Creating Stronger Resilience in Urban Regions
-Lessons of Hurricane Katrina, New Orleans, USA -

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Creating Stronger Resilience in Urban Regions

Outline

1. Resiliency - definitions
2. Natural Hazards
3. Total Hazard Risk- Community response
4. Hurricane – Katrina an Example
   - Various Infrastructure Systems
5. Hurricane Katrina- Systems failure
6. Rebuilding Infrastructure after a Disaster
   - 10 years after Katrina
7. Community Resiliency – Capacity Building
8. Conclusions

Resiliency - some misperceptions

Resiliency ⟩ [Reliability Robustness Redundancy]

Reliability engineering is closely related to *safety engineering* and *system safety* .
Redundancy is the duplication of critical *components* or functions of a system with the intention of increasing reliability of the *system*.

Robust - when a system can continue to function in the presence of internal and external challenges without basic changes to the original system.

Resilient: When a system can adapt to internal and external challenges by changing its method of operations while continuing to function. There is a fundamental shift in core activities adapting to the new environment.

ISO 22114 : Ability of a structure to withstand events (like fire explosion, impact) or consequence of human errors, without being damaged disproportionately to the cause.

Resiliency

Definition

"A Resilient City is one that has developed capacities to help absorb future shocks and stresses to its social, economic, and technical systems and infrastructures so as to still be able to maintain essentially the same functions, structures, systems, and identity."

(100 Resilient Cities)

"Resilience is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents or naturally occurring threats or incidents."

U.S. Presidential Policy Directive 21 (2013)

General Criteria for Community Resilience

"Have demonstrated a dedicated commitment to building their own capacities to prepare for, withstand, and bounce back rapidly from shocks and stresses".

Resiliency

- Whereas, Sustainability deals with our experience and solutions based on that experience,
- Resiliency has to deal with *events not experienced yet and may be uncertain at best*.

Strengthen Resiliency = Reduce Vulnerabilities

- Restore to *Acceptable* Functionality –

People of a city contribute to its resilience as much as its walls and bridges.

Types of Resiliency →

- Individual resiliency
- System resiliency
- Community Resiliency
- Infrastructure Resiliency

Infrastructure Resiliency

Definition

"The ability of a system, -------- ---------------including through the preservation and restoration of its essential basic structures and functions". (UNISDR, 2009)

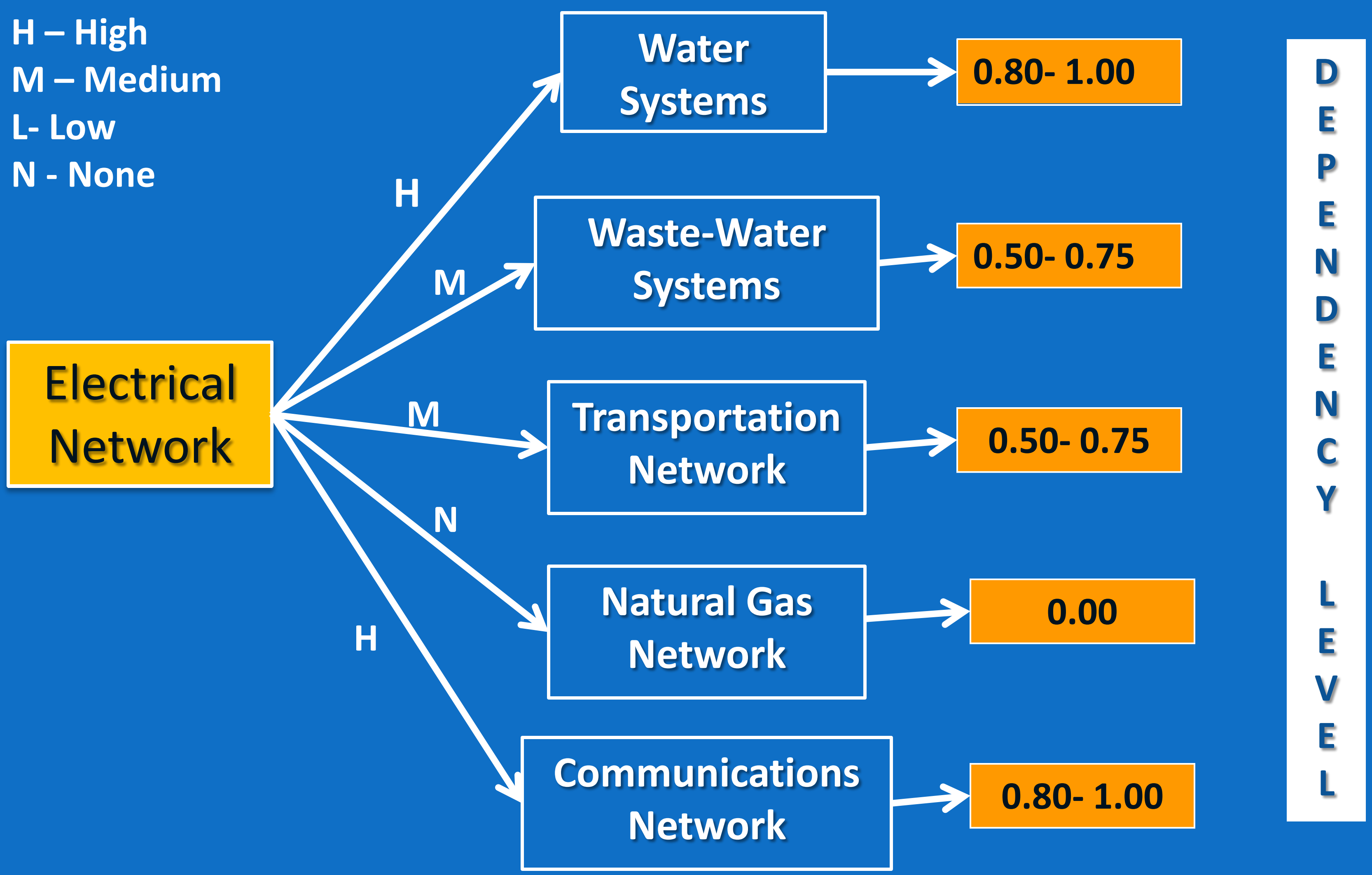
Specific Characteristics

Infrastructure often lasts a long time, thus climate change and disaster risks should be considered over the full lifespan. Infrastructure must also be planned as part of wider strategy to consider climate effects, and low carbon development.

Infrastructure systems are important when considering infrastructure resilience. The resilience is not just related to individual infrastructure elements but how these work together and affect each other. *Infrastructure Systems are interdependent*.

