Communicating Advanced Infrastructure Resiliency Analytics to Diverse Groups of Stakeholders

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Abstract:

Data science holds vast potential for providing rich insights into infrastructure resiliency challenges. However, the highly complex, analytical nature of data science is often unfamiliar to people working in disparate professions, this leads to disinvestment by those who stand to benefit most from these infrastructure resiliency insights. Overall, little progress has been made towards intuitively communicating the analytical complexity of infrastructure resiliency to untrained audiences. Advanced web applications with graphic interfaces create opportunities to correct this issue by making data both highly accessible and interactive. For example, an advanced model has been developed that allows airport security officers to identify combinations of airport security measures that minimize undesired risk events. In another instance, a simulation was built to assist government officials in planning for hurricane risk events by combining probabilistic hurricane paths and flood inundation data.

INTRODUCTION

Emergency managers and disaster planners have historically faced great challenges when encountering disaster events. Hurricane Andrew left large portions of Florida in shambles from its destructive wind. Hurricane Katrina steamrolled much of New Orleans and the 9th Ward and might be the best example of resiliency challenges as no one expected the levees to break. In 2017, Hurricane Harvey joined Katrina as being one of the costliest hurricanes in history as it placed Houston underwater (National Oceanic and Atmospheric Administration, 2018). Alongside Harvey, several other major hurricanes made landfall in the US, including Maria and Irma. Emergency managers (EMs) and disaster planners are tasked with the tall order of building resiliency for these destructive events and guiding them to safety through a collaborative ground-up approach. EMs need insights that address the dynamic disaster landscape to effectively execute their jobs (Kapucu, Arslan, & Demiroz, 2010; Waugh Jr & Streib, 2006).

For instance, an EM may need to address several complex and important disaster questions including:

1. How vulnerable are we to a disaster?
2. What disaster impacts will likely be felt by my community?
3. How can I better protect the most vulnerable populations?
4. What type of recovery efforts are likely needed after the disaster?
5. What can we learn from the disaster to better our response/mitigation efforts in the future?

These questions are complex, and in some cases, even chaotic. In addition, they are rarely known, especially among EMs with limited resources. The Cynefin framework describes these types of decision making problems as through operative contexts in Table 1 (Snowden & Boone, 2007).

Table 1: Cynefin framework

Decision Level	Description	Math Relationship
Simple	These are straightforward management issues as there is a clear cause and effect relationship and therefore the decision is quite clear.	Direct linear relationship between X and Y.
Complicated	Complicated issues involve cause and effect relationship, but these relationships are not always apparent to everyone.	The relationship between X and Y is not known but can be worked out. Subject matter experts help dissect complicated problems.
Complex	Complex issues have no apparent order or cause and effect relationship. Instead, these issues are ever evolving with no clear answer at first but with research one eventually emerges.	The relationship between X and Y is unclear and may have feedback loops.
Chaotic	There is no order or researchable order in chaotic issues as the system is constantly changing and therefore unmeasurable and unmanageable.	If a relationship between X and Y exists, it will be hard to impossible to identify.

The Cynefin table provides a framework to help identify where knowledge needs to be built or where current knowledge needs given to the right people. This is true for resiliency too. Building resilient communities is complex or even chaotic when there is a lack of understanding of cause and effect relationships, feedback loops, and interdependencies of the different forces at play. Knowledge and understanding is therefore key in making what are chaotic, complex, or even complicated issues into more

simple problems. For example, a community may believe evacuations are complex because no matter how much planning is involved, there always seems to be traffic jams. However, if that same community understood that traffic jams are caused by improper evacuation routing or a lack of fuel for evacuating motorists, then the problem because simpler to correct. Providing quick, adoptable, intuitive, and useful knowledge provides EMs with the necessary bits of information to plan for resiliency issues that were once more difficult than simple.

