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Review of Data Landscape: Challenges and Opportunities

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Valuing Economic Impacts and Resilience in the Electric Power System

There is a considerable range of measures and timeframes used to quantify regional and national economic impacts. For some classes of natural and manmade disruptive events, a simple calculation involving the number of anticipated causalities and property damage may be enough to provide the rough magnitude of the economic impact. However, property damage and value of statistical life (VSL) are incomplete for understanding the implications of the total impacts on an economic system, or are not sufficient when the disruption does not result in widespread physical damage and death. Metrics of impact include imports, exports, sales, price changes, and business failures. It is typically the losses associated with employment income and indirect losses that occupy the efforts of economists in the field of disaster and disruption research.

Resilience is not a new concept and has a history within the ecological, engineering, and mental health disciplines, yet there is no common consensus regarding how it should be defined. Beginning in the 1960s, the economic literature began to propose solutions to seismically resistant electric power (EP) generation and transmission solutions. The literature is filled with proposed solutions to identifying the benefits and costs of seismic fragility; nowadays this is referred to more generally as increasing resiliency of critical infrastructure. Resilience has recently emerged as a national and homeland security priority with several efforts in progress at the local and national level with particular interest given to EP systems and long duration outages from natural and manmade disruptions. A unifying theme of many proposed resilience methodologies is the inclusion of economics as a mechanism on which to compare various resilience solutions.

Traditional (macro-) economic impact analysis has a role in the long-run analysis of the effects of changes in resilience, since in the long-run the economy adjusts to the microeconomic impacts through various mechanisms (Kunreuther & Roth, 1998). However, measures of economic health, growth, or expansion are not sufficient for measuring resilience. The majority of infrastructure in the United States is privately owned and operated or is managed through some private-public arrangement. Most effects from changes in resilience should be assessed through short-run microeconomic analysis since the actions of firms will be spurred by internal economic decision-making that will have immediate impacts on local economies. Any forthcoming efforts to include resilience in the economic impacts of long duration EP outages must accommodate the private and simultaneously public nature of the EP infrastructure as well as its role as lifeline infrastructure.

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Resilience metrics and methodologies will only be helpful to stakeholders if these metrics help them understand the value of improvements to the resilience of communities, infrastructures, or industries.

Summary of Data Landscape: Challenges and Opportunities

In their paper, Schellenberg et al. (2018) have provided a well thought out "lay of the land" of the common methods of estimating the economic costs of EP disruptions, which includes discussion of the difference between costs of outage and regional economic modeling, strengths and weaknesses of methods, the difficulty in incorporating resilience, data collection and availability issues, and recommendations for future research. They identify many difficulties faced by economists in calculating the cost of outages when including non-residential customers and indirect effects. Including resilience valuation adds complexity. They also point out that many of these investment decisions, having impact on resilience of regional economies, are private firm decisions, thereby limiting the role of the public institutions.

The authors outline the importance of the EP infrastructure, especially its role as a "linchpin" infrastructure since it is often the system on which the other 16 critical infrastructures (CI) rely. Without it, many services would cease (or at least perform below optimal levels), resulting in cascading impacts throughout the CI, the economy, and public health. The speed at which the EP infrastructure has both a direct and indirect effect on the overall speed of recovery for a community or regional economy post-disruption further emphasizes its role in ensuring resilience.

The authors present several metrics and methods used by utilities to quantify investments. Resilience has not traditionally been part of their analyses. Some of these analyses have been more focused on the business case for their investments such as cost benefit analysis (CBA), selective hardening, cost effectiveness, and least cost alternatives, all of which are useful for comparisons. Considering catastrophic events, the methods are more focused on consequences such as avoided negative impacts, avoided costs of lost lives and injuries, and negative impacts to infrastructure. Quantifying resilience based on these metrics can be helpful but is largely dependent on the probability and frequency of a catastrophic disruption.

Schellenburg et al. (2018) present their findings from the literature and apply methods to identify potential solutions to the difficulties associated with resilience quantification and these improvements to the family of CI and the community. They present methods from the Federal Emergency Management Agency (FEMA), survey methods and willingness-to-pay (WTP), and regional economic modeling.

FEMA Methods

I had not spent much time reviewing the FEMA software since its previous inception as Summit, which utilized infrastructure models developed by the National Infrastructure Simulation and Analysis Center (NISAC), such as Sandia National Laboratories' (Sandia) Regional Economic Accounting tool (REAcct). I very much appreciated learning the current model details, with its focus on informing CBAs. I think it is an important contribution to assign a monetary value of lost time (VLT) within the context of infrastructure disruptions. It provides a better understanding of how cascading impacts can affect individuals' daily lives, since any infrastructure disruption will increase the amount of time it takes to complete a previously simple task, and how an EP outage, particularly a catastrophic one, will compound any other infrastructure effects. Many current approaches to resilience focus on

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community/urban resilience as impetus as to why a utility should invest in technology that improves resilience. The VLT has the potential to monetize something many have a difficult time contextualizing in dollars. Many of the other metrics that are part of the FEMA CBA are perhaps less promising given the data requirements. Aside from data constraints, which I'll discuss in more detail later , a major hurdle will be the adoption of "welfare loss" metrics. This is something I've previously proposed to non-economists. While immediately disregarded, the topic of how to measure benefits to individuals from a resilience improvement continues to be discussed.