Electrical Network

Dependency Relationships



Natural Hazards

Natural Hazards

- **Earthquakes -** Geologic phenomena
- **Tsunamis -** Geologic phenomena - cascading
- **Landslides** – Geologic phenomena – cascading !
- **Volcanic Eruptions** – Geologic phenomena
- **Severe Wind Storms** – Weather related
- **Floods** – Weather /other causes
- **Droughts** – Weather related
- **Fires /Wildfires** – accidental/manmade/resulting from other hazard

Attributes of different Natural Hazards

1. **Earthquakes**
   - Geologic
   - Impact could be widespread
   - Low Probability, high consequences
   - No prior warning
   - Could cause *landslides, fires, tsunamis*

2. **Hurricanes (Cyclones)**
   - Weather (atmospheric)
   - High probability
   - Plenty of warning
   - Covers wide areas and could cause extensive damage
   - Could cause storm surge and flooding

Attributes of different Natural Hazards

3. **Floods** (climate change effects significant)
   - Weather (atmospheric)
   - High probability
   - Could be a result of hurricanes, typhoons, cyclones
   - Due to extensive rainfall
   - Could cause landslides
   - Coastal areas vulnerable
4. **Tsunamis**
   - Geologic, follows an earthquake usually
   - Low Probability
   - Significant warning
   - Could cause significant damage
   - Coastal areas very vulnerable

Natural Hazards – Some causes

❖ **Losses seem to be increasing due to:**

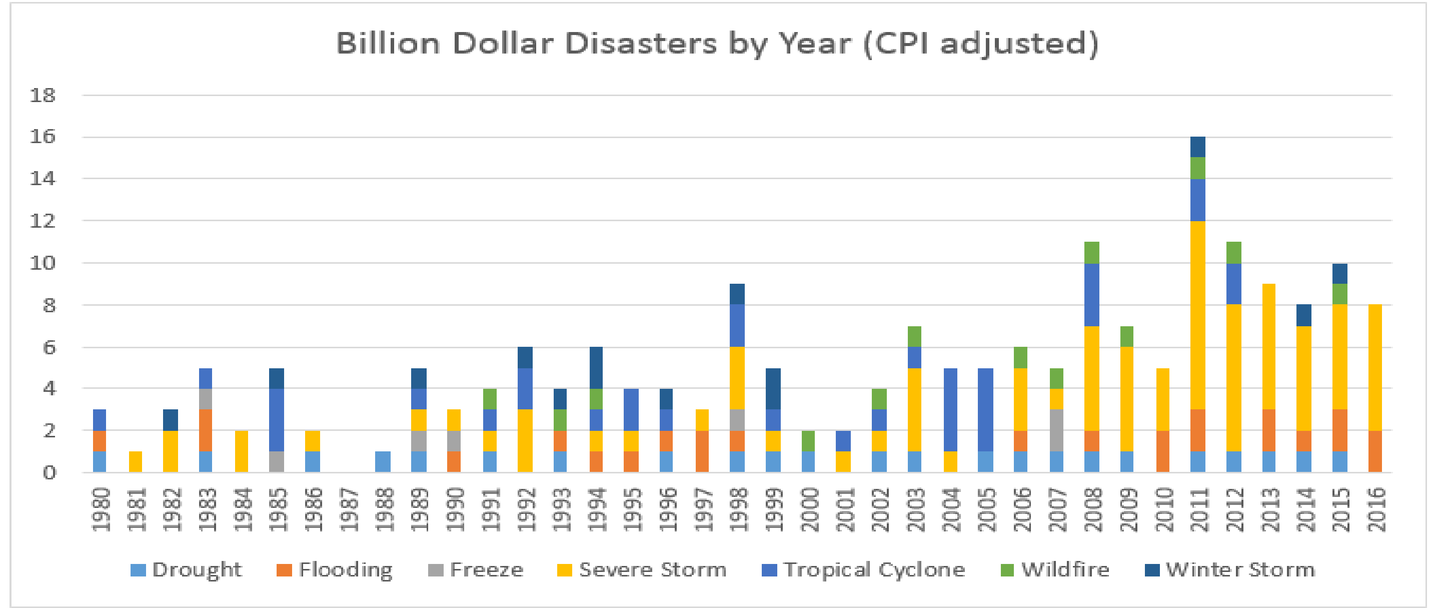
a. Increasing urbanization from (Projected to be 5 B in 2030),

b. Environmental degradation

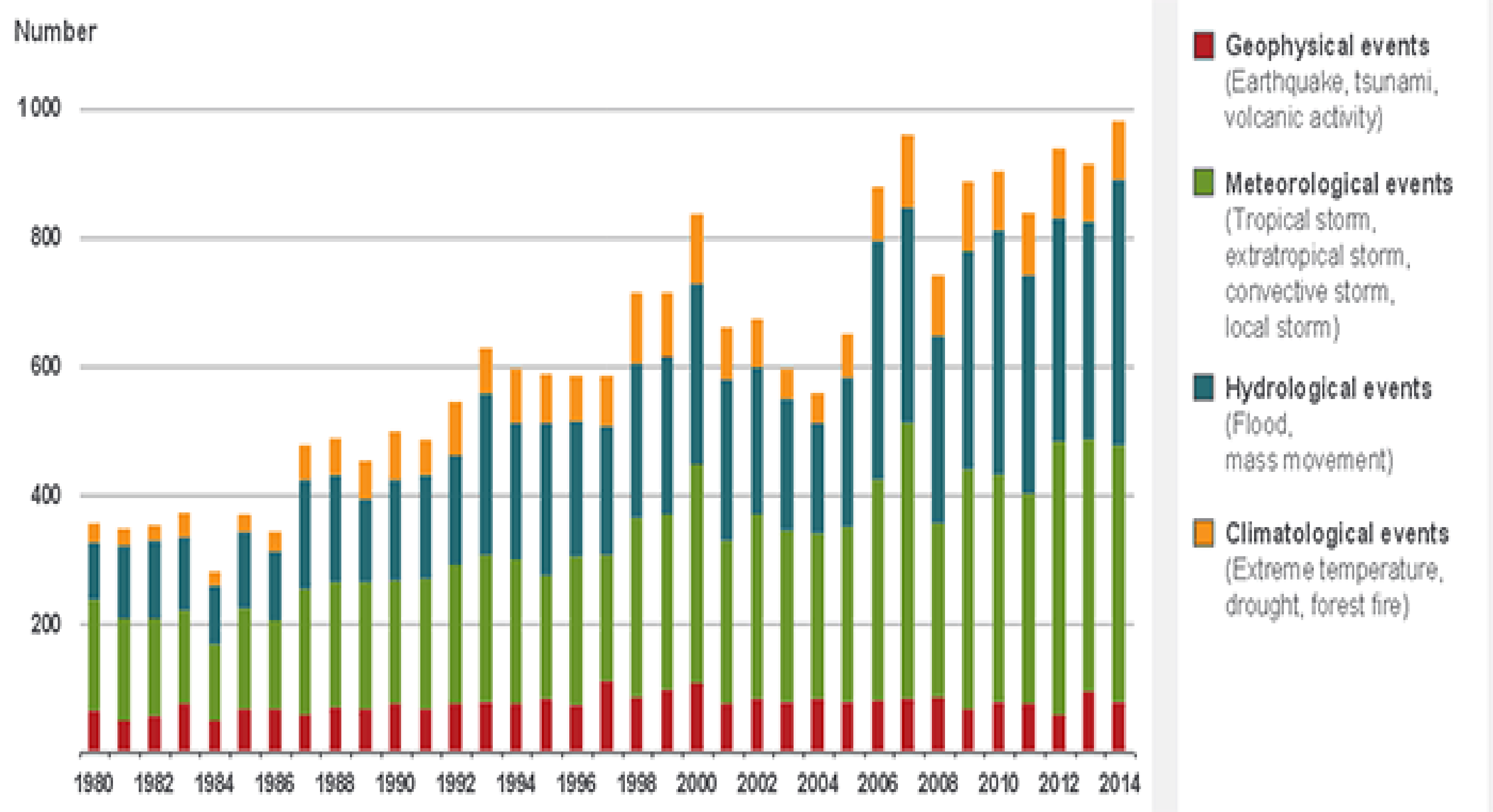
c. Increasing vulnerability

d. Climate Change

e. Lack of maintenance of infrastructure



WORLD NATURAL CATASTROPHES (1980–2014)



Source – Munich RE- 2015

Natural Hazards – Global Annual Data (2005-2014)

- **Economic Losses – $180 B/yr – 10 year average**

  (Annual loss of Consumption > $500 B – World Bank -2016)

1. Number of events - 870
2. Fatalities – 68,000 +
3. Floods – 35% – 40 %
4. Severe storms and Typhoons - 30%
5. Earthquakes, Tsunamis, and Landslides – 20%
6. Fires – 10%

World Bank estimated that during 1990-2000, natural disasters resulted in damage that is between 2% and 15% of an exposed country's annual GDP.