Community EMs are seeking effective and efficient resiliency assessment and decision-making tools to create useful, collaborative, and clearly focused resiliency plans (Ostadtaghizadeh, Ardalan, Paton, Jabbari, & Khankeh, 2015) as this sets the foundation for the disaster recovery processes (Pfefferbaum et al., 2013). Much of the current set of tools lack iterative and stakeholder input in creating scenario-based planning tools (Sharifi, 2016), which renders these tools less effective.

THE NEED FOR BETTER DECISION SUPPORT TOOLS IN AN ERA OF ADVANCED RESEARCH

The 2017 hurricane season highlighted the need for practical, accurate, and user-centric resiliency planning tools. Hurricanes are the most destructive natural hazard the eastern and gulf coast of the United States experiences. Most of the fatalities and infrastructure damage is caused by rainfall, storm surge, and high winds. Hurricane Harvey in 2017 was positioned stationary over the Houston area producing torrential rainfall and windspeeds reaching about 130 mph. This left the area devastated for several days with roughly 300,000 people without electricity and thousands of homes and businesses destroyed (NOAA NCEI, 2018).

Also in 2017, Hurricanes Maria and Irma wind speeds (150 mph) destroyed Puerto Rico's power grid, completely ruining over 75% of the island's agriculture (NOAA NCEI, 2017). The US fared much better than Puerto Rico by only having a few hundred households without power.

Emergency managers and disaster planners need decision support tools that overcome the shortcomings of complicated and easily misinterpreted static map overlays, disparate and discontinuous data sources, and delayed maps to help minimize impacts created by hurricanes in 2017. Static maps may only offer EMs incomplete spatial information as they require complicated spatial overlays, careful interpretation, and time to digest the information. Therefore, EMs need tools that quickly provide the necessary spatial information and knowledge without requiring convoluted and time-consuming data processing and GIS functions. When given this ability, EMs are better able to make quicker and more informed decisions. The research-driven approaches to creating resilience help build incredible sets of knowledge that EMs use for more effective decision making. The scientific research approaches conducted at RS21 and its partners, including the Office of Cyber Infrastructure and Analysis and National Laboratories, offer a rich bed of knowledge including surge and wind modeling. However, the scientific research results, in a raw format, can sometimes become obscured for those who need them the most. Research is focused on the identification and advancement of theories, but it also holds an intrinsic value for practitioners and other non-academics. Research consumers, such as non-academics, often have a strong need for cutting-edge research insight but are the least skilled in producing and digesting this information.

This is not to say that these consumers are not intelligent or properly educated. They are. It is also not an issue of scientific research outpacing the needs of practitioners. It is not. It is a matter of connecting the right people with the data insights they need in a consumable way.

USER CENTRIC APPROACH TO RESILIENCY TOOLS THROUGH CONTEXT BUILDING

User centric approaches to creating disaster resiliency planning tools introduces an opportunity for stakeholder buy-in, which creates powerful and more utilized tools. Resiliency issues are complex. Providing insight into the complexity of these issues requires an understanding of the resiliency problems and approaches, the data to solving the problem, an understanding of who is consuming the information, what information should be presented in a tool, and a host of other considerations. The alignment of these components increases the likelihood for a tool to be successful. We have found that the best way to ensure that these components align is through our discovery process.

Collaborative and holistic engagements with stakeholders prove to be effective at not just establishing trust but laying a foundation for successful tools. One of the first engagements with our clients involves our discovery session to layout a series of goals, motivations, and challenges. One of the motivations is to help the client (when necessary) hone in on a problem and begin the process of mutually discussing potential solutions through a data science and design lens. In a data scientist lens, this involves examining different analytical approaches and unique datasets needed to solve the problem with the client. This is an iterative approach as the client's problem, the datasets available, and the methods used are intrinsically linked.

Understanding these elements and their interconnected relationship helps us identify what type of impacts and insights data science can provide to the client. Therefore, this approach catalogs the client's methods, data, and past insights derived and begins to identify method and data gaps that can be enhanced. Furthermore, our core team of data scientists work with the end users to identify insights that are consumable and important, or human-centric. In a design perspective, the discovery session is intended to begin the user-centered design approach. Executing a user-centered design approach helps us identify what tool features and elements are useful and helpful for users to fully engage with and understand the data. This includes building use cases for the tool, user personas, and mood boards that help maximize the connectivity between users, the tool, and the data. The information gathered in the discovery session allows our development team to efficiently structure the backend databases for the analytical procedures and data and the frontend based on design aspects.

Working in the innovative space of resiliency interfaces, this approach to product development is indispensable. This approach allows for solving the known challenges, but also for the unknowns uncovered during iterative research and brainstorming and creates a balance necessary to scope the vast amount of options generated in user centered design approaches. The end output of partnering user centered design with design thinking is not just a creative exercise or a trendy overly cool tool, but an effective and user adoptable system - allowing us to provide the best insights in an intuitive, inspiring and evolving interface.

Furthermore, this process allows teams to put future enhancements on hold and to create a strategic product roadmap. Instead of re-conceiving and creating a tool from scratch when old tools fail, this design thinking approach allows for iterative improvements over time - which leads to a much more sustainable, scalable, and cost-effective resiliency product.

This broad framework applies not only to the project overall but can also be applied to any element of a project in-progress. Because of this, our workflow is a process of frequent strategic iteration. Just as Snow did not instantly know how to solve the cholera puzzle, we do not always nail it out of the gate in any product design. While design thinking is a beneficial approach to interactive product design, design thinking is merely creative exploration without a matching iterative development process to realize real world manifestations of theoretical software. Working in an iterative development method while building

an innovative digital product is crucial to realizing these iterative designs in a way that allows for real-time user and stakeholder feedback and testing on a project in flux.

CONCLUSIONS

Disaster management and planning approaches have come a long way in the last few years but are still focused on antiquated frameworks and tools. Planning tools over the past few decades have gone from overlaying confusing, disparate, and discontinuous static maps for resiliency scenario-based assessments to GIS-based approaches that require vast datasets and specialized staff.

Building custom decision support tools overcomes the issues presented by static maps and GIS applications. Custom decision support tools give users the ability to interact with data insights and build different resiliency scenarios through a map interface. Here users can toggle switches, zoom in and out of areas, use slide bars to change the surge levels, and pull different levers to change prediction schematics.

For instance, EMs can use our tools to zoom into states, towns, and neighborhoods, then use a slide bar to change the amount of surge flooding entering an area. After that, users can examine how multiple levels of expected flooding will impact different pieces of infrastructure including critical lifeline assets such as, hospitals, police stations, evacuation routes, and shelters. This information is presented to the user instantly, which offers them the ability to circumnavigate the need for static maps and GIS tools. Lastly, our custom tools can be created in 4-8 months using our frameworks and development process.

Overcoming sterile resiliency assessment tools requires human-centric approaches to building tools. Human-centric approaches should not be mistaken with conducting social-science research but instead should focus on the interconnectedness of a problem (resiliency, infrastructure, and other interdependencies See Hightower et al., 2018) with the people who make the decisions. The Double-Diamond technique offers a cyclical research approach for data-driven research and creative thinking to hone in on solving the client's problem. This approach helps breakdown the barrier of tool being developed without stakeholder and user engagements. Furthermore, human-centered thinking helps connect data and data methods to not only resiliency problems but to the way people engage with solving problems through data. The more connected people are with the data, the more successful the tool becomes.

Our data science, development, and design agile approach help resiliency planners and EMs better prepare for hurricanes and other natural disasters by giving them unique abilities to fully leverage knowledge embedded in data. Collaborating with clients in this non-prescriptive approach creates successful custom tools that turn complex problems or pain points clients' experience into simpler versions of the same problem which leads to better resiliency.