DECISIONS IN DISASTER RISK:

A NOVEL MODEL FOR DISASTER RISK ASSESSMENT USING THE AHP

Madhury (Didi) Ray, MD, MPH, CEM

AGENDA

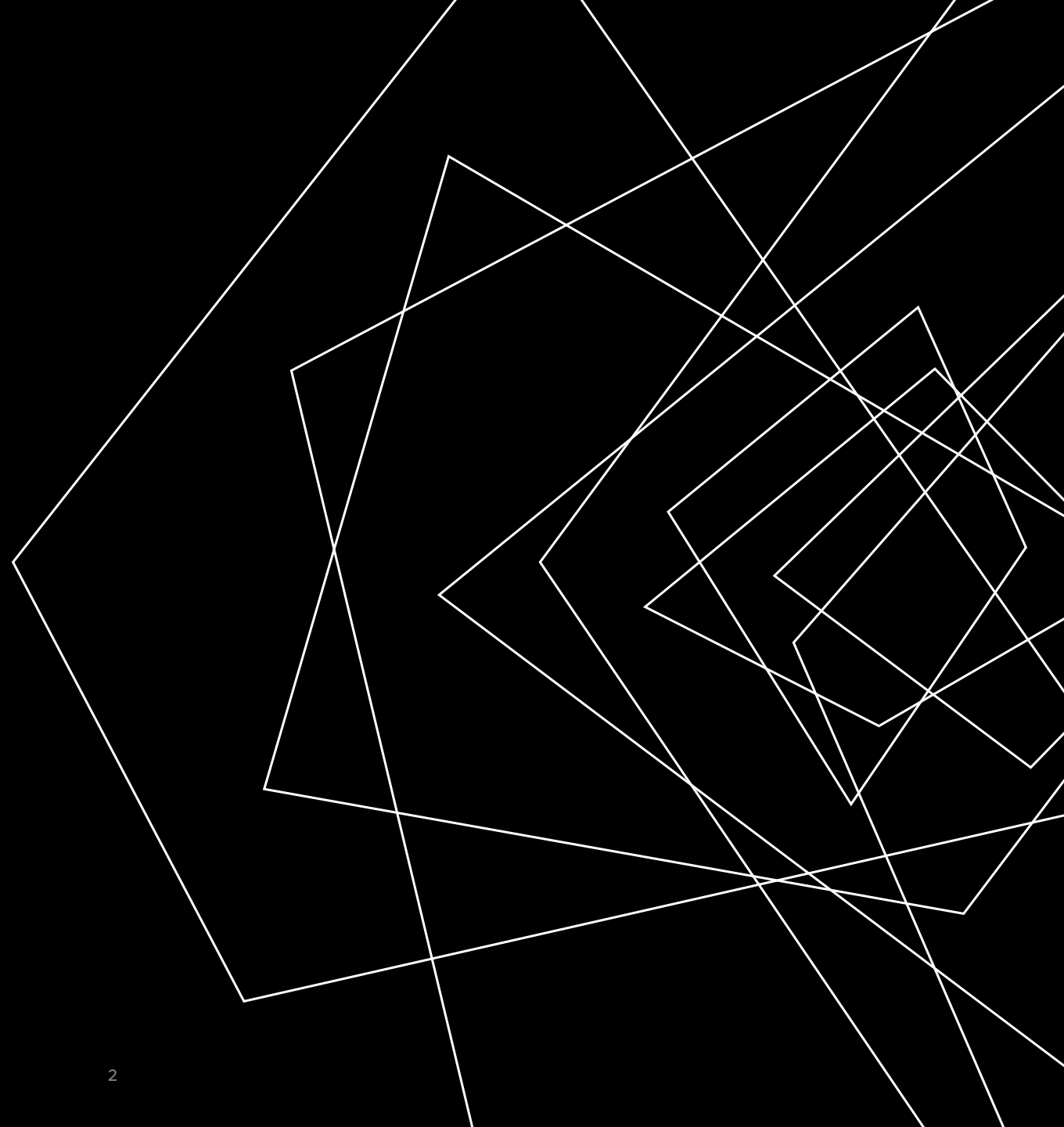
Background & Core Principles

NYC’s Disaster Risk Assessment

Analytical Hierarchy Process

- Decomposition
- Measurement
- Synthesis

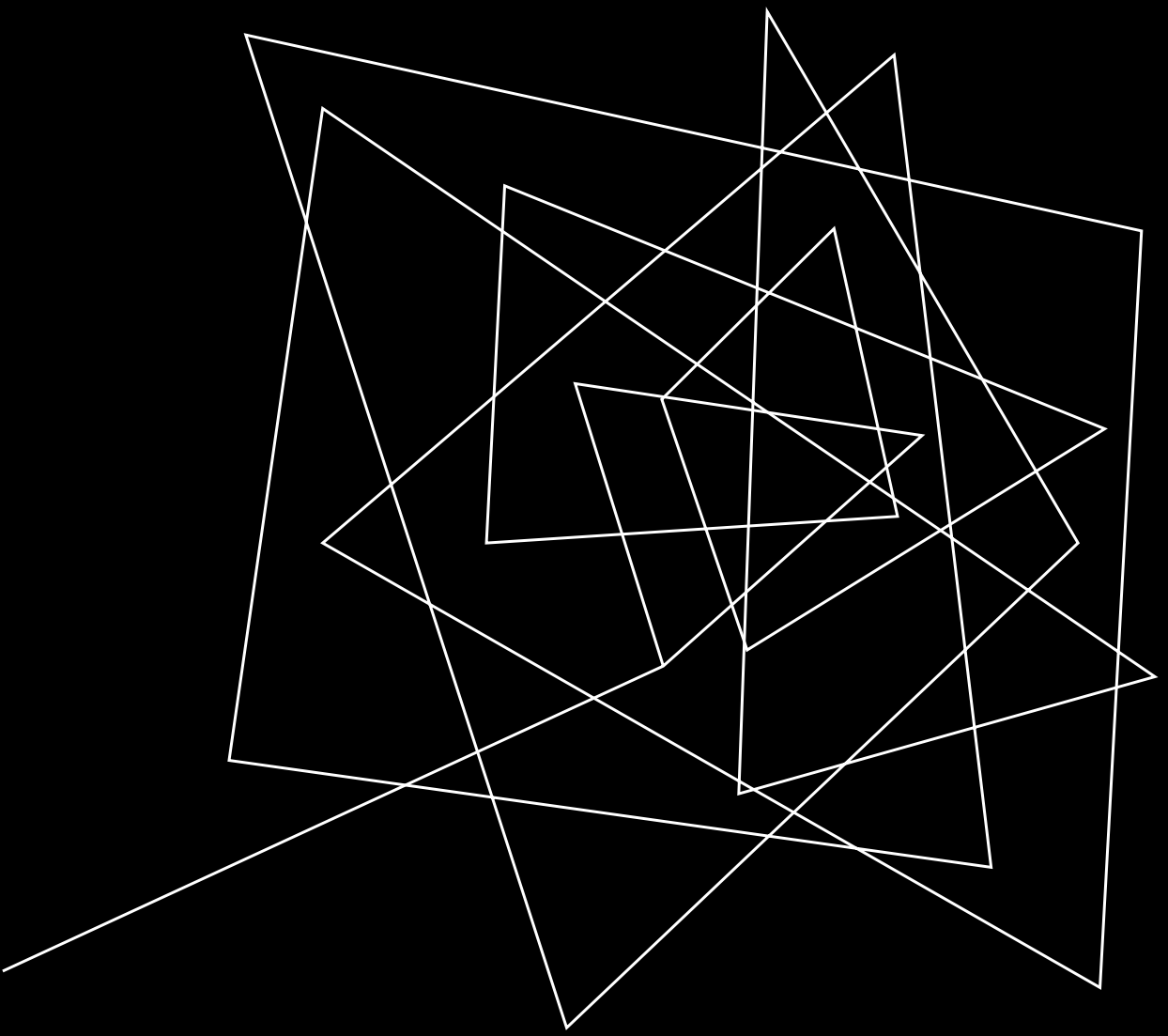
Conclusion



INTRODUCTION

We are living in age of disaster, marked by an increasing number and severity of devastating events worldwide. Allocating preparedness resources for these high probability, low frequency events is more critical than ever before, but what threats are the most important to prepare for? What are the most critical functions for government to protect? And how can governments make these decisions?

A disaster risk assessment answers these questions, providing the foundation for an ongoing cycle of disaster preparedness. These disaster risk assessments can take many forms; they can be as simple as a ten minute conversation by leadership prioritizing which hazards to attach resources to, or complex, involving murky calculations using large datasets. In 2018, the New York City Department of Health invented a new model for disaster risk assessment using the AHP. This talk will describe the methods and rationale of this model, as well as several unique features that may transform the way that risk assessments shape emergency preparedness work.