In 2014 - $110 B in economic damages

Natural Hazard Data

- Globally, severe storms, droughts, tornadoes, earthquakes, floods, hail storms, wildfires, have killed more than a million people, affected 4.4 B and caused more than $2 Trillion in damages (1994 – 2014).
- Earthquakes killed the most people, an average of 50,184 people a year (2000 to 2008)
- Floods, however, affected the largest number of people – an average of 99 M people a year.
- With urbanization increasing rapidly, more people, often in the poorest countries, are being exposed to disaster risk.
- Climate change threatens to push that risk out of control, as extreme and more variable weather becomes more common (UNDP-2015)

Hurricanes - *Harvey, Irma, Maria*, Two significant *EQs in Mexico - 2017*

Volcanic Eruptions – *Hawaii, Italy, Guatemala*

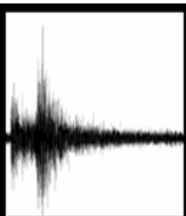
Transient Hazard- H

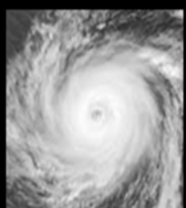
Vulnerability -V

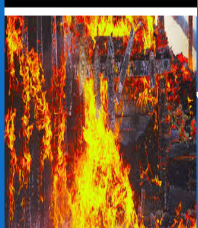
Consequences -C

Physical Damage | **Societal impact** | **Response & Recovery**

Coping







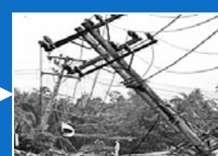
B U I L T E N V I R O N M E N T

P H Y S I C A L S Y S T E M S V U L N E R A B I L I T Y

Building Stock

Transportation Systems

Utility Systems



Communication Systems

S O C I E T A L S Y S T E M S V U L N E R A B I L I T Y

Short Term

Immediate

Direct economic losses, functionality reduced

Response

a. Provide basic needs

b. Restore Critical Infrastructure

1.Transportation

2. Power, Water, Gas, Communications

3. Hospitals

Long Term

Long Term

Fatalities, Indirect Economic losses, Social effects

Response

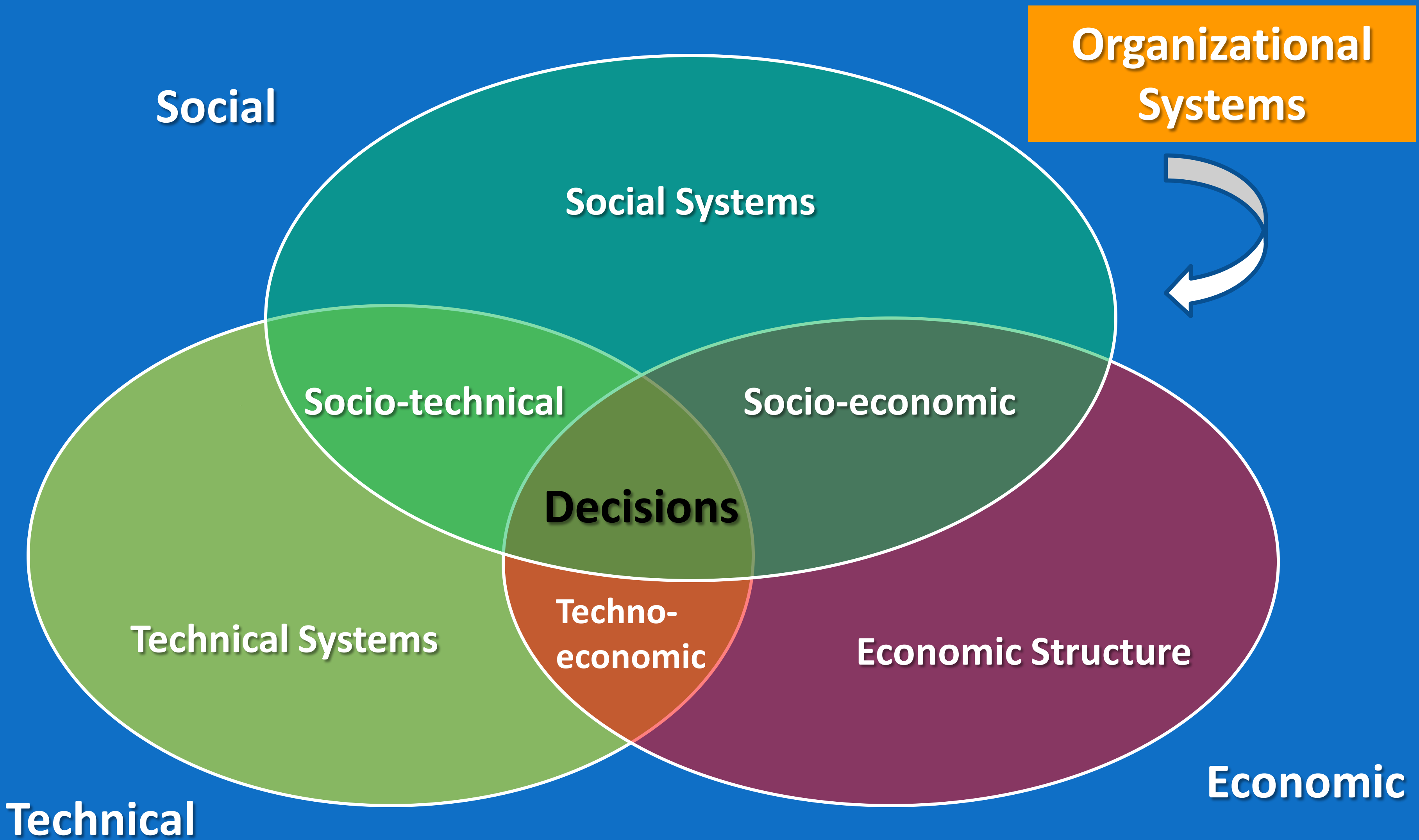
a. Assess Damage

1. Physical Systems
2. Societal Systems

b. Develop Policy

1. Reconstruction
2. Alternates, redesign
3. Economic recovery
4. Long term health issues
5. Sustainability

Community – A Coupled Complex System



Disaster Risk Management

A. Prior to major hazard event

Mitigation

a. Has upfront costs
b. Need economic incentives
c. Don't fix till it is broke

B. During major hazard event

Response

a. Societal Preparedness
b. Timeliness – efficiency
c. Resource availability
d. Resource Mobilization