Survey Methods

The authors highlight survey methods as a potential avenue for measuring EP outages and resilience. There have been proposed WTP surveys in Europe and the U.S. that could offer valuable data on residential users and how individuals think about resilience. However, as Schellenberg et al. discuss, it is a potentially expensive, time consuming, and error prone endeavor. Beyond survey compliance the authors highlighted many of the pitfalls of survey design: sampling precision, frame errors, and non-sampling errors. Surveys are often discussed as the best way to approach how residential and non-residential users value resilience. I've considered it myself, but when considering the non-responses, response errors, and specification errors this paper reminds me why this is often an unappealing proposition.

Regional Economic Methods

I appreciate that the authors have identified the same challenges as myself when considering applying regional economic models to increasingly granular geographic levels. The common models have typically been designed for the state, county, and census tract level. First, this facilitates fairly easy use with federally available and macroeconomic data. Second, there hasn't been much use for regional economic models at a neighborhood level. This is an important point given that many of the proposed EP resilience solutions center around micro-grids, which often service a few city blocks at most. Another difficulty of applying regional economic models is that service territories do not follow predetermined economic geography. The authors discuss the difficulty this presents, a difficulty not often appreciated outside the economics bubble. Often a desire to use a regional economic model is driven by trying to satisfy the stakeholder desire to have a single number to point to, this single number often being gross domestic (or regional) product or jobs.

Potential Solutions

With regard to long duration outages and incorporating resilience into the EP system, many solutions have been proposed as well as how to use past measures of valuing outages to this new concept. The authors provide a useful review of past work and the difficulties in applying the traditional methods of valuing lost load, survey methods, and estimating economic impact to resilience improvements. Data availability is a well-known constraint to many working within this field. However, I think the authors have identified promising solutions and (perhaps previously unidentified) opportunities for collaboration.

The proposition of combining survey data with regional economic models is an exciting path that can be useful to stakeholders in the public and private sectors. I believe surveys and other methods from experimental economics can help fill some of the data gaps in the existing models (this applies to both the FEMA Tool and regional economic models). Two starting places are potentially the NISAC suite

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of infrastructure tools and Argonne National Laboratory's (Argonne) attribute-based survey for resilience. The NISAC tool suite includes infrastructure-specific models that have been exercised for scenario analysis and real-world events for over 10 years. In the past these tools were used to identify locations of vulnerable populations, hospitals in flood zones, production facilities at risk, and other at-risk infrastructure. Recently, these tools have also been used to co-locate CI with potential locations for micro-grids in New Orleans, LA with the purpose of increasing resilience during extreme weather events. I've recently been alerted to a survey tool out of Argonne that seeks to categorize the level of resilience and resilience needs of specific CI locations, creating a catalogue of attributes by location. Sandia and Argonne are currently working to combine our resilience consequence framework with Argonne's attribute method.

The struggle is especially perilous given the granularity of many proposed resilience solutions. Several of the proposed technologies for the EP infrastructure are applicable at the site level or at most a few blocks, a challenge well-outlined by the Schellenberg et al. (2018). I greatly sympathize with this challenge and have sought potential data solutions with little to no success. The first challenge is financing—that is, identifying a sponsor or funding source to supplement the data purchases. The second is determining how exactly to use such highly granular data. Businesses are born and die quite regularly and could impact relevance of such a granular analysis. The third is considering how useful it is to actually conduct analysis at such a granular level given the overall infrastructure improvements needed throughout the system. It could be that a regional economic impact at this level is not the most helpful pursuit of economists.

Conclusions

I do generally agree with the conclusions of the paper, with varying levels of what I think is possible to achieve.

- **Improvements in valuing avoided impacts to critical facilities.** Highly achievable and resources should be put toward the effort.
- **Explore the use of regional economic models in the context of resilience planning in a regulatory environment.** I think this is a useful and achievable pursuit, but will take funding to accomplish and should be applicable to every type of infrastructure disruption, not just the EP infrastructure.
- **Conduct a nationwide survey using representative sample.** I think this will be a struggle to achieve and, given the survey difficulties outlined in this paper, perhaps not the best use of funding given the speed at which potential resilience technology could come online and the increasing frequency of long duration power outages. Perhaps it is best to focus on incentive structures for encouraging adoption of resilience.
- **Increase information sharing among utilities regarding extreme weather forecasts and performance of resilience investments.** This seems like a common-sense approach and I am grateful for the hopefulness of the authors. I am, however, doubtful of the achievability of this level of coordination.

I clearly do not have the answer, but this is a common topic I and others wrestle with daily. The answer is likely dependent upon the stakeholder audience and the specific customer.

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