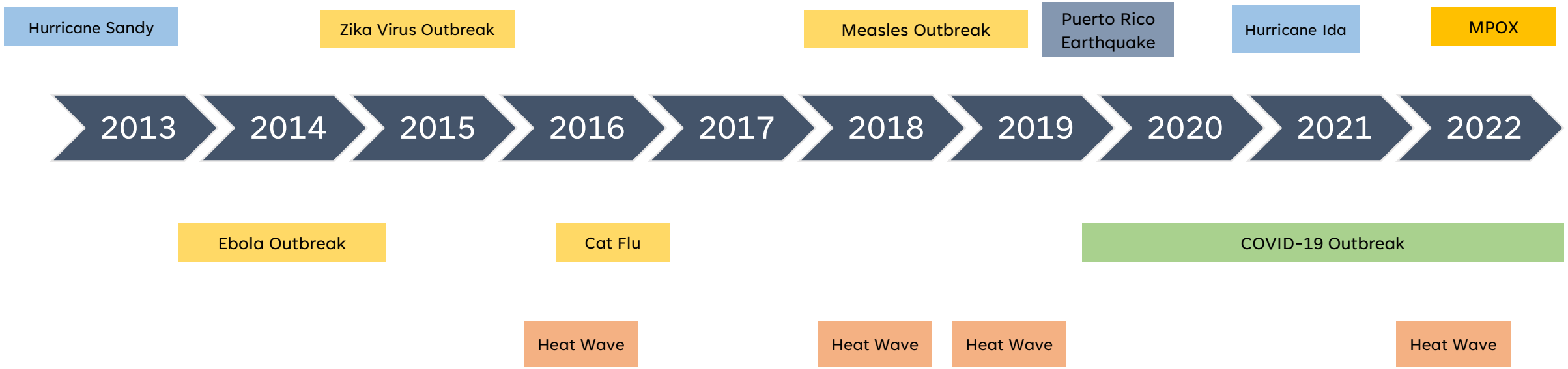


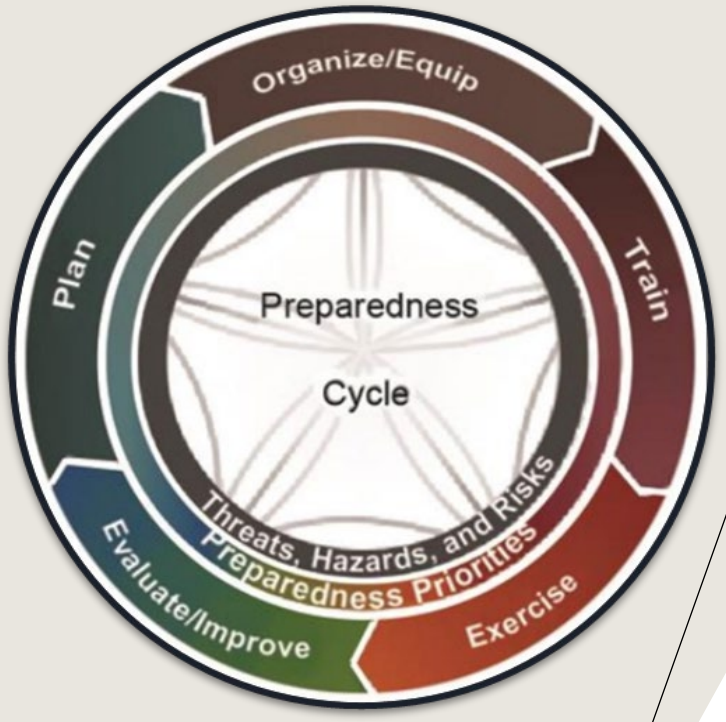
BACKGROUND & CORE PRINCIPLES

Emergency Management Doctrine


A
N
T
H
R
O
P
O
C
E
N
E

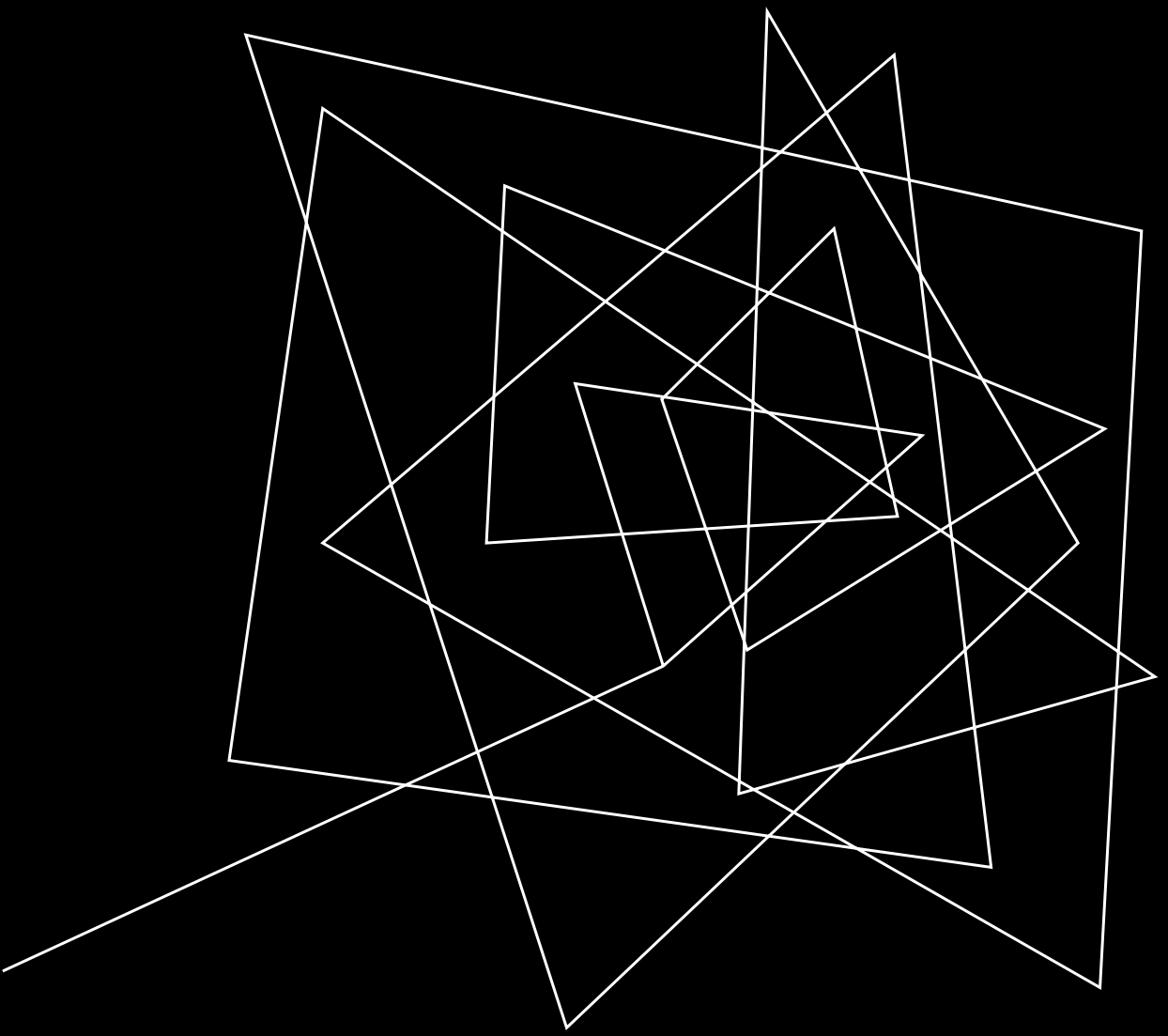
NYC DISASTER RESPONSES





RISK ASSESSMENTS SHOULD DRIVE PRIORITIZATION AND RESOURCE ALLOCATION THROUGHOUT THE PREPAREDNESS CYCLE.