C. After major hazard event

Recovery

a. Strong economy – *private industry*
b. Govt. Programs for Reconstruction

R E S I L I E C Y

Hurricane Katrina

Aug. 29, 2005 – New Orleans, LA, USA

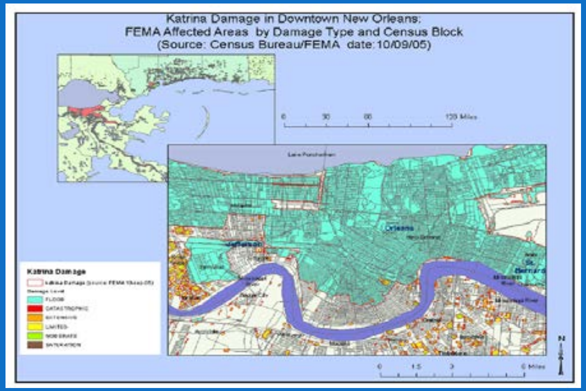
Hurricane Katrina

1. **Hurricane Category** – 3, affected Alabama, Mississippi & Louisiana
2. **Highest wind speed –** 175 MPH (1 min. sustained)
3. **Storm Surge** – 7 ft.- 16 ft. spread over 6 miles inland
4. **Areas affected** – 80 % of New Orleans flooded
5. **It is the only American city below sea level**
   - **Without 25-foot levees, spillover basins, and pumps, Mississippi River would reclaim it every spring.**
   - ***The failures of levees and floodwalls caused the worst engineering disaster in the history of the US.***
6. **The flood disaster halted oil production and refining which increased oil prices worldwide**

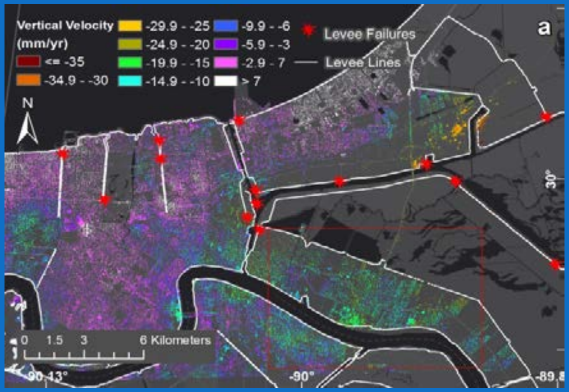
Economic damage - $100 B (2005 Dollars), Fatalities - 1465

Hurricane Katrina

Hurricane- Katrina



Affected area- New Orleans



Existing Levee System- Breaches

New Levee System

Superdome- Iconic Structure

Strong Wind Effect- an Example

FEMA called it "the single most catastrophic natural disaster in U.S. history," estimated $80 billion from the damage that ensued and $150 B in costs

Hurricane Katrina Impact

Physical Infrastructure Systems

1. Levees
2. Ports
3. General Transportation
4. Railroads
5. Bridges
6. Buildings
7. Water and Wastewater System
8. Energy Systems
9. Communications

Hurricane Katrina

Existing Levee System before Katrina

New Levee System

Levees

169 miles of the 350-mile Levee and floodwall system was destroyed

According to CORPs " The current New protection system must be considered an interim step, and we cannot be complacent that the current system is 'good enough"

Hurricane Katrina

Levees

- The rebuilt levee system was designed with a requirement to be "resilient"
- The earthen levees and floodwalls would remain in place if overtopped -- and not wash away or topple over as they did during Katrina. Overtopping will last only a few hours, as a hurricane passes across the area, limiting the amount of water entering the bowl created by the levee system.
- The rebuilt levee system, 10 years after the hurricane, remains inadequate to protect the city from another Hurricane Katrina or larger storm, according to nationally-known engineers and scientists
- "The executive order (Presidential) says that a 500-year standard is the new 'floor,'.
- By adding a few feet to the height of the existing structures, much of New Orleans can be protected from 500 -year surge due to floods.

- The Louisiana Coastal Protection and Restoration Study estimated that increasing protection to a 400-year or 1,000-year level could range from $59 billion to $139 billion for the entire Louisiana coast.

Hurricane Katrina

Ports

Port and maritime related industries support over 150,000 jobs in the region

Motor vessels Sea Wolf and Sea Falcon above ground in Empire, LA

- New Orleans is a major port, handling 20% of all US cargo: grain from America's heartland, petroleum from the Gulf of Mexico, and a wide range of commercial and consumer products,
- The storm caused extensive damage to port infrastructure, shut down the port for two weeks and disrupted supply chains,
- Maritime commerce in New Orleans did not return to full capacity for almost a year.

- Learning from this experience, the Coast Guard developed marine transportation system recovery units, or MTSRU. These are public-private partnerships that include a wide range of port stakeholders. They are dedicated to port recovery operations.

Recognition of the importance of port recovery and resilience was one of the primary lessons learned from Katrina.

Hurricane Katrina

General Transportation

Transit has a vital role to play in the restoration of strength and vitality to hurricane-ravaged communities

- Before Hurricane Katrina, the New Orleans Regional Transit Authority (NORTA) provided over 50 million transit trips per year.
- The system sustained considerable damage and destruction to vehicles, rail, and facilities in the hurricane's wake.
- To restore economies, requires transit systems to provide transportation for workers, commuters, and families— for many their only means of getting around.
- In the first days after landfall, Federal Transportation Authority (FTA) with industry partners provided transportation, mainly buses, into and out of hurricane-ravaged communities.
- Other states transit agencies came for help.
- Engage in the planning process, to ensure that transportation options are part of the future planning for cities and regions.

Hurricane Katrina

Railroad Transportation

Twisted Tracks due to flood waters

US-90 Railroad Bridge

CSX estimates $250 M worth of Hurricane Katrina damage along its Gulf Coast line

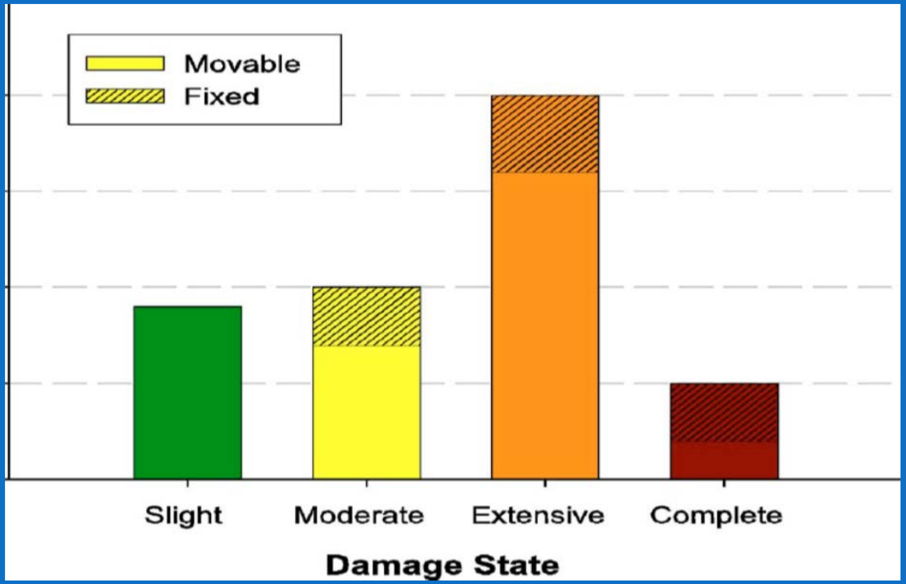
- On the Gulf Coast, Hurricane Katrina severely damaged or destroyed about 200 miles of CSX railroad track between New Orleans and Pascagoula, Mississippi,
- Six miles of track — largely intact — were forced upward into a line of nearby willow trees 80 feet away,
- In addition to many miles of washouts and twisted track, the hurricane knocked out about a dozen railroad bridges,
- Freight shipments to the East Coast were rerouted north through Memphis or other cities, putting additional strain on the nation's freight rail system,

Within one year all freight railroads were fully operational

Hurricane Katrina

Bridges

- Nearly 44 highway bridges sustained damage. 4 in Alabama, 33 in Louisiana, and 7 in Mississippi. Most of the damaged bridges were adjacent to water with damage resulting from storm surge-induced loading.
- Much of the damage was to the superstructures, due to *unseating or drifting of decks and debris impact in the form of barges, oil rigs, and boats.*
- Extent of damage depended upon the connection type between decks and bents.



