Case Study 3:
Pre-Disaster Community Resilience Indicators

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The Problem

Natural disasters pose a unique threat to the well-being of people. They are often unpredictable and very destructive. In seconds, whole families can be made homeless, security and happiness ripped from their grasps. This puts the disaster relief services of the nation in the most delicate situation and necessary position. Our task for this case study was to assist those who help the country in some of the most dire times of need and uncertainty. In particular, we were tasked with looking at how data and modeling can be used to make decisions about housing and unmet needs before and after a disaster.

Our Solution

Before we even attempted to solve the problem above, we had to look further into how disasters affect the lives of the everyday population. Utilizing the English literature analysis skills on our team and a CNN article (Willingham), we were able to determine four core concerns for survivors of hurricanes: (1) how to deal with sudden homelessness and whether or not to leave or rebuild, (2) finding proper healthcare, (3) securing income, and (4) assistance for young and old. As we continued researching, we found a study done by researchers at prestigious East Coast universities that described how post-disaster levels can be restored to pre-disaster happiness levels with the right community support and stress prevention (Calvo et. al). With that, we set out to create a way to help counties discern their pre-disaster risk and better mitigate the effects of disasters.

Our problem scope was limited to hurricanes in Florida, and we hoped to synthesize a set of ‘resilience indicators’ to aid government officials in mitigation decisions and cost calculations. Resilience indicators are characteristics that can be used to determine what the

potential, relative resilience of a particular area will be in the event of a disaster, which indirectly provides insight into the potential costs incurred (financial and otherwise) post-disaster.

In gathering the data, we initially looked at a set of 28 resilience indicators as designated by FEMA (sourced in Appendix B). Based on the data format, we decided to run our analysis by county, and chose to include three of the 28 indicators: income (per capita), unemployment level (3-year average), and healthcare availability (number of primary care physicians per 100,000 residents). Through external sources, we also designated age (<18 and >65 groups) from the 2017 ACS and housing density (proportion of households with more than 1.5 people per room) from the Department of Housing and Urban Development as additional factors to consider.

Furthermore, to make the data easier to digest, we devised a scoring system designed to summarize the five indicators we chose into a single number that describes a county's overall vulnerability. We achieved this by applying principal components analysis to the data (five indicators for each of 67 Florida counties).

Applying theoretical results from linear algebra, principal components analysis finds the best set of p linear combinations of the observed variables which minimizes the loss in variation explained by each subsequent principal component, while requiring that each component is orthogonal to all the others. Thus, taking p equal to 1, the first principal component yields the linear combination of our five indicators which explains the highest proportion of total variation in the data, making the coefficients of this linear combination an ideal candidate for our score.

Specifically, a simple implementation of the analysis in R returned the coefficients given in Appendix A, and this one-dimensional score variable all on its own captures about 43% of the variation in the five-dimensional observed data. Note that the coefficients given are for

standardized variables (this is a necessary step when dealing with wildly varying unit sizes, like income and proportions) so the magnitudes are unimportant, but the signs of the coefficients reinforce our interpretation of this objective summarization of the data as a resilience score. The score variable will increase with healthcare availability and income, factors that should make a county more resilient, whereas the other factors which we would expect to make a county more vulnerable carry a negative sign and would be inversely related with the score variable.

As a final technical note, because principal components have a property called equivariance, we can adjust the scale of the coefficients in order to improve the scale of the final output. Thus, the coefficients in Appendix A are scaled versions of the original coefficients, and the final score is computed for a given county by multiplying its standardized indicators into these coefficients, summing, and adding a constant term of .6, in order to ensure that scores generally fall between 0 and 3.

Our Tool

Using the information gained in our statistical analysis, we developed an online tool that can be found at https://rebeccalassiter.github.io/communityResilience/ . This tool is used to visualize and quantify a community's resilience in the face of natural disasters so that municipal leaders can make informed policy decisions, particularly about adequate housing for families and individuals. Officials at the county level can enter in their county's data regarding the five indicators. The users are given a resilience score based on their inputted data and the above statistical analysis. Users are also shown a radar chart that compares their community's performance in the different areas. The inputted data is normalized by the state median and the radar chart displays their performance as a factor of the state median for each category.