Integrated Preparedness Cycle *(United States Department of Homeland Security, 2020)*



NYC’S 2018 DISASTER RISK ASSESSMENT

Analytical Hierarchy Process

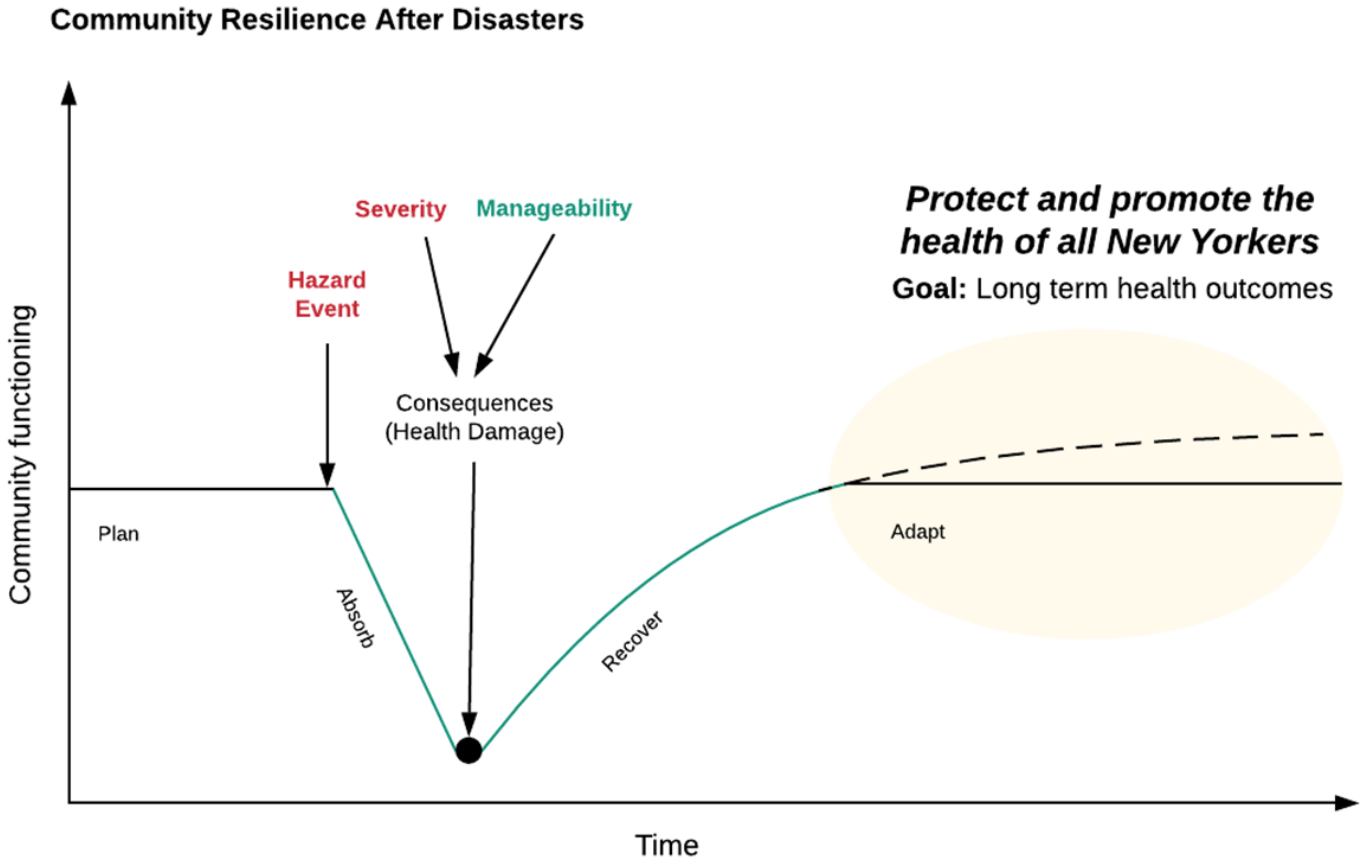
NO CONSISTENT METHOD EXISTS

- Explicit definition of risk:
  - What are the **elements of risk**?
- What **data** determine risk? Where do these data **come from**?
  - How **diverse or comprehensive** are these data?
- How are data **aggregated** to determine risk?
- How will the risk assessment be used in **preparedness**?

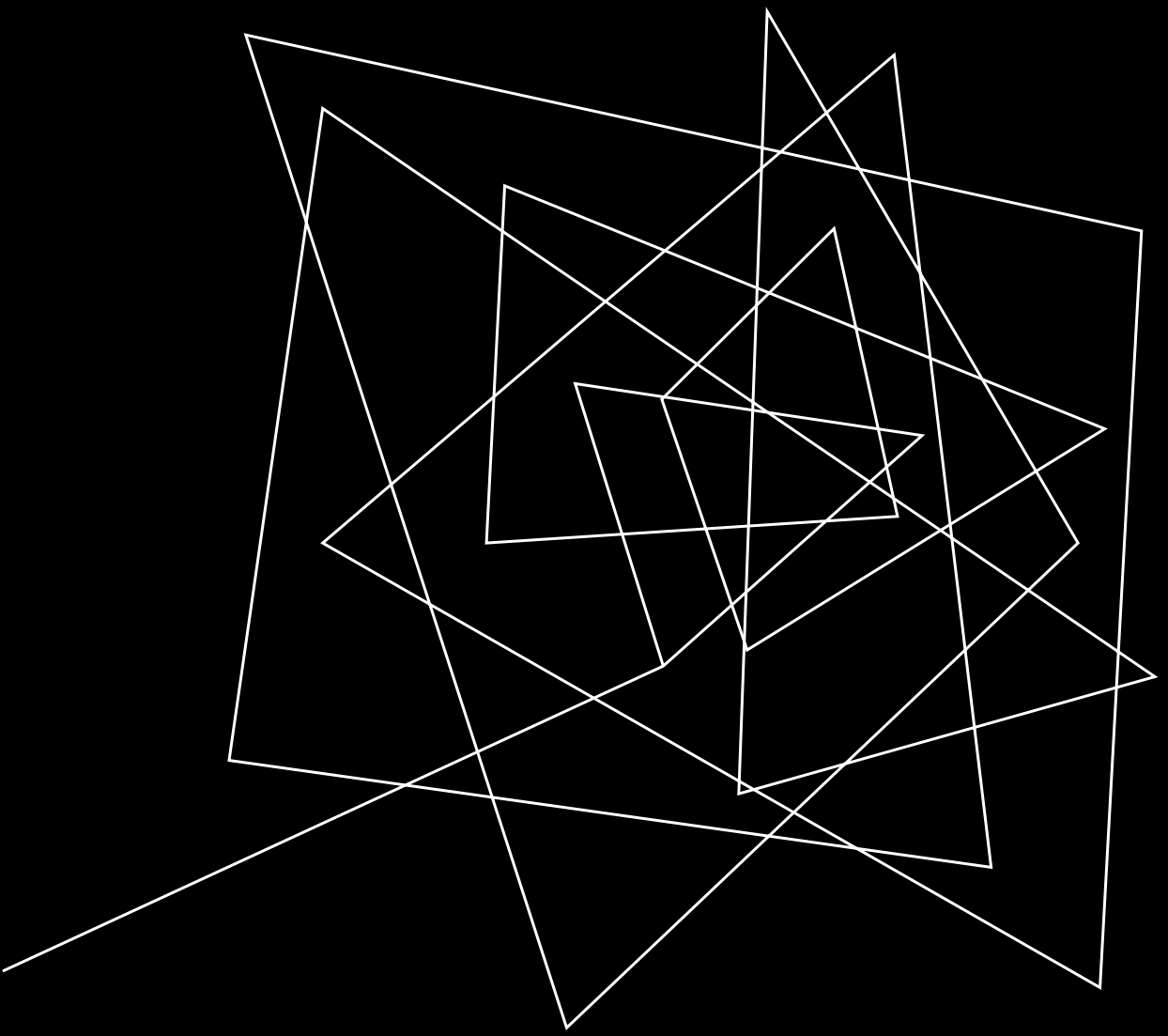
EXAMPLES OF RISK ASSESSMENTS

Project	Hazard Risk Equation	Method/Data	Participants	Data Collection	Data Aggregation	Integration into Preparedness Cycle
2013 NYC DOHMH JRA *(See Appendix 3, Section 4)*	*Manageable Risk* comprised of *Probability*, *Severity* (6 discrete sector domains), and *Planning Impact*	Risk perception, Delphi Method for collective decision, survey based on scenarios.	23 Health Department staff representng different sectors.	Absolute scale scores collected from Delphi method survey	Arithmetic mean of component and domain scores (each has equal weight), Borda counts of component scores to generate hazard scores/ranks	Leadership can review risk scores/ranks relative to a preparedness score/rank to identify gaps
Public Health Risk Assesssment Tool (PHRAT) *(Peters et al., 2019)*	*Probability* x *Severity*, adjusted for impact to "at-risk" populations.	Largely quantitative; PHRAT Excel Tool prompts entry of quantitative data; qualitative estimates for probability and, if no quantitative data available, for severity. Based on general disaster definitions.	Mostly "objective" data entered into PHRAT Tool; a single entry for qualitative assessments.	Quantitiative data converted into scores, qualitative selections are on an absolute scale	PHRAT Tool calculates risk automatically based on internally defined standard weights.	A planning priority score is generated by dividing a hazard's adjusted risk score by a preparedness score, which is a weighted average of Federal-level capability scores from outside self-assessments.
Hazard Risk Assessment Instrument (HRAI) *(Dean et al., 2013)*	Risk incorporates *probability* and *severity* elements. *Severity* = *Magnitude* - *Mitigation* (4 discrete sector domains).	Risk perception. *Probability* is estimated qualitatively. *Severity* is assessed after comparing quantitative hazard-specific severity data to baseline demographic data. Based on general hazard definitions.	Analyst enters data.	Probability and severity (4 sector domains with 4 sub-domains each) are scored on an absolute scale.	Arithmetic mean of severity sector domain and sub-domain scores (equal weight).	*Severity* vs. *probability* are plotted for each hazard for leadership review and preparedness planning.
West Virginia Jurisdictional Risk Assessment *(West Virginia State Center for Threat Preparedness, 2018)*	*Risk* = *Probability* x (*Impact*-*Mitigation*). *Impact* and *mitigation* are each separated into 3 discrete domains.	Risk perception. Representatives convene a group to collectively score *probability*, *impact*, and *mitigation* for each hazard. Based on general disaster definitions.	Representatives of each county (51) in the state of West Virginia convened stakeholders from the whole community with special attention to at-risk populations for facilitated discussion and qualitative assessments.	*Probability*, *impact* (3 domains), and *mitigation* (3 domains) scored on an absolute scale.	Arithmetic mean of domain scores and of each county's results. Counties advised that the arithmetic mean can also be used to generate values for collective decision.	Results compiled into state and county-level hazard risk profiles and to assess county-level preparedness by *mitigation* domain.
Idaho Public Health Jurisdictional Risk Assessment (PHJRA) *(Frazier et al., 2020)*	*Residual risk* = *Hazard Probability* x *Severity of Consequences*/*Mitigation*. *Severity* and *Mitigation* are separated into two discrete sector domains. *Severity of consequences* = *Vulnerability* x *Health Impact*.	Largely quantitative and geographic. Probability and vulnerability were estimated using spatially disaggregated quantitative data; *Health Impact* and *Mitigation* capabilities assessed qualitatively.	Analyst collects and aggregates quantitative, geographic, and modeled data. Public health and emergency management staff, healthcare system, and others score *health impacts*. A respresentative from each health districts (7) scores *mitigation* capabilities	Quantitative data converted to scores, qualitative selections are on an absolute scale.	Arithmetic mean of Health Impact and Capability scores (Mitigation) Health Impact scores are weighted by a standardized spatial vulnerability according to their Spatially-Explicit Resilience-Vulnerability model.	County or district level leadership can review residual risk scores/rank by hazard. Mitigation scores are drawn from CDC and ASPR capabilities.

DISASTER RISK EQUATION



$$R_H \equiv \frac{P_H \times S_H}{M_H}$$

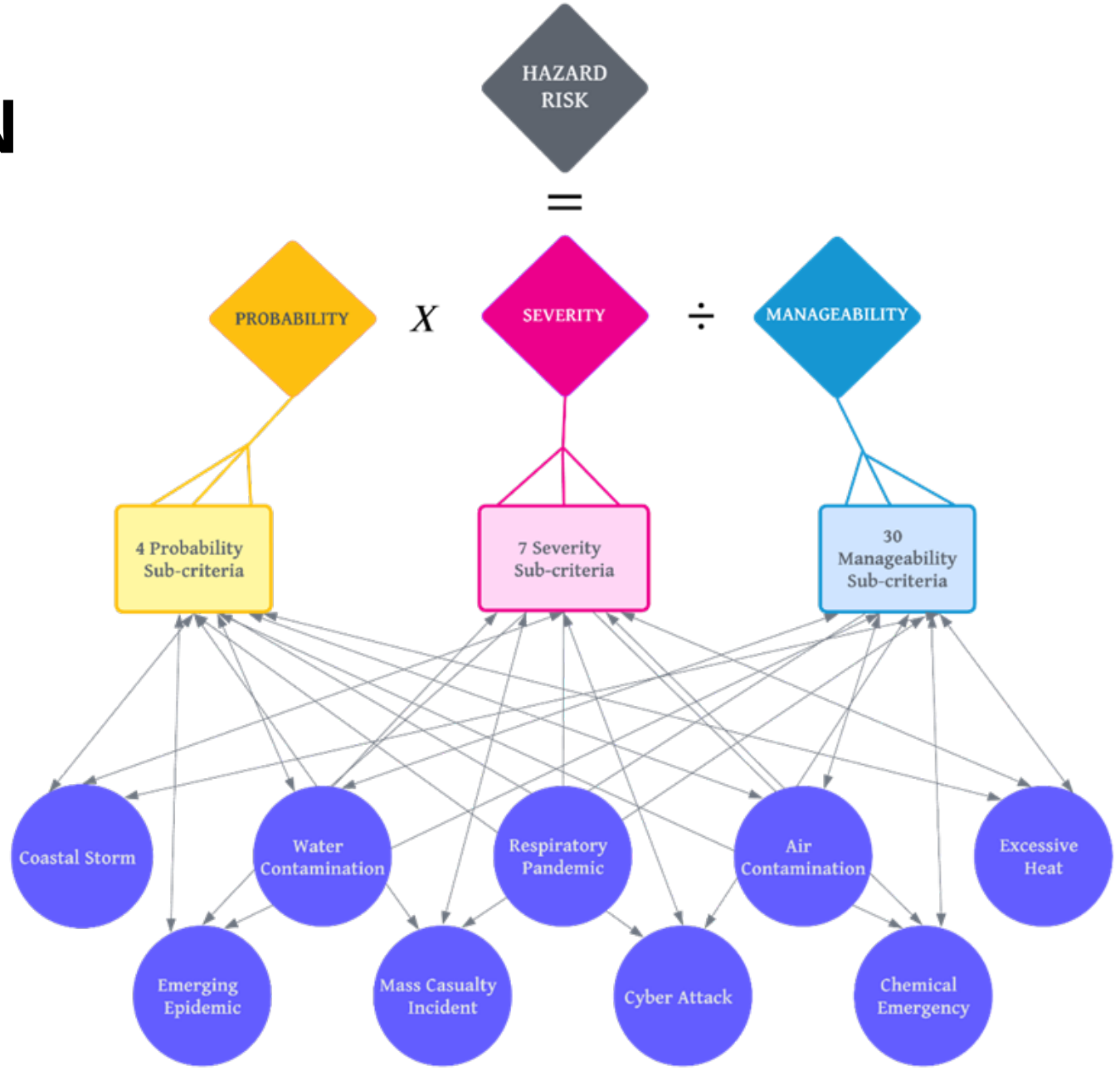


ANALYTICAL HIERARCHY PROCESS

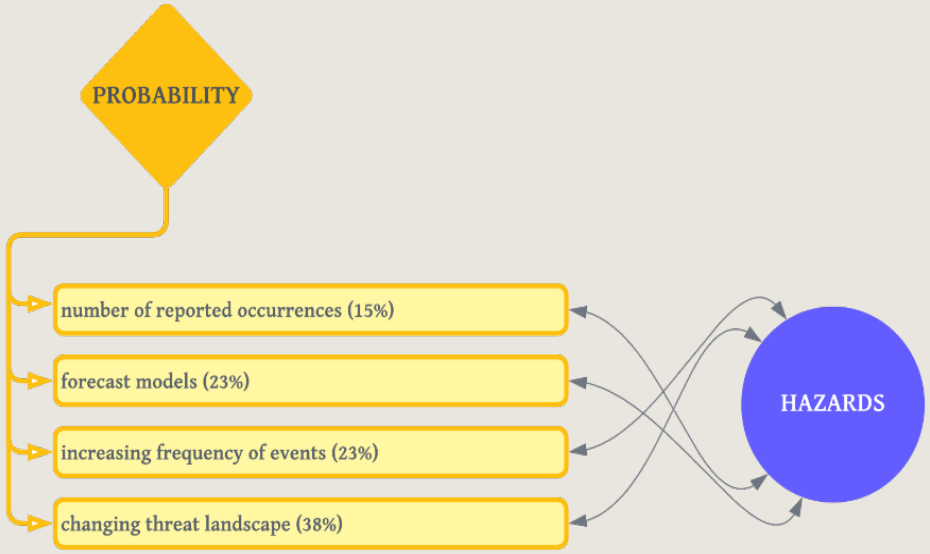
Methods & Features

DECOMPOSITION

- **Hazards = alternatives**
- **Elements = sub-criteria**
- Surveyed participants to generate a “long list” of sub-criteria and alternatives
- Engaged a steering committee and second survey to develop a “short list” of sub-criteria and hazards.



PROBABILITY SUB-CRITERIA



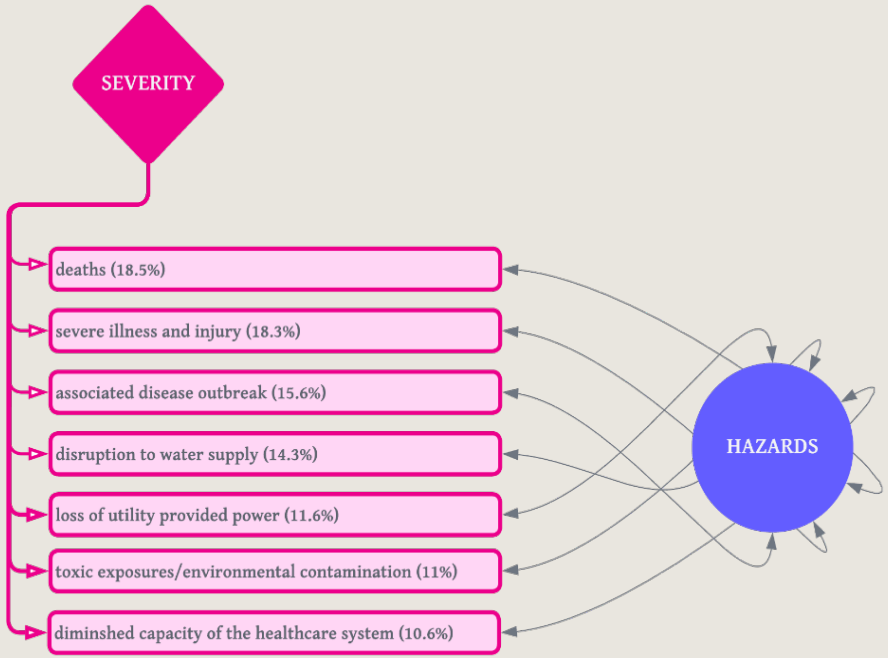
Disasters are high-impact low probability events.

- Method incorporates a **spectrum of probability methods** rather than just one.
- Each method is **weighted**.
- Most **“interpretive”** models are weighted the highest.

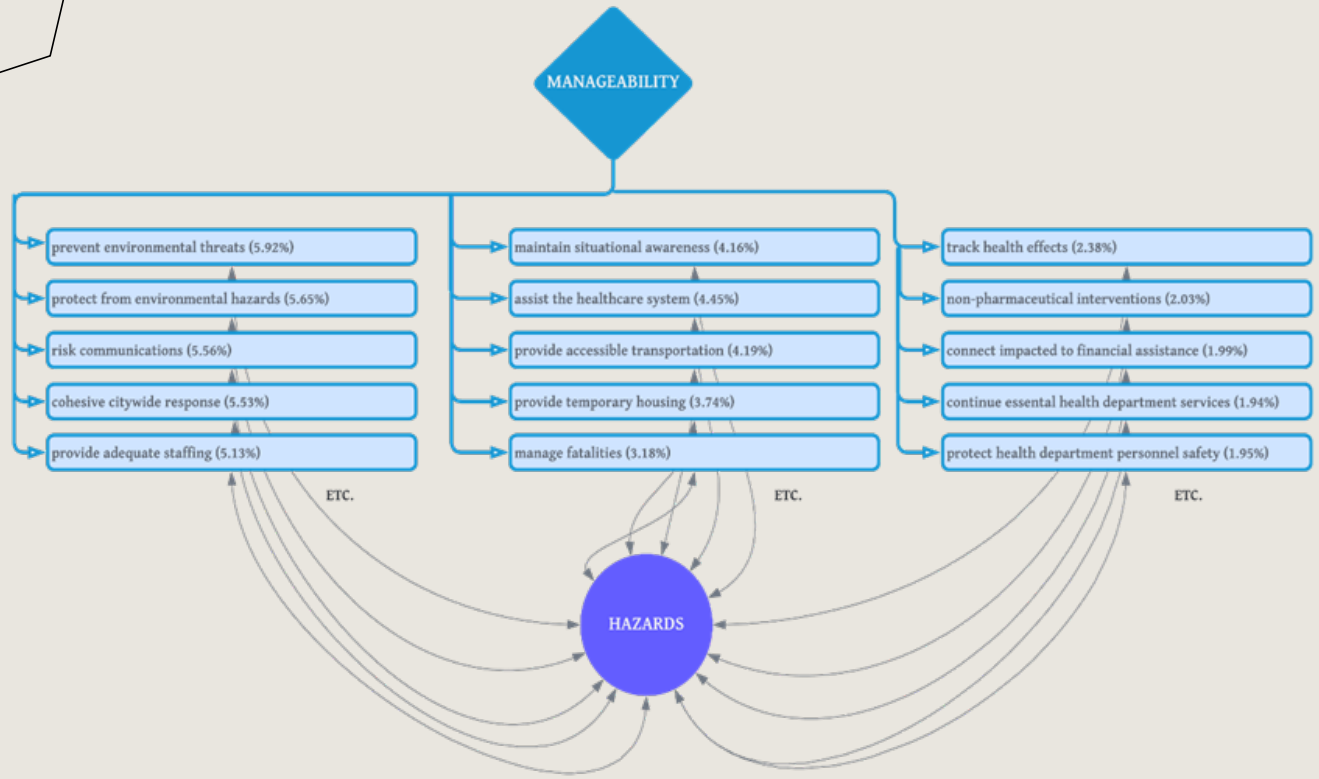
SEVERITY SUB-CRITERIA

Risk as a collective statement of values.

- Sub-criteria are rooted in the **social determinants of health.**
- Different parties may **value** impacts differently.
- Model creates **transparency** around how impact is assessed.
- Allows for community conversations based on a **common understanding** of what impacts are most severe.



MANAGEABILITY SUB-CRITERIA

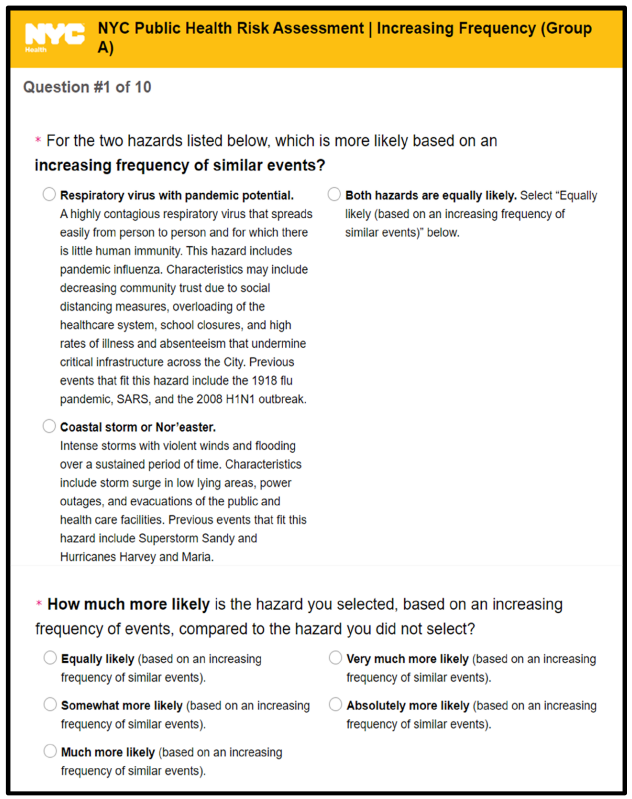


Manageability sub-criteria are mapped to existing operational frameworks.

- Added **complexity** to data collection and analysis.
- Based on a **comprehensive response inventory** of disaster response activities.
- Each activity is **“owned”** by a different group in preparedness.
- **Joint exercises, training, and evaluation** are often hazard-based and involve a subset of activities.

MEASUREMENT

- Accessible platform
- Summary view to increase consistency
- Easy export for analysis



NYC Public Health Risk Assessment | Increasing Frequency (Group A)

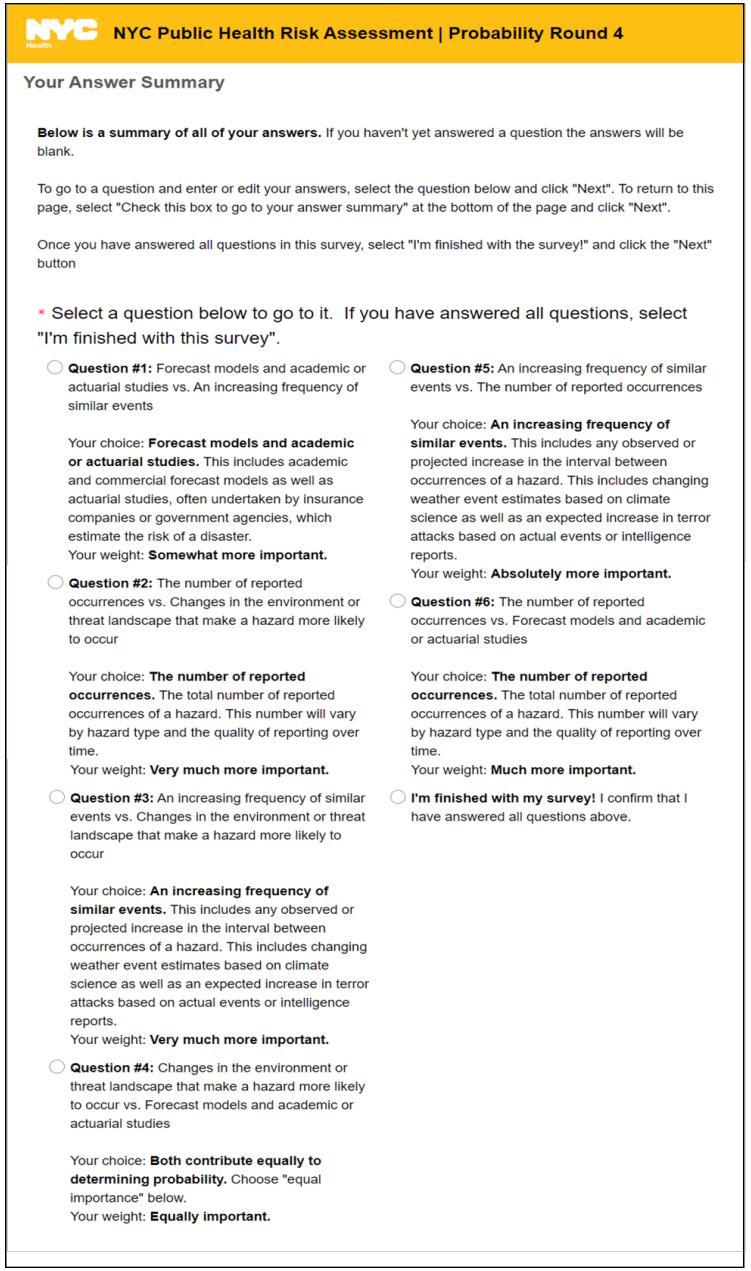
Question #1 of 10

* For the two hazards listed below, which is more likely based on an **increasing frequency of similar events?**

- **Respiratory virus with pandemic potential.** A highly contagious respiratory virus that spreads easily from person to person and for which there is little human immunity. This hazard includes pandemic influenza. Characteristics may include decreasing community trust due to social distancing measures, overloading of the healthcare system, school closures, and high rates of illness and absenteeism that undermine critical infrastructure across the City. Previous events that fit this hazard include the 1918 flu pandemic, SARS, and the 2008 H1N1 outbreak.
- **Coastal storm or Nor'easter.** Intense storms with violent winds and flooding over a sustained period of time. Characteristics include storm surge in low lying areas, power outages, and evacuations of the public and health care facilities. Previous events that fit this hazard include Superstorm Sandy and Hurricanes Harvey and Maria.
- **Both hazards are equally likely.** Select "Equally likely (based on an increasing frequency of similar events)" below.

* **How much more likely** is the hazard you selected, based on an increasing frequency of events, compared to the hazard you did not select?

- **Equally likely** (based on an increasing frequency of similar events).
- **Somewhat more likely** (based on an increasing frequency of similar events).
- **Much more likely** (based on an increasing frequency of similar events).
- **Very much more likely** (based on an increasing frequency of similar events).
- **Absolutely more likely** (based on an increasing frequency of similar events).



NYC Public Health Risk Assessment | Probability Round 4

Your Answer Summary

Below is a summary of all of your answers. If you haven't yet answered a question the answers will be blank.

To go to a question and enter or edit your answers, select the question below and click "Next". To return to this page, select "Check this box to go to your answer summary" at the bottom of the page and click "Next".

Once you have answered all questions in this survey, select "I'm finished with the survey!" and click the "Next" button

* Select a question below to go to it. If you have answered all questions, select "I'm finished with this survey".

- **Question #1:** Forecast models and academic or actuarial studies vs. An increasing frequency of similar events

  Your choice: **Forecast models and academic or actuarial studies.** This includes academic and commercial forecast models as well as actuarial studies, often undertaken by insurance companies or government agencies, which estimate the risk of a disaster.
  Your weight: **Somewhat more important.**
- **Question #2:** The number of reported occurrences vs. Changes in the environment or threat landscape that make a hazard more likely to occur

  Your choice: **The number of reported occurrences.** The total number of reported occurrences of a hazard. This number will vary by hazard type and the quality of reporting over time.
  Your weight: **Very much more important.**
- **Question #3:** An increasing frequency of similar events vs. Changes in the environment or threat landscape that make a hazard more likely to occur

  Your choice: **An increasing frequency of similar events.** This includes any observed or projected increase in the interval between occurrences of a hazard. This includes changing weather event estimates based on climate science as well as an expected increase in terror attacks based on actual events or intelligence reports.
  Your weight: **Very much more important.**
- **Question #4:** Changes in the environment or threat landscape that make a hazard more likely to occur vs. Forecast models and academic or actuarial studies

  Your choice: **Both contribute equally to determining probability.** Choose "equal importance" below.
  Your weight: **Equally important.**
- **Question #5:** An increasing frequency of similar events vs. The number of reported occurrences

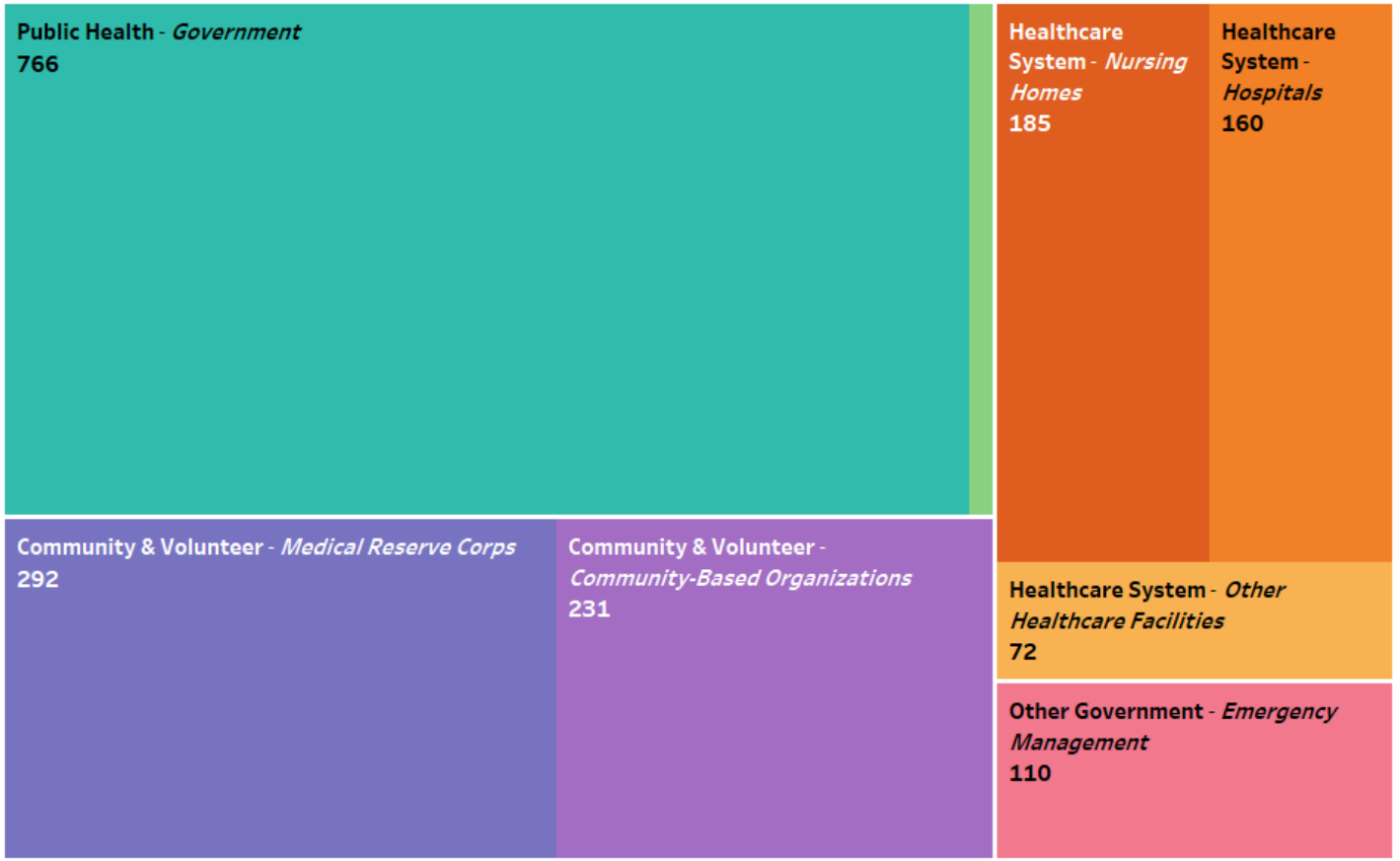
  Your choice: **An increasing frequency of similar events.** This includes any observed or projected increase in the interval between occurrences of a hazard. This includes changing weather event estimates based on climate science as well as an expected increase in terror attacks based on actual events or intelligence reports.
  Your weight: **Absolutely more important.**
- **Question #6:** The number of reported occurrences vs. Forecast models and academic or actuarial studies

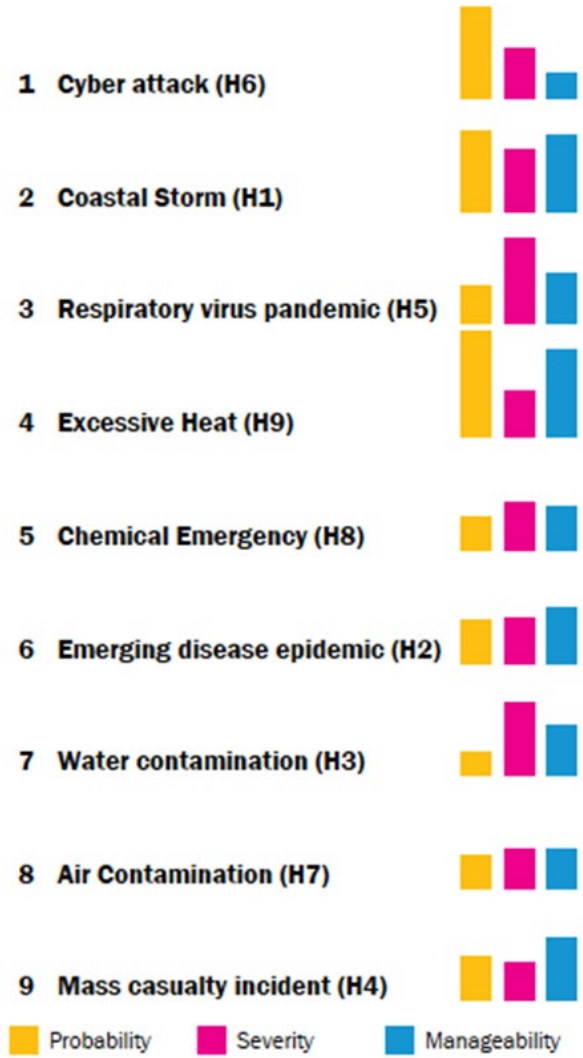
  Your choice: **The number of reported occurrences.** The total number of reported occurrences of a hazard. This number will vary by hazard type and the quality of reporting over time.
  Your weight: **Much more important.**
- **I'm finished with my survey!** I confirm that I have answered all questions above.

1,834 Total Participants

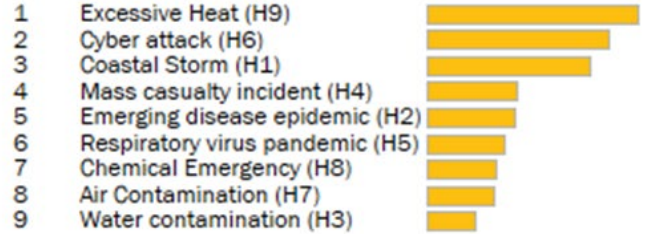
- Public Health
- Academic
- Community Based Organizations
- Volunteers
- Hospitals
- Nursing Homes
- Emergency Managers

EXPANDING THE DEFINITION OF EXPERTISE

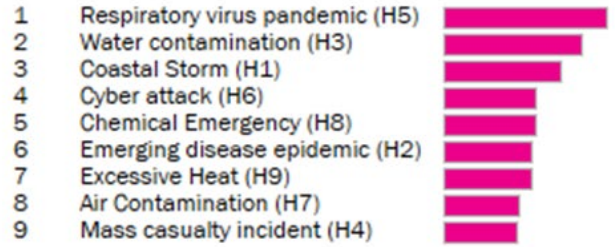




Hazards in order of relative **Probability**



Hazards in order of relative **Severity**



Hazards in order of relative **Manageability**

SYNTHESIS

	|Weight|	H1	H2	H3	H4	H5	H6	H7	H8	H9
m_1	**0.0592**	0.0071	0.0045	0.0074				0.0039	0.0051	0.0115
m_2	**0.0565**	0.0061		0.0050				0.0040	0.0042	0.0122
m_3	**0.0556**	0.0090	0.0063	0.0048	0.0057	0.0058	0.0020	0.0058	0.0038	0.0123
m_4	**0.0553**	0.0097	0.0061	0.0050	0.0081	0.0057	0.0022	0.0036	0.0047	0.0101
m_5	**0.0513**	0.0062	0.0049	0.0050	0.0106	0.0054	0.0035	0.0041	0.0044	0.0073
m_6	**0.0481**	0.0083	0.0040	0.0051	0.0076	0.0049	0.0023	0.0034	0.0036	0.0089
m_7	**0.0508**	0.0094	0.0062	0.0038	0.0085	0.0050	0.0026	0.0034	0.0042	0.0076
m_8	**0.0456**		0.0044			0.0054			0.0028	
m_9	**0.0410**	0.0028	0.0046	0.0041	0.0030	0.0048	0.0028	0.0039	0.0035	0.0114
m_{10}	**0.0375**	0.0045	0.0036	0.0036	0.0047	0.0043	0.0029	0.0032	0.0036	0.0070
m_{11}	**0.0416**	0.0055	0.0045	0.0049	0.0053	0.0046	0.0015	0.0049	0.0040	0.0064
m_{12}	**0.0445**	0.0065	0.0051	0.0047	0.0058	0.0055	0.0024	0.0039	0.0042	0.0065
m_{13}	**0.0419**	0.0043	0.0051		0.0036	0.0045	0.0039		0.0044	0.0069
m_{14}	**0.0374**	0.0052	0.0041	0.0055	0.0069		0.0033	0.0022	0.0019	
m_{15}	**0.0318**	0.0041	0.0025	0.0033	0.0052	0.0022		0.0022	0.0017	0.0071
m_{16}	**0.0265**	0.0044	0.0044		0.0045	0.0024	0.0010		0.0014	0.0026
m_{17}	**0.0238**	0.0049	0.0022	0.0022	0.0051	0.0022	0.0017	0.0014	0.0015	0.0026
m_{18}	**0.0250**	0.0036	0.0034	0.0031	0.0038	0.0034	0.0007	0.0014	0.0014	0.0042
m_{19}	**0.0259**	0.0021	0.0026	0.0051		0.0039	0.0021	0.0025	0.0019	
m_{20}	**0.0230**	0.0029	0.0029	0.0022	0.0019	0.0030	0.0010	0.0026	0.0020	0.0046
m_{21}	**0.0238**	0.0033	0.0018	0.0024	0.0033	0.0030	0.0016	0.0018	0.0027	0.0040
m_{22}	**0.0203**	0.0040	0.0025	0.0017		0.0026		0.0015	0.0013	
m_{23}	**0.0199**	0.0043	0.0011		0.0029		0.0005			
m_{24}	**0.0194**	0.0028	0.0023	0.0018	0.0026	0.0019	0.0013	0.0016	0.0017	0.0035
m_{25}	**0.0195**	0.0019	0.0016	0.0014	0.0012	0.0022	0.0034	0.0031	0.0009	0.0038
m_{26}	**0.0194**	0.0026	0.0023	0.0019	0.0014	0.0029	0.0008	0.0018	0.0013	0.0044
m_{27}	**0.0195**	0.0023	0.0018	0.0013	0.0016	0.0024	0.0016	0.0016	0.0024	0.0044
m_{28}	**0.0149**	0.0028	0.0010	0.0012	0.0032	0.0009	0.0013		0.0012	
m_{29}	**0.0140**	0.0025	0.0016	0.0018	0.0020	0.0017	0.0005	0.0010	0.0009	0.0020
m_{30}	**0.0071**	0.0013	0.0007	0.0009	0.0008	0.0006		0.0005	0.0004	0.0012
$\|M_{11}\|$	**1**	**0.1548**	**0.1128**	**0.1027**	**0.1264**	**0.1051**	**0.0540**	**0.0798**	**0.0888**	**0.1756**

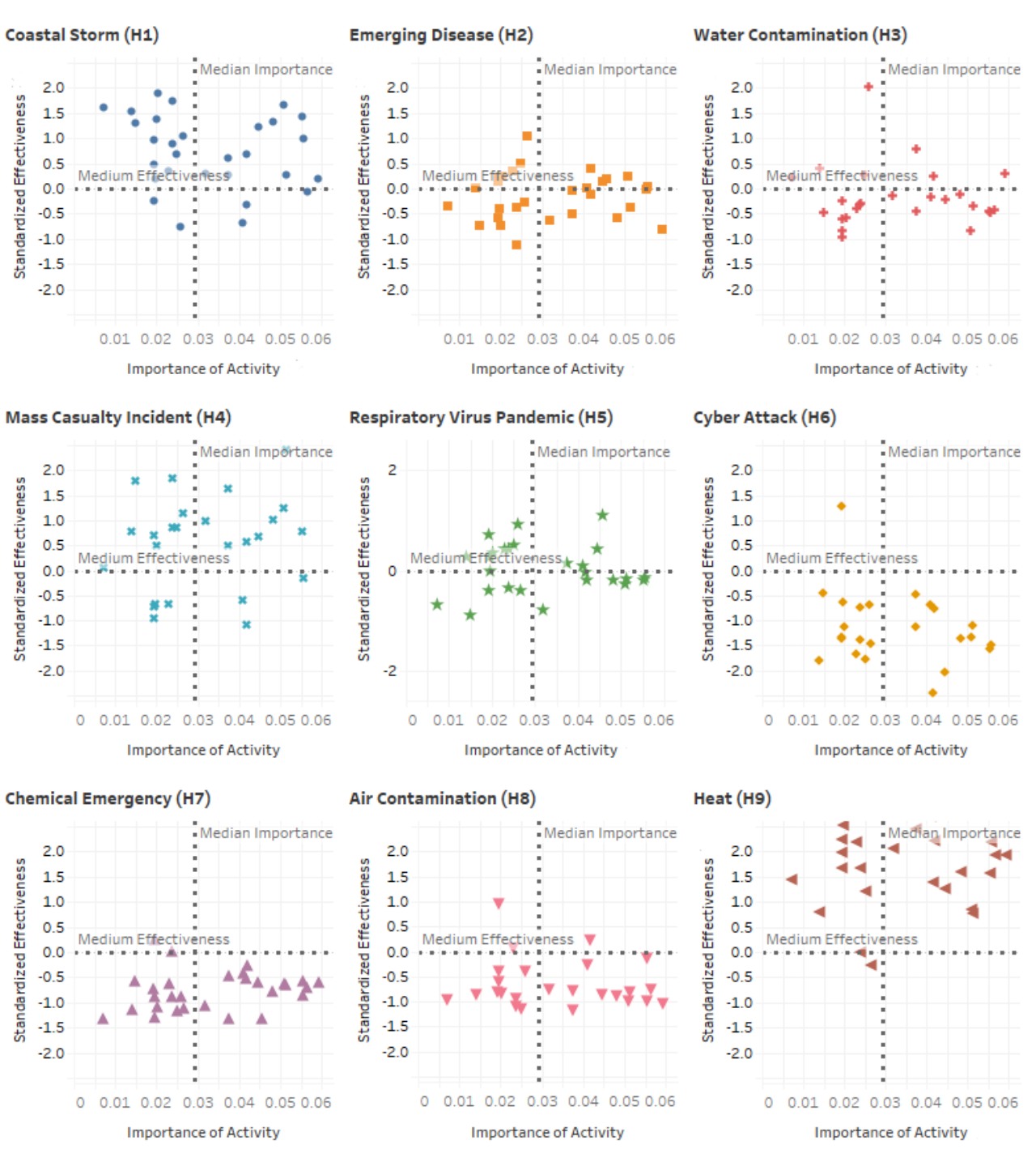
APPLICATION: PLANNING

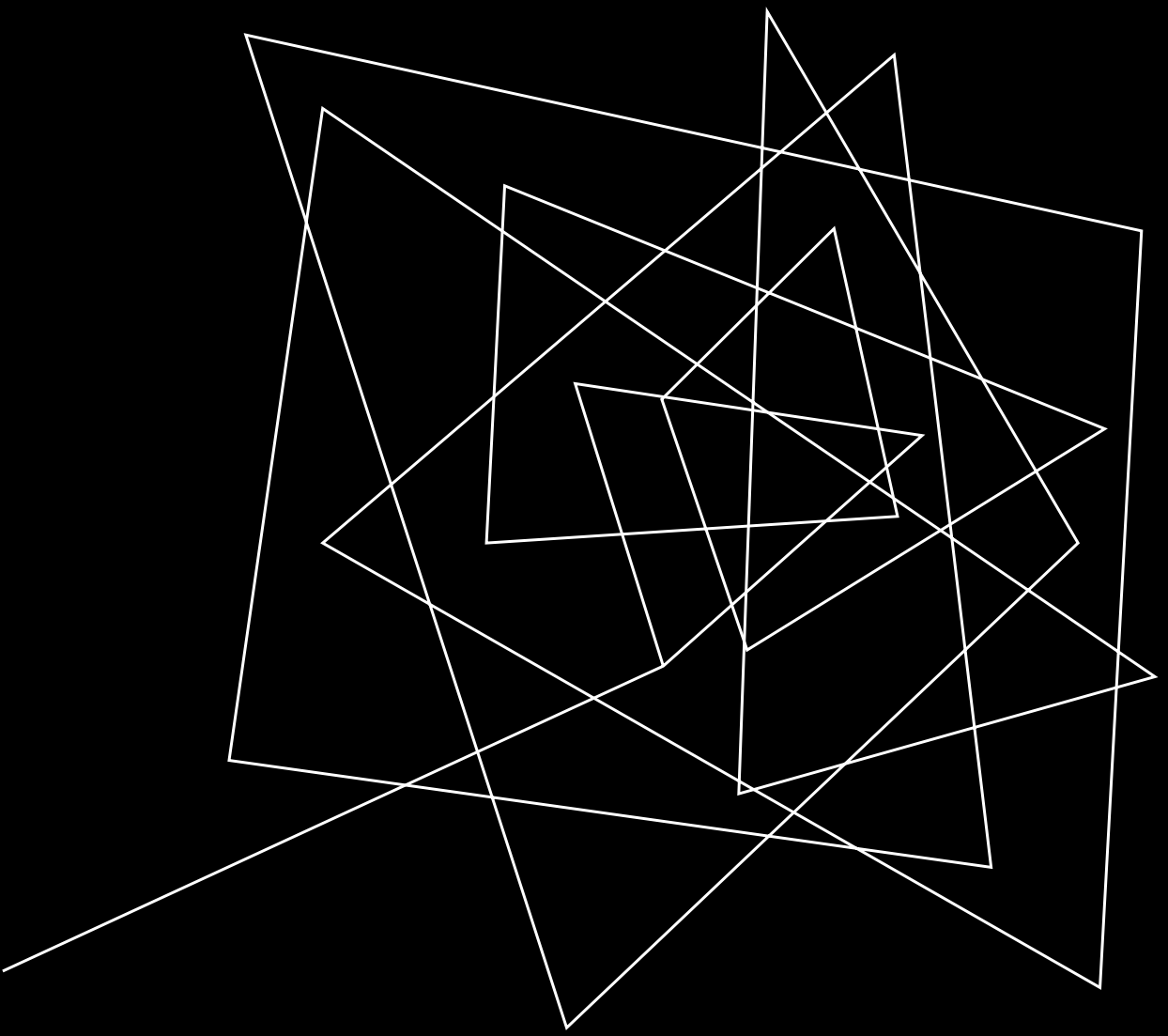
- Division owners can prioritize between activities m_i
  - Which are important to invest in?
- For a given activity,
  - In which hazard scenarios are we weakest?

APPLICATION: EXERCISES & TRAINING

For a given hazard H_n:

- Exercises & Training should focus on **high importance** activities.
- Activities we are **good** at should be refined and practiced.
- Activities we are **poor** at should be evaluated to guide new trainings.





CONCLUSION

SUMMARY

EXPANDS THE TRADITIONAL DEFINITIONS OF **“EXPERTISE”** TO INCLUDE LIVED EXPERIENCE OF DISASTER.

DIRECT PARTICIPATION IN THE RISK DECISION BY A VARIETY OF INDIVIDUALS WITH DIVERSE BACKGROUNDS, EXPERTISE, AND KNOWLEDGE OF PUBLIC HEALTH DISASTERS.

ACCOMMODATES A NEARLY **UNLIMITED NUMBER OF PARTICIPANTS**.

INTEROPERABLE WITH INTERNAL NYC DOHMH **OPERATIONAL FRAMEWORKS**, WHICH FACILITATED IMMEDIATE USE OF FINDINGS.

TRANSPARENCY AND DETAIL WITH WHICH DECISION CRITERIA ARE PRESENTED, WHICH CAN SERVE AS THE BASIS FOR **RICHER PARTNERSHIPS** WITH COMMUNITY, HEALTHCARE, AND OTHER SECTORS.

NOVEL, NUANCED METHOD TO **ESTIMATE DISASTER PROBABILITY**.

REQUIRES **MINIMAL STAFF AND SOFTWARE RESOURCES**.

NYC’S 2018 DISASTER RISK ASSESSMENT

THANK YOU

Madhury (Didi) Ray, MD, MPH, CEM

madhury.ray@alumni.harvard.edu

www.linkedin.com/in/madhury-ray