Courtesy- Journal of Bridge Engineering-ASCE

Total Damage - $1 B

Hurricane Katrina

Unseating of Bearing

Collapse of Spans

Misalignment due to Barge Impact

Damage due to Scour

Courtesy- Journal of Bridge Engineering-ASCE

Type of Bridge Damage

Hurricane Katrina

Bridges

The massive storm surge that pushed into Lake Pontchartrain lifted sections of the two bridges, knocking them out of alignment or sending them to the bottom of the lake closing a vital link from Slidell to New Orleans.

Storm Surge Impact Damage

Reconstructed Bridge - 5 M long - 2011

The new, three-lane spans stand 30 feet above the lake (60 feet in high-rise sections) where the old bridge was eight feet off the lake.

"This ... is built to last for 100 years, we knew we couldn't just rebuild what we had before. It had to be better." Gov. Jindal of Louisiana

Cost- $803 M

Hurricane Katrina

Buildings – Resilient Construction

800,000 housing units were destroyed and displaced more than 1 Million people

- **Many nonprofits assoc. supported the construction of green homes, starting a green building trend in the city. This can serve as a model for other communities.**
- ***Make it Right Foundation*, has built more than 100 homes that have solar panels that reduce energy use, and countertops made from recycled materials.**
- **Green homes have energy bills of around $30 per month, including gas and electricity, compared to more than $100 per month in conventional homes.**
- **Green building materials, can also improve environmental health, especially in low-income communities where asthma is particularly prevalent.**
- ***Make it Right*, builds homes elevated 5 or 8 feet off the ground.**
- **All homes include roof access to ensure that residents aren't trapped in the attic during a flooding situation—as happened during Katrina.**

"Every dollar up front is more effective than five spent after the fact," said Mike Foley, CEO of Zurich North America.

"We need to shift the conversation from one of recovery to one of *resilience*"

Hurricane Katrina

Water and Wastewater Systems

1,200 drinking water systems and 200 wastewater treatment facilities in Louisiana, Mississippi, and Alabama were affected, endangering public health

- **American Water Works Association indicated that more than $2 billion in damages to drinking water infrastructure alone were caused by flooding, storm surge, and other impacts.**
- **In areas that were not directly flooded, power outages prevented lift stations from pumping, leading to sewage overflowing into homes and roads. *(Interdependency)***

- **Water infrastructure in New Orleans was particularly devastated**
  - **The city's largest drinking water plant was submerged under floodwaters for almost two weeks.**
  - **The city's largest sewage treatment plant was flooded for a month and did not provide secondary treatment until nearly three months after the storm.**

Hurricane Katrina

Energy Systems

- Flood waters immersed gas distribution facilities in New Orleans and took out natural gas service to customers
- The entire *Entergy Electric* grid was damaged, 263 substations and 1550 feeders were taken out.

- Overhead lines were replaced with new overhead lines.
- The utility Co. hardened the system by using newer, more rugged equipment and, replacing wooden transmission structures with concrete or steel structures.
- Power providers, assisted by contractors and utility crews from all parts of the country, (more than 200 companies from around the country) moved quickly to repair damaged infrastructure and restore power.
- Substation equipment was raised in flood zones.
- By the end of 2005, power was fully restored.
- $200 million community development block grant enabled Entergy New Orleans to restore service without raising customer rates to pay for storm damage.

Hurricane Katrina

Communications

Communication in the aftermath of Katrina was critical--and challenging

- Within the first week after landfall, FTA provided vital information through phone calls, the FTA website, and informational packets with comprehensive contact information and policy guidance.
- The Congress report found that there was "a complete breakdown in communications that paralyzed command and control and made situational awareness murky at best."
- Agencies could not communicate with each other due to equipment failures and a lack of system interoperability.
- These problems occurred despite the fact that FEMA and predecessor agencies have been giving grants to state and local governments for emergency communication systems since the beginning of the Cold War.

Katrina - Systems Failure

To minimize damage in a disaster, all systems in a community need to be robust, resilient, and responsive and work together for a speedy recovery

- A New York Times article said there was "uncertainty over who was in charge" and "incomprehensible red tape."
- Katrina made clear that the government's emergency response system is far too complex. There are 29 different federal agencies that have a role in disaster relief under the National Response Framework. These agencies are involved in 15 different cross-agency "Emergency Support Functions."
- There is also a National Incident Management System, a National Disaster Recovery Framework, and numerous other "national" structures that are supposed to coordinate action.
- Such centralization is giant mistake—you don't get efficiency, learning, innovation, and quality performance from top-down command. Indeed, increased centralization and complexity is a disease of modern American government that is causing endemic failure.

1. Engineering Systems
2. Government Systems/Agencies

Katrina - Systems Failure

1. Engineering Systems

- The Levees failed because of the combination of design flaws and faulty decisions by the individuals charged with designing and managing the system,
- Decades leading up to the Katrina disaster bore witness to a pattern of decisions that compromised the safety and reliability of the New Orleans levee system based on cost, scheduling, or political pressure,
- The hurricane protection system as a whole was significantly under designed for its purpose, representing a lapse in vigilance on the part of the engineers and other decision makers in their obligation to protect the residents,

- One example of these compromises in safety lay in the U.S. Army Corps of Engineers' calculation of soil strength for the 17th Street Canal levee and floodwall. The Corps engineers based their estimate of soil strength below the canal on boring samples spaced across a 1.5 mi distance, although the New Orleans area is characterized by high variability in soil strength.

Courtesy-ASCE

Katrina - Systems Failure

1. Engineering Systems

- **The engineers used a factor of safety of 1.3 to account for this variation, which is at the low end of acceptable value and below its own engineering guidelines,**
- **The combination of a non-conservative interpretation of sample data and a low factor of safety led to overestimate the average soil strength by some 30%,**

A second example involved the decision to design the levee system for a less severe hurricane.

- **The Corps chose to model its system on a *standard project hurricane*, with "reasonably characteristic" of the region. On the basis of wind speeds of 101 to 111 mph as representative of the area, the Corps once chose the low end of the spectrum and designed the system for a wind speed of 100 mph. When the National Weather Service later raised the maximum wind speeds to 151 to 160 mph, the Corps failed to update its hurricane assumptions or to alter its design,**
- ***Thus, the system was incapable of handling Katrina's 125 mph winds and associated storm surge.***

Courtesy-ASCE

Katrina - Systems Failure

1. Engineering Systems

A third example of safety compromises involved the heights of the levee structures.

- The Corps designed the levee system relative to mean sea level, but many structures were built with reference to land-based datums that were incorrectly believed to be equal to local mean sea level.
- New Orleans region is subsiding at a rate of roughly 0.2 in. per year, the Corps declined to make an allowance for this subsidence in its design, a decision attributed to a congressional restriction on considering water above "authorized levels."
- In the area of Industrial Canal, the combination of improper elevation data and subsidence led the structures to be 2 feet lower than called for in the design.

Courtesy-ASCE

Katrina - Systems Failure

2. Government Systems/Agencies

Coordination between federal, state, and local agencies *failed*

1. **Absence of a central authority with responsibility for the system,**
2. **A poor funding mechanism and pressures from government to lower design standards to increase affordability,**
3. **The failure of city disaster planners to mitigate the risk with more effective evacuation procedures,**
4. **Confusion**
   - **Key federal officials were not proactive, they gave faulty information to the public, and they were not adequately trained,**
   - **The report also found that there was "general confusion over mission assignments, deployments, and command structure."**
   - **FEMA's executive suites were full of political appointees with little disaster experience.**

Courtesy-ASCE

Katrina - Systems Failure

2. Government Systems/Agencies

Failure to Learn

- The government was unprepared for Katrina even though weather forecasters had accurately predicted the advance of Katrina before landfall,
- A year prior to Katrina, government agencies had performed a simulation exercise—"Hurricane Pam"—for a hurricane of similar strength hitting New Orleans, but governments "failed to learn important lessons" from the exercise.

Supply Failures

- Emergency supplies were prepositioned before the storm, but were not enough,
- In places that desperately needed help, such as the New Orleans Superdome, it took days to deliver medical supplies,
- FEMA also wasted huge amounts of supplies. It delivered millions of pounds of ice to holding centers in cities far away from the Gulf Coast. Two years after the storm, the agency ended up throwing out $100 million of unused ice,
- FEMA also paid for 25,000 mobile homes costing $900 million, but they went virtually unused because of FEMA's own regulations that such homes cannot be used on flood plains, which is where most Katrina victims lived.

Courtesy- Cato Institute

Katrina - Systems Failure

2. Government Systems/Agencies

Indecision

- Indecision plagued government in deployment of supplies, in medical personnel decisions, and in other areas,
- Even the task of body recovery was slow and confused. Bodies went uncollected for days "as state and federal officials remained indecisive on a body recovery plan,"
- FEMA waited for State of Louisiana to make decisions about bodies, but the governor of Louisiana blamed FEMA's tardiness in making a deal with a contractor,
- Too much bureaucracy hampered decision making in many areas.

Fraud and Abuse

- Free-flowing Katrina aid unleashed a torrent of fraud and abuse.
- Federal auditors estimated that more than $1 billion in aid payments to individuals were invalid. An Associated Press analysis found that "people claiming to live in as many as 162,750 homes that did not exist before ---".
- The New York Times concluded: " Katrina produced one of the most extraordinary displays of scams, schemes and stupefying bureaucratic bungles in modern history, costing taxpayers up to $2 billion."

Courtesy- Cato Institute

Katrina - Systems Failure

2. Government Systems/Agencies

Obstruction of Private Efforts

- FEMA repeatedly blocked the delivery of emergency supplies ordered by the Methodist Hospital in New Orleans from its out-of-state headquarters,
- FEMA turned away doctors volunteering their services at emergency facilities. because their names were not in a government database,
- FEMA officials provided no help in coordinating private medical air transport services, and they actively blocked some of the flights.
- FEMA "refused Amtrak's offer to evacuate victims, and wouldn't return calls from the American Bus Association." The Motor coach Association and the American Bus Association could not get anyone at FEMA to offer help for evacuations,
- The Red Cross was denied access to the Superdome to deliver emergency supplies,
- FEMA turned away trucks from Walmart loaded with water for New Orleans, and it prevented the Coast Guard from delivering diesel fuel,
- Offers of emergency supplies, vehicles, and specialized equipment from other nations were caught in federal red tape and shipments were delayed.

Courtesy- Cato Institute

Katrina - Systems Failure

2. Government Systems/Agencies

"A Failure of Initiative" Congressional report: Key Findings:

Local & State Government:

Late decisions to issue mandatory evacuations by New Orleans Mayor Ray Nagin and Louisiana Governor Kathleen Blanco led to deaths and prolonged suffering

Federal Government:

1. The Federal Emergency Management Agency (FEMA) suffered from a lack of trained and experienced personnel,
2. FEMA implemented the emergency response systems "late, ineffectively or not at all", which delayed federal troops and supplies by as much as three days,
3. White House staff were unable to effectively "substantiate, analyze and act on the information at its disposal", giving President poor and incomplete counsel

- " ---- Katrina was a national failure, an abdication of the most solemn obligation to provide for the common welfare",
- "At every level - individual, corporate, philanthropic and governmental - we failed to meet the challenge that was Katrina".

Rebuilding Steps after a Disaster

Assess the Damage

1. Damage to Built Environment
2. Social services disruption
3. Direct Economic impact
4. Indirect Economic impact

Start Recovery and Rebuilding Process

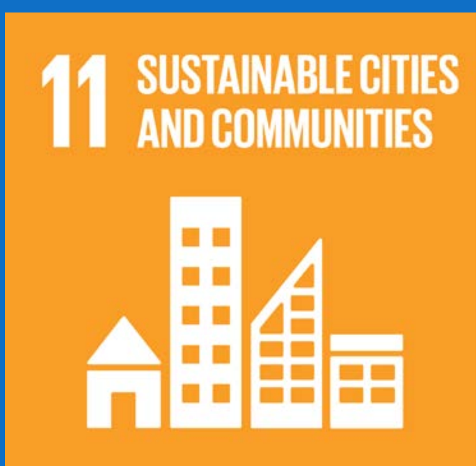
1. Rebuild Built Environment,
   - *Same as before,*
   - *Less than before,*
   - *Better than before*
2. Financial considerations

Assess Existing Capacity

1. Assess Capacity of Built environment, e. g. Water,, communications, energy, sewage, Transportation, and temporary shelter
2. Resource Mobilization
3. Rerouting transportation
4. Restoring essential services, Governmental Operations
5. Banking and Financial services

UN-Sustainable Specific Goals

Build resilient infrastructure, promote sustainable industrialization and foster innovation



Make cities inclusive, safe, **resilient** and sustainable

UN Sustainable Development Goal -11

Goal 11

Make Cities and human settlements inclusive, safe, resilient and sustainable by *Resource Utilization, considering Long-term Costs, & creating a Circular Economy*

Pre-Requisites

Future City

Shared Vision by All

Social

- Trust between all stakeholders
- Sensitivity to different Cultures
- Practice of Socio- economic realities

Economic

- Financial and non-financial resources
- Incentives for Building and adoption of Resilient and Sustainable practices promotion of Public-private partnerships in various sectors

Rebuilding Infrastructure - Criteria

1. Proactive maintenance

- U.S. infrastructure grade "D+" ASCE Report Card (2017)
- Repair cost for all roads, bridges and dams - $520 B in 2040
- To avoid disasters, need to maintain the existing infrastructure

2. Build Effective institutions, not just infrastructure

- Infrastructure design parameters are set by institutions and shaped by politics, financing and policy goals, So failures in infrastructure *are not just technical failures*; they *are institutional ones as well.*
- They are *system - failures* in ability to generate, communicate and utilize knowledge within and across institutions
- Design of more resilient infrastructure will depend on our ability to *design effective institutions* to manage complex problems, learn from failures and adapt.

Source- Scientific American-2017

Rebuilding infrastructure - Criteria

3. Design for climate change

- Infrastructure's inability to withstand extreme events due to climate change is not because of bad engineering or faulty technical designs. Infrastructures are typically designed based on the data from historical events. These historical conditions are now routinely exceeded,
- Since 1979, Houston alone has experienced three 500-year storms. Particularly, after hurricane Harvey - 2018, *basic 100-year* flood design parameters are acknowledged as *fundamentally flawed,*
- Climate change will make preparing for future storms much harder,
- These events will cause more precipitation, inland flooding, more extreme heat, cold, drought, wildfires, coastal flooding and wind,
- Infrastructure designers and managers must shift from risk-based to resilience-based thinking, so that infrastructure systems can better withstand and bounce back from these extreme events.

Source- Scientific American-2017

Rebuilding infrastructure - Criteria

4. Infrastructure is interconnected and interdependent

- Infrastructure is an integral part of ecological, technological and human systems and interacts with them in increasingly uncertain and complex ways,
- Infrastructure design cannot be considered on a piecemeal basis. Infrastructure planning and design must consider the legacy of past decisions and how risks build up over time.

5. Infrastructure systems need to be flexible

- Current infrastructure systems are centralized, robust and redundant. They satisfy demands that don't change rapidly, and thus tend to be inflexible,
- Managing institutions are also structured and constrained to create flexibility
- However, flexibility is a necessary precondition for resilience,
- In the case of hurricanes, roadways with smart signaling and controls that dynamically adjust stoplights and reverse lanes to allow vehicles to evacuate quickly would be of significant value.

Source- Scientific American-2017

Rebuilding infrastructure - Criteria

6. Design infrastructure for everyone

- Large disasters almost always highlight systemic social inequalities in communities, (*1995 Chicago heat wave, 2005 Hurricane Katrina and 2018 Hurricane Harvey*)
- During rebuilding, the issue of making low-income and minority populations, more vulnerable to extreme weather events is usually sidestepped. For this to change, infrastructure must be designed with the most vulnerable in mind first,
- Too often climate-resilient infrastructure are first built for the communities that have the economic and political power,
- Policymakers and planners must engage diverse communities and ensure that infrastructure services are designed for everyone – and communities need to demand it.

Source- Scientific American-2017

Rebuilding – 10 years after Katrina

Future Guidance & Recommendations (FEMA, IBC, ASCE)

- FEMA developed foundation guidance (FEMA 550),
- Recommended Residential Construction for the Gulf Coast – not just New Orleans
- Design Guide for Improving Critical Facility Safety from Flooding and High Winds (FEMA 543),
- Developed Residential Wind Retrofit Guide (FEMA P-804). Wind retrofit projects to be eligible for HMA funding, are required to follow FEMA P-804.
- Louisiana passed a law requiring mandatory adoption and enforcement of building codes. Louisiana now enforces the 2012 IRC. However, the high-wind design or wind-borne debris region maps were not adopted.

- The 2015 IRC and ASCE 24-14 require at least 1 foot of freeboard for all residential and commercial buildings.
  - According to CORPs study, this would raise as many as 230,000 structures, affecting as many as 460,000 residents at a cost of $28 B, and drastically reduce flood damages.

Hurricane Katrina

Assessment/Evaluation

- Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) to evaluate *building performance during the event*, and the *adequacy of building codes and construction practices* in place at the time
- The operation of many critical and essential facilities was hampered or eliminated as a result of storm induced damage

Immediate Actions

- FEMA issued Advisory Base Flood Elevation (ABFE) maps requiring rebuilt and retrofitted buildings to be raised to an elevation that would protect buildings from damage in future storms. MAT recommended that all new essential facilities be located above the 500-year flood elevation. ASCE 24-14 requires essential facilities (Category IV) to be elevated or protected to the ABFE plus 2 feet or the 500-year flood elevation, whichever is higher
- Funding for emergency services to local authorities is critical to give residents and evacuees the basic mobility they need. It is a first, vital step in the long process of rebuilding individual lives and communities. FEMA provided $1.7 billion in Hazard Mitigation Assistance.

Rebuilding – 10 years after Katrina

- Most new construction and post-Katrina elevation projects were built on open foundations, consistent with MAT recommendations for the area.
- These buildings consistently had minimal, if any, damage compared to adjacent non-elevated properties in subsequent hurricane, *Isaac (8 years after Katrina).*
- On Aug. 1, 2015, University Medical Center opened in New Orleans to replace the Katrina-damaged Charity Hospital. The state-of-the-art hospital located all critical functions 21 feet or more above the Base Flood Elevation,
- Backup power to allow it to be fully operational for a power outage of up to one week.
- The exterior is also designed to resist the effects of high wind.

Conclusions

- After 10 years, it is clear that Katrina-impacted areas are successfully rebuilding with flood- and wind-resistant design and construction in mind.
- Progress has been made in voluntary actions to elevate and repair existing buildings, and regulatory requirements for new construction.
- Hurricane Katrina shaped the national dialogue on building for flood resistance, and has led to improved resilience in the impacted area, and to greater resilience need in national model codes and best practices for flood and wind mitigation.

Rebuilding – 10years after Katrina

How do you rebuild better than before while retaining the essence and charm of New Orleans - one of the USA's most unique cities?

Some Positives

- High school graduation rates have jumped from 56% before the storm to 73% due to a proliferation of charter schools
- There are more and higher-paying jobs,
- An influx of millennials, brought a stream of educated professionals to the city flush with new ideas and energy,
- City is safer from floods due to a $14.5 billion hurricane and flood protection system,
- The Louisiana state says, 80% of the damaged infrastructure is fixed.

Rebuilding -10 years after Katrina

Some Negatives/Questionable?
Bigger Societal Issues

- 97,000 fewer African Americans living in the city,
- The city's population of 484,000 plummeted to 230,000 immediately after the storm, then increased — reaching 384,000 by 2014 including 30,000 outsiders ,
- Black households now earn 54% less than white households,
- The poverty rate dropped somewhat after the storm but has surged back to its prior level — an astonishing 27%,
- The number of vacant housing units doubled, from 26,000 in 2000 to nearly 48,000 in 2010, empty vacant lots are being auctioned off,
- The crime rate has hit the roof, especially in poor black neighborhoods, with a 26% spike in murders (2015) compared to previous year
- The storm radically altered the lives of thousands of people along the Gulf Coast. In New Orleans, a tradition bound place, those changes left a lasting impact.

Federal aid to Louisiana totaled $76 billion, but some question whether all this effort helped the *have-nots*!

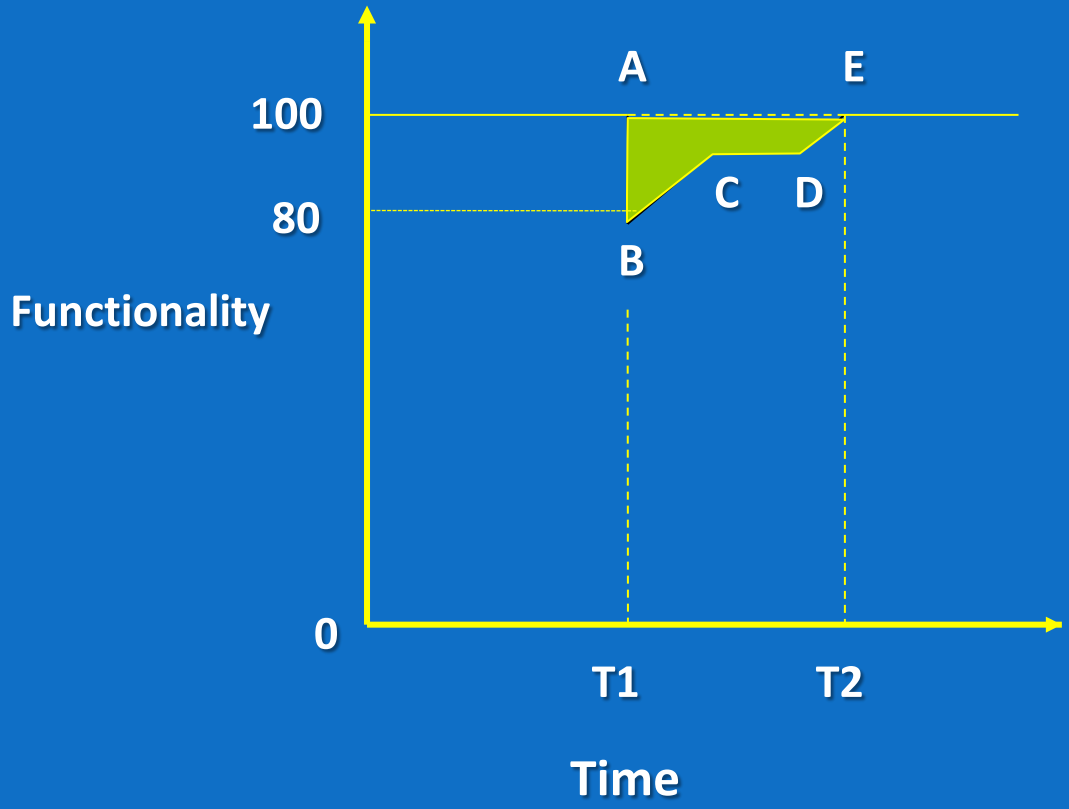
Resiliency - Barriers

Barriers to Develop Resilience

1. Widespread risk illiteracy and limited understanding of the dependencies and interdependencies that pervade our connected lives;
2. Not embedding resilience in the design of key systems, networks, and infrastructure;
3. Lack of economic incentives for investing in proven resilience measures;
4. Unprepared governance structure and policy guidance to foster resilience;
5. No interdisciplinary training and education programs to support the development and implementation for advancing resilience.

Measure of Resiliency
(Area under ABCDE)

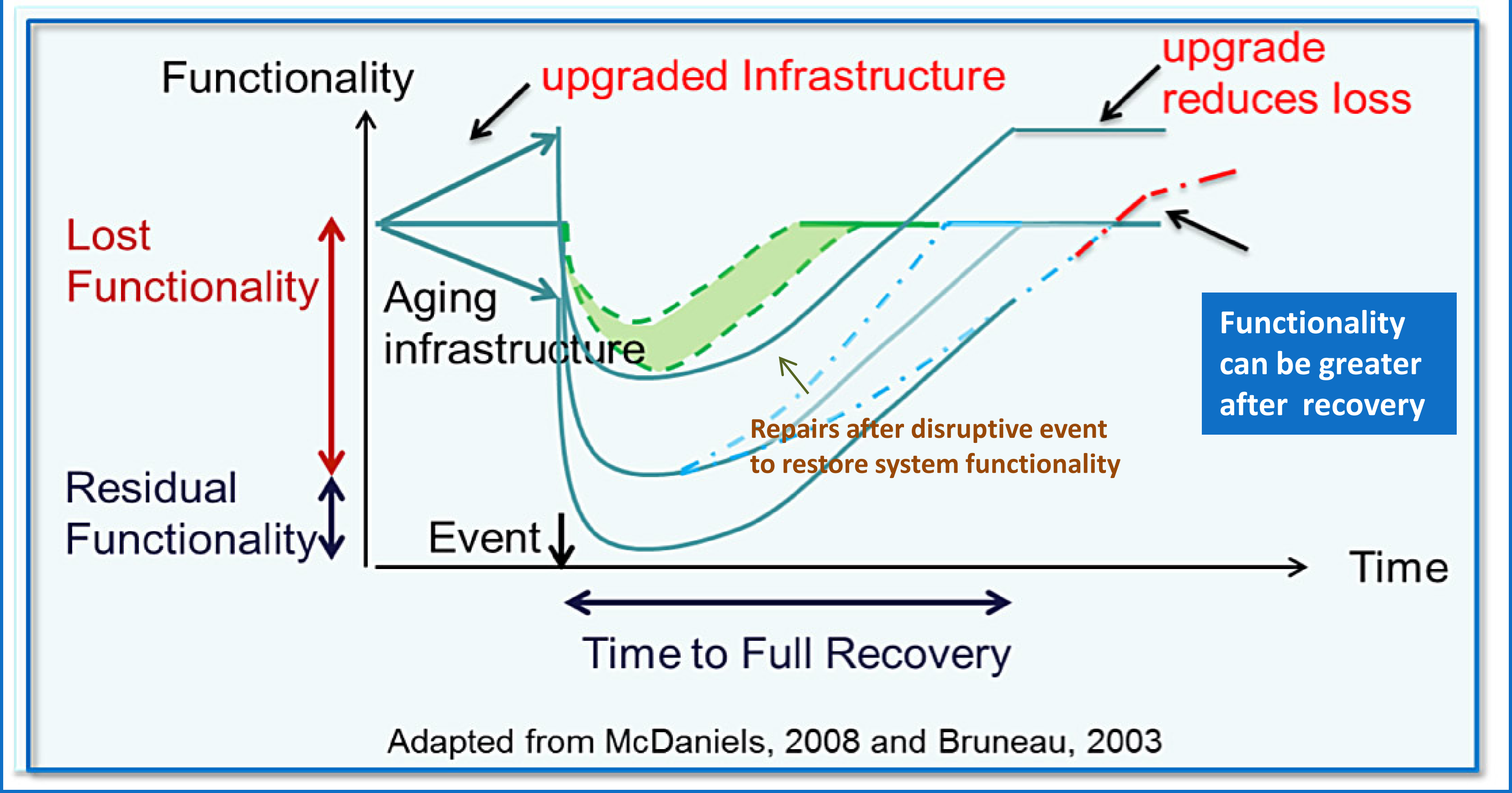
Smaller the area under curve, the greater the resiliency



B = Event Occurred
E = Full Recovery

$T_2 - T_1$ = Rate of Recovery (Rapidity)

Resilience Strategies for the Built Environment



- Maintain acceptable functionality during and after disruptive events
- Recover full functionality within a specified period of time

Community Resiliency

Generalized equation for Community Resiliency:

$$R_C = \sum R_{B,} R_{E,} R_S \mid F$$

Where,

R_C = Total Community resiliency

R_B = Resiliency of Built Environment

R_E = Economic system resