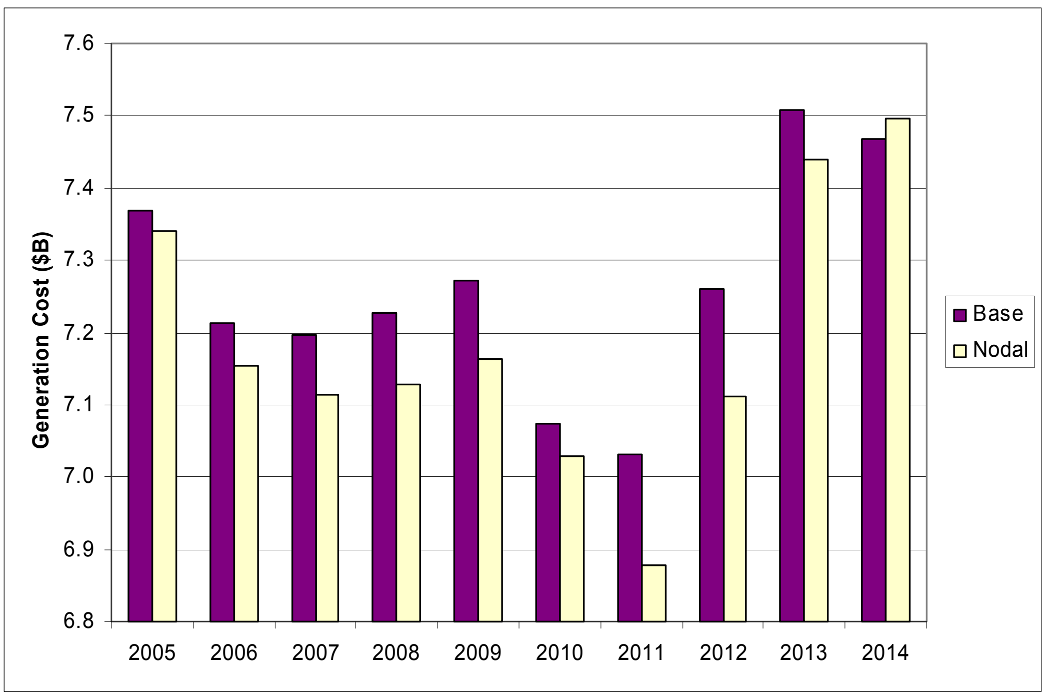


Though these dynamic effects were certain to have been uncovered, given the intention of measuring certain impacts of the market design policy choices, the fact that the study group did not discuss their possible existence (and especially that of the zonal model reinforcing effects) until the results of the study were presented is indicative of one or more interesting behavioral characteristics of this stakeholder group—and, most likely, of similar groups elsewhere.

Synopsis of Model Results

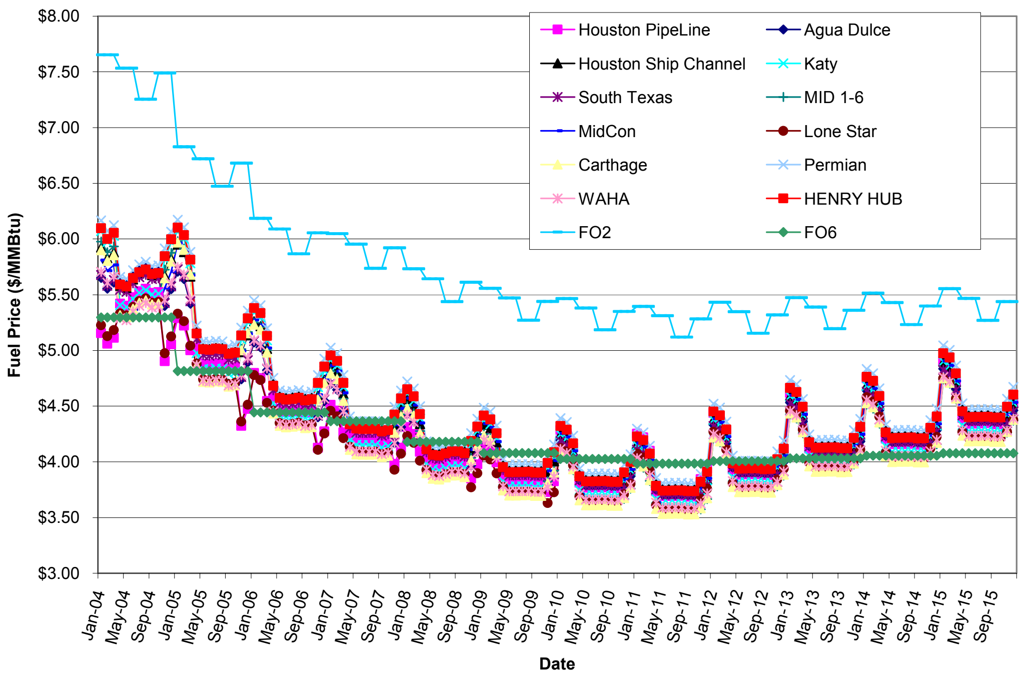
Figure 4 shows the total system costs predicted by the model; these costs capture the essence of the results of the study. The figure is rich with dynamic (time-varying) impacts, some of which are exogenous to the model and some of which reflect endogenous characteristics (some dynamic and some not). These results yielded several important insights about the behavior of the system as it was represented in the model.

Figure 4. Difference in System Cost Between Zonal and Nodal Cases



The results in Figure 4 for both the zonal ("base") and nodal cases follow the same general trend, which is essentially dictated by the prices of fuel oil and natural gas that were forecast for this study and used as exogenous variables. (Figure 5 shows the fuel price forecast.)

Figure 5. Model Fuel Price Forecast



What was of particular interest in this study was not the overall trend but rather the year-by-year difference between the "zonal" and "nodal" bars in Figure 4, as this represents the potential benefits of moving from one policy design to the other.

To consider the behavior of the benefits between the Base and Nodal cases, it was useful to divide the study time horizon into three periods.

Study Horizon Periods

1. Near-term (2005–2008)
   - Transmission upgrades explicitly considered with transmission model changing every year
   - Surplus supply–demand conditions are satisfied through 2008 subject to announced (same in both cases) capacity additions
2. Mid-term (2009–2011)
   - No transmission upgrades are defined; same 2009 load flow case is used
   - Resource capacity is added subject to market signals created within each market framework
   - Transmission system appears capable of accommodating capacity additions
3. Long-term (2012–2014)
   - No transmission upgrades are modeled; ERCOT 2009 load flow case is used
   - Transmission system is no longer capable of accommodating resource capacity additions based on purely economic criteria
   - Resource capacity addition process is no longer formalized, and is driven by "trial and error" methods to find feasible placement scenario

In the near term (2005–2008), the siting of generation capacity is the same in both cases, so the nodal case benefits shown in Figure 4 do not arise from differences in siting. The near-term results suggest a system sensitivity to a particular assumption in the model. As can be seen in Figure 4, the difference (gap) between the Base and Nodal cases grows from year to year from 2005 to 2008. The cause of this dynamic is a subtle one that went unnoticed by the study group and later emerged as an important assumption sensitivity point. The dynamic results from relative treatment of two transmission system characteristics over the study horizon: (1) the overall physical capacity of the major interzonal paths and

Table 1	
Year	System Cost Δ (million)
2005	$27
2006	$59
2007	$82
2008	$100
Average	$67

(2) an operational conservatism (limit) imposed on the interzonal paths under the zonal (Base) case.[12] Recall that transmission system upgrades are implemented in the model during the near term, increasing the physical transfer capability of the interzonal interfaces. However, the methodology to set the model's operational limit for the zonal case, established in the assumptions phase of study, was fixed over the study horizon. In actuality, it is likely that the operational limit would also track with the physical limit to some level.

The result was that while the nodal case allowed more and more flow on the interzonal paths as the transmission system was upgraded, the operational model continued to limit flows to the levels established based on the 2005 topology. This increased the difference between the cost to meet load in the nodal and zonal cases in each of the near-term years, as shown in Table 1.

The mid term (2009–2011) exhibits the impact of treatment of the generation siting differences between the two cases (in addition to the impact of the operational conservatism discussed above. During 2011, for example, the Nodal–Base Case system cost gap reaches $152 million. This substantial difference is driven by the generation siting policy.

During the long term (2012–2015), the assumption that the transmission system remains fixed (not upgraded to support new generation to meeting load growth) was found to be unworkable. Load growth requires the addition of a substantial amount of generating capacity, but that capacity could not be sited in accordance with the prescribed generation addition model without overloading the transmission system.[13] As analysts, we ultimately recommended that the years 2013 and 2014 not be relied upon to provide useful insights given the inconsistency between the generating resource needs and the study's lack of upgrades to the transmission system.

Ultimately the study suggested that there should be substantial value to the movement to the nodal-based transmission pricing policy, representing an expected benefit of approximately $76 million per year on average.[14] The study identified "winners" and "losers," predicting that generators stood to lose significant revenues with the new nodal market design (roughly $800 million per year) and that the load-serving entities would capture that value.

Postmortem

The focus of this section returns to the process questions:

[12] The operational limit, a construct actually employed by ERCOT operators, is required because under the zonal model, all generators within a zone are (by definition of the zonal settlement) treated equally with respect to their impact on the inter-zonal interfaces during the scheduling process. In fact, each generator has a different impact on the interzonal flows given its location. Under this equal-treatment design, the operators must schedule less than the full physical capacity (or impose this operational limit) of the paths to ensure that actual physical flows do not exceed the physical limit of the path.

13 That the 10-year study ran into such difficulty is not unexpected; most long-term transmission system studies are plagued by the inability to forecast transmission system needs and their associated upgrades so far into the future.

14 Note that while this seems like a substantial sum, it represents less than 1% of the total system cost.

- Why is it so hard to apply systems approaches during the course of policy analysis?
- How can we as modelers approach such analyses so as to have more success in the deployment of systems approaches?

Those barriers to effective systems analysis that seem most overwhelming and impenetrable relate to the inherent tendencies of human nature, especially as influenced by multi-disciplinary stakeholder groups.

Pitfalls and Barriers Perspective I: "Modeler as Victim of Circumstances"

From this point of view, the barriers are the following:

1. People like what they know and resist what they don't: they like setting input data and parameters because they can relate to that process and dwelling on it makes them feel comfortable. Similarly, they are very attached to output data as such. They feel less comfortable discussing subtle system behaviors—or the potential for such behaviors—so they generally do not give such matters a priority in terms of study resources. Because of their attachment to detail and data, stakeholders tend not to identify leverage points, or even to recognize them as important until after the fact, when it becomes apparent what drives the output data.

   Individual stakeholders in our study group were essentially self-selected, and they chose a production-cost model approach. During the "assumptions" process, they seemed to dwell mostly on the familiar details of production cost modeling (e.g., generating-plant parameters).

   After the fact, there was criticism of certain assumptions in the model that had previously been given very little focus. It is noteworthy that transmission system conservatism, which causes the Nodal–Zonal delta spread shown Table 1, was essentially not discussed in the multitude of stakeholder forums, although it later became an area of considerable concern. Similarly, it was known (or at least knowable) when the study was being defined that the generation siting process included a positive feedback loop in the Base Case, and yet this matter was given little particular attention at the time.

   One may ask: why did we as consultants not raise the importance of some of the critical issues identified in the study, either during the study definitional phase or at some other time early in the process? This is a critical question, and consideration of it reveals what seems to be a key characteristic of such multi-stakeholder policy efforts. The perception from the facilitator/consultant's view is that the stakeholders insist that significant levels of effort be devoted to the things the stakeholders are focused on a priori. (Of course, this is perfectly rational from the stakeholders' perspective!) For example, in the case study in question, countless hours were spent discussing and verifying the specific representation of generating plant characteristics. While the consultants strongly believed that the level of scrutiny of such parameters well exceeded what was warranted,[15] it seemed virtually impossible to dissuade the stakeholder members from focusing on those areas.

2. The issue of "Winners and Losers" seems to take priority over globally optimal solutions.

   This is an age-old issue, and it came into play directly in this policy analysis. Stakeholders seemed to begin from a position of thinking that the leverage point for them is ensuring that their relative position as a winner or loser is protected.

3. Stakeholders believe that their particular piece of the system warrants examination in excruciating detail. Supporting this detracts from energies that might better be devoted to addressing systems relationships.

   This issue may simply be a re-emergence of pitfall/barrier item 2. Stakeholders know their part of the system well (for example, their transmission system or load service area), and they want to be assured that they do not end up being a "loser" because they—as individuals—incompletely represented their own system.[16] They therefore demand particular accuracy and detail for their particular area of accountability. This compartmentalization seems to further impede finding system leverage points and shared learning.

4. The time pressure of the business cycle prevents capturing value from feedback from insights in policy processes.

   While the case study project was conducted consistent with the defined objectives of the study, the policy analysis was not initiated with SD approach in mind. The case study project (a) was not designed with the intention of using systems approaches that identified leverage points, (b) was executed in a manner that focused on details, but probably most critically (c) it was carried out on a schedule that allowed *no time for a feedback loop in the process itself*. As analysts, we developed original methods of modeling this particular electricity market, incorporated all the specific detail, debugged the modeling, and provided meaningful interpretations and insights from the work. All of this was completed nearly on time and with a non-trivial donation of consultant resources beyond the project budget. Yet it was not enough of a process to allow for a substantial feedback loop in the modeling process, and this was probably one of the most important steps.

   This is not to suggest that what is needed is simply more time and money devoted to good policy work. It is quite likely that if more time had have been allotted for this study, all of it would have been spent digging into the details up front—that is, into those details

15 If for no other reason than that such parameters did not change between the two cases of interest.

16 In the case study, this presented itself with a generation owner, for example, noting that in the simulated results his generating plants ran 10% or 20% less than they do in current time. As modelers we spent a significant amount of time investigating such issues, though essentially we recognized this would be "noise" in the grand scheme of the results. We knew this but again were ineffective at persuading stakeholders to forego the investigations.

that the stakeholders saw as most critical. What must happen instead is a shifting of focus from detail to overlying behavior.

5. Traditional (linear) approaches have a successful history that is difficult for SD approaches to match, and to some extent are inherently incompatible with systems approaches. Thus, while one may say: "why didn't you take a more systems approach to begin with," that is easier said than done. The traditional modeling techniques are often, or nearly exclusively, the ones that prevail in the consultant selection phase, for example. To be responsive to the stakeholders' belief regarding the proper approach often steers modelers to traditional approach. This may eliminate the systems viewpoint from consideration before the project even begins.

   Also, and probably more relevant in the case study, for some systems such as the electrical system, the behavior—at least the short-run behavior—is sensitive to the response of individual components at a detailed level; and it seems difficult for SD tools to handle both the overarching systems behavior and the underlying detailed behavior. Perhaps more important, stakeholders[17] seem nearly always to be willing to focus first on the detailed component response, sometimes to the exclusion of seeing overarching system behavior (as described in pitfalls 2 and 3 above). This suggests a potentially inherent conflict between detailed traditional approaches (e.g. operations research), which requires a constant effort to ensure the ultimate existence of sufficient detailed data, and SD, that calls for more focus on system relationships.

6. While there may be a desire to have a long-term study perspective, the lack of data required to support such an effort means that dynamic results are not credible.

   That the study in this case was to be a 10-year study though only 5 years of transmission upgrades were feasible, is an instance of this issue. (And this is accentuated by the fact, described in barrier/pitfall 5, that the detailed hour-by-hour solutions were also viewed as relevant.) More broadly, there are very few aspects of policy making in the electric power industry that support a long (e.g., 10 year) time horizon.[18]

While the above considerations may be intriguing and redeeming, do they enable our community to take actions that effect change? In thinking through the next steps or the "so what" question, it is not clear that it does. Reflection suggests a fundamental reason why such insights are not particularly powerful: the above barriers and pitfalls are not seen from the perspective of the modelers/facilitator/analyst as part of the cause of the barrier but rather suggest that the modeler is essentially an exogenous variable in the process system. In such a role there is virtually no leverage to effect change.

Consider, as an alternative, a different view or perspective on where the barriers lie.

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17 This is likely not true of the highest-level stakeholders (e.g., in our utility case, the Public Utility Commissioners), yet stakeholders at this level are not responsible for selecting the methodology, hiring the analysts, or providing ongoing oversight of the work.

18 Of course there is the well-studied dynamic of generation development, with a very pronounced time delay and therefore a behavior mode that can be modeled.

Pitfalls and Barriers Perspective II: "Master of my Fate"

An alternative perspective suggests entirely different pitfalls and barriers.

7. As for-hire[19] modeler/policy analysts, we believe that we must first be selected to perform the analysis if we are to have any impact at all. That is, no matter how good the modeler and her team, they cannot do any "good" unless the stakeholders choose them. A modeler therefore tends to increase her chances of getting the job by being accommodating with regard to the stakeholders' expectations about the process (approach, timetable, etc.) for the work.

   Furthermore, there is a delay in the ultimate dynamic; the consequences of failure to be responsive on client schedule and budget requirements are very immediate (that is a failure to be selected to be the modeler), while the consequences of having to resolve self-imposed schedule and budget constraints generally are not strongly felt until the latter part of the project.

   The result is that analysts may under-represent the process that may seem ideal or preferred—at least from a systems analyst's perspective. An improper balancing of the trade-off between performing the work within a reasonable time and cost scope, and designing an approach and process that supports robust systems analysis, self imposes critical schedule and budget pressure and may apply unworkable constraints regarding approach.

   Alternative treatment would likely require the policy analysis team to assume the risk of not winning the assignment or grant money. Similarly, modelers may ultimately benefit from making the compelling case for why robust approaches are necessary and why it is necessary for the policy assessment to be afforded reasonable time and budget resources. This suggests that like a commitment to meet time and budget requirements, a modeling team's commitment to ensuring a structure that supports good analysis is also important to applying systems approaches.

8. Consistent with barrier/pitfall 7, once engaged to perform the assessment, continuing to "look good" in the eyes of the sponsoring organization is perceived to be important to one's long-term ability to "do good work." In other words, once the analysis is under way, a constant ability to meet deliverables—especially in the face of complex or subtle systems—again creates the temptation to succumb to schedule and budget pressure, compromising critical stages of the process.[20] Especially coupled with any tendency from the relationship described in 7, where the modeling or analysis effort may have been underrepresented to begin with, the incentive to compromise on process in order to meet deliverable commitments and to work within budget can be strong.

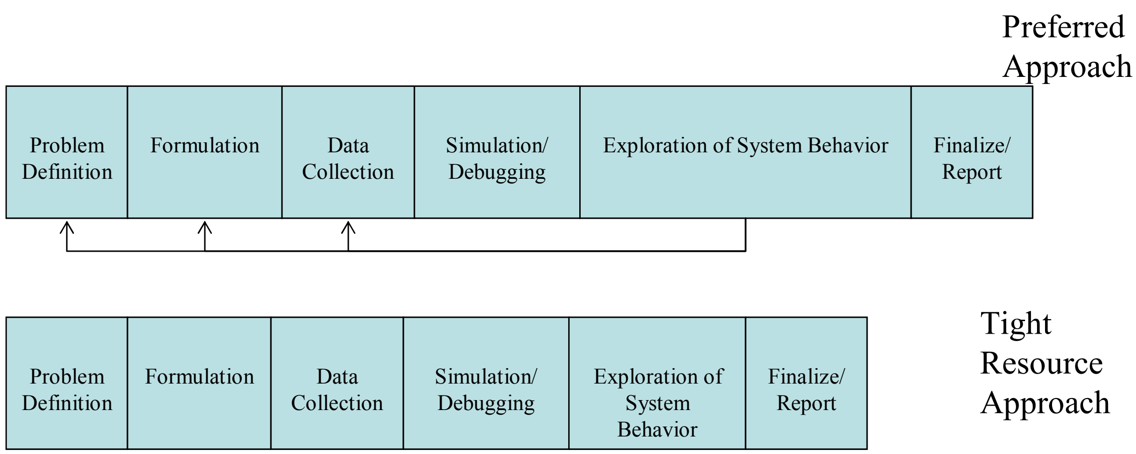
19 Note that this phenomenon is not limited to external analysts; in-house policy analysts must also "sell" analysis approaches and processes internally, and they likely have more at stake regarding perception than do outside consultants, for example.
20 In this sense, schedule or budget pressure refers primarily to the first-order effect of a gap between the needed resource and the actual available resource. Certainly, however, second-order effects, such as the loss of focus cased by the perception of time or budget gap, worsens the impact.

Distinct from pitfall 7, however, the appropriate response is likely not to lobby for modification to the project process (e.g., deliverable schedule or budget), but rather to hold in especially high regard the commitment to integrity both with respect to the deliverable and cost commitments and with respect to maintaining a process that fully supports a robust systems approach.

To the extent the resource (e.g. time, budget) requirements for ensuring modeling process completion exceed the resources that are required, the modeling process may become compromised.

Figure 6 illustrates the potential impact of a process requirement that exceeds the process resource.

Figure 6. Effect of Resource Pressure on Process



When the resource (e.g., time) constraints in the project become active, the impact is that the critical exploration process following results outputs, and the feedback it allows, is curtailed. It is not unusual to have not ability to iterate, addressing questions such as the following:

- Did we define the problem properly? For example, did we set the boundaries of the impacts properly?
- Did we use the model correctly? (Our example of the transmission constraint limit that did not change over time with the changing transmission topography was such an example. A modeling iteration as part of the exploration phase would have provided for the ability to adjust that assumption, perhaps making the constraint limit dynamic based on the transmission topography.)
- Did we use the correct data?

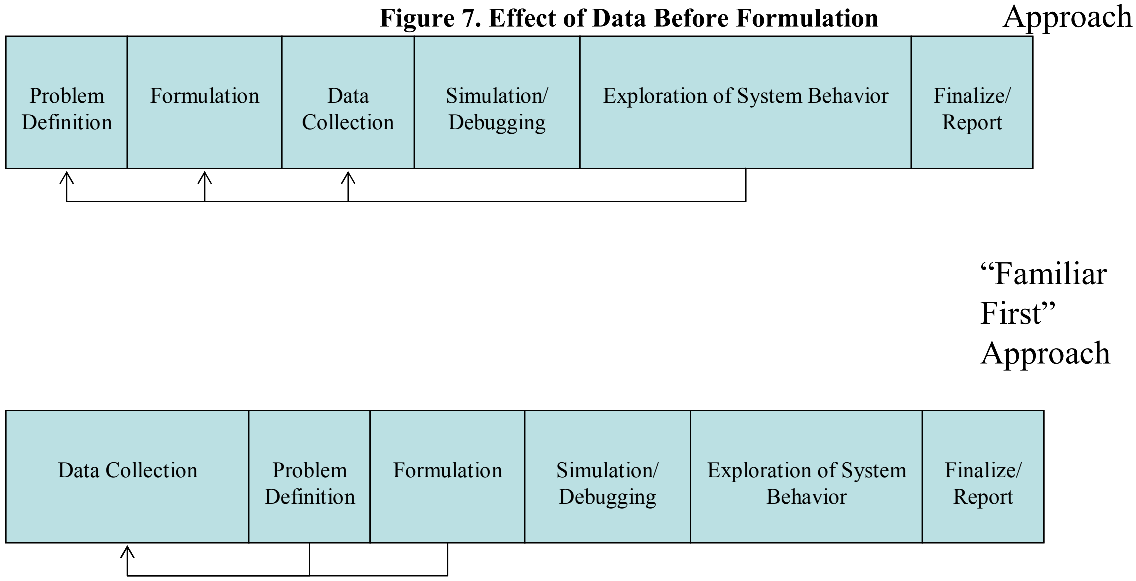
This reinforces the importance of effective project planning, focus on ultimate objectives, constant diligence regarding completeness, accuracy, etc. However, similar to pitfall 7, it also requires the confidence to be willing to point out to the stakeholders when unexpected process conditions arise that warrant consideration of a change in plans. (That is, for example, carefully making the case for adjustments to model structures, assumptions, or the modeling process itself—as opposed to "looking good" by meeting the time, deliverable, and cost objectives—with the goal of providing the most valuable service to the stakeholders.)

9. Policy analysts have the temptation to start with a modeling task easy to initiate or accomplish. Doing so offers some tangible action. This is the policy analyst's corollary view to barrier/pitfall 1 in the earlier "Victim of Circumstances" set, where stakeholders are similarly attached to dwelling on something tangible. Treatment in the case study exemplifies this. One of the first tasks performed by the modeling team was to provide the "Assumptions Memo," which addressed detailed data requirements. The logic of this was that stakeholders need considerable lead time to collect and review the large amount of data required for GE-MAPS modeling.

   This has two consequences, however, both undesirable. Consider for example Figure 7.

Figure 7. Effect of Data Before Formulation

Preferred Approach



The early release of the Assumptions Memo, while intended to "get a jump" on data needs, in effect ruled out a data needs *assessment*, with its critical elements of formulation and problem development. In fact, it was necessary to collect additional data during the study, because ultimate formulations had alternative data needs. More important is that early release set the stage for stakeholders to focus on that aspect of the study. It created a distraction from the important formulation and definitional aspects and unproductively focused on detailed data and systems behavior; in fact, it likely *caused* the stakeholder behavior described in "Victim" pitfall/barrier 1. The effect of this was a distraction from stakeholders' awareness of critical formulation assumptions and an expenditure of disproportionate resources on detailed data examination, which then mandated the compression of the exploration stage.

Clearly, once revealed, this dynamic indicates that it would be highly advisable to de-emphasize data initially, even if doing so means forgoing the opportunity to perform some tasks in parallel. In other words, the value of having the consultant and the stakeholder group think about formulation first, coupled with the decrease in the re-doing of data collection, is high enough that it pays to restrain the data processes until the formulation process is complete or nearly so.

10. A modelers' attachment to the formulation process may discourage offering a significant opportunity to iterate. This plays a role in the design of the process not in the sense of resistance to iterating during the exploration phase, but rather more conceptually during the design of the analysis process and timeline, with for example, a thought process of: if the schedule is tight already then shall we reveal our model for criticism potentially requiring "rework." That is, a priori, the initial results of the analysis are not yet available to compel the modeler to value the iteration process highly. Yet if the ability to iterate is not valued initially, there may be little or no process support for iteration once the need for it becomes compelling.

Conclusions

This paper has examined the barriers to robust application of systems approaches in mainstream policy and business decision making, addressing the question of how analysis processes can be improved to better capture the benefits of systems aspects such as dynamic effects, interrelationships, subtle underlying behavior, and leverage points.

The case study demonstrated that systems treatment and effects were available in this non-traditional SD modeling policy work and that proper treatment of the modeling process to capture those benefits was desirable. Several barriers and pitfalls arose during the course of the analysis effort detailed in the case study. The barriers and pitfalls when experienced by the modeling team ("Victim" pitfalls 1 through 6) appear as inherent process and stakeholder body characteristics. However, these human system/social system characteristics are generally well known, and focusing on them in this way seems to offer little leverage or power for the modeling community to learn and thereby to effect improvements in the modeling process.

The "Modeler as Master of her Fate" set of pitfalls (pitfalls 7 through 10) provided some examples[21] of self-inflicted modeler behaviors that worked to affect the outcome of the modeling process. Reflecting on these pitfalls offered several important insights.

These include the following.

[21] There are likely many more than those few articulated that are not yet distinguished.

- Establishing at the onset of the policy analysis a structure supportive of systems approaches may require the modeler to take some risk and engage the stakeholders in this as a priority, rather than only following approaches and processes proposed by stakeholder bodies.
- Modelers must work diligently to stay within time and budget resources so as to not self-inflict undue resource pressure and sacrifice critical iteration and reflection stages of the process.
- A modeling teams' efforts to focus the stakeholder group on the formulation process initially rather than delving into details or data better supports mutual gain from discovering underlying system behaviors. Further, analysts should challenge themselves to support the stakeholders' interest in underlying systems relationships even when the issue being modeled requires processing at a very detailed level.
- Analysts can commit to transparency of their own modeling assumptions and model formulations. This would encourage further dialog about the model structure and make possible an even deeper level of understanding for the stakeholders.

Until we can see ourselves as creators of the barriers, little progress will be made in effectively reducing or eliminating them.