Additionally, the values for the categories of housing density, employment opportunities, and age are inverted before they are displayed on the chart. This ensures that a larger polygon is associated with a better outcome, making the display more intuitive. The radar chart allows municipal leaders to view their community's performance as a whole and compare their performance across different resilience indicators.

Moreover, when a given category's performance is above or below the state median (given the indicator and it's sign), policy suggestions for that given category are displayed. This provides county and city leaders with tangible suggestions to improve their resilience score.

Communication

The tool is intended for use on the municipality-level to drive informed policy decisions depending on a county's resilience score and to disseminate information on a county's disaster preparedness. Sharing this tool with FEMA and leveraging their existing relationships with disaster-prone areas will ensure widespread awareness and distribution of tool. Additionally, sharing with FEMA will also ensure these areas have easy access to the tool since most resources needed for disaster preparedness can be found in one place.

Recommendations

Further analysis and input from experts is required for a better choice of indicators. The indicators used in our tool were chosen based on what made practical sense to calculate a county's overall resilience score and also based on the county-level data available to us, but there could be a more comprehensive method of choosing these indicators.

The current tool uses state median as the benchmark for each of the resilience indicators so counties are able to compare their resilience scores with other counties within the state. An

important extension that we believe requires input from subject-area experts is benchmarking both the indicators and the final score in order to better interpret the output of our tool. The current benchmarking system implemented could be misleading; for instance, the state median income could still be low in terms of disaster preparedness, so benchmarking on the current state median might not be as helpful or informative. We would need experts' inputs to determine what a better benchmark compared to the state median could be; this could mean asking experts what the target median counties should aim for to reach a good disaster-preparedness level. Since our tool is intended to drive informed policy and mitigation recommendations, the tool would also require input from experts to determine what recommendations make sense for each of the resilience factors. For instance, a resilience benchmark for the housing density indicator would be the minimum proportion of overcrowded households beyond which a county would have to specifically address those households in its housing mitigation plan. If a county falls below the benchmark, no special attention is needed; if it exceeds it, then it should consider allocating more resources to recovery-period housing that can accomodate these large families which live in such a condensed space. Because of the linear nature of our scoring function, a benchmark for each indicator immediately yields a benchmark for the score, above which a county can be considered resilient and below which it can be considered vulnerable.

Lastly, we recommend generalizing the tool so it can be used for other geographies and disasters since it's currently catered for Florida counties' hurricane preparedness. For example, a drop down box could be added onto the tool for the users to choose their state and the tool could then output different disasters the area is prone to and calculate that state's preparedness for that specific disaster.

Appendix A: Scaled coefficients of the principal components analysis

Variable	Coefficient
Healthcare Availability	0.063271
Vulnerable Age	-0.01803
Income	0.07212
Housing Density	-0.03561
Unemployment	-0.06948

Appendix B: Works Cited

Calvo, Rocío et al. “Happily Ever After? Pre-and-Post Disaster Determinants of Happiness Among Survivors of Hurricane Katrina” *Journal of happiness studies*vol. 16,2 (2014): 427-442.

[data source] FEMA, and NOAA. *Draft Interagency Concept for Community Resilience Indicators and National-Level Measures*. https://www.fema.gov/media-library-data/1466085676217-a14e229a461adfa574a5d03041a6297c/FEMA-CRI-Draft-Concept-Paper-508_Jun_2016.pdf

Willingham, AJ. “The Biggest Question for Hurricane Survivors Is, 'What Now?'.” *CNN*, Cable News Network, 29 Nov. 2018, www.cnn.com/2018/09/18/us/hurricane-survivors-what-now-next-steps-trnd/index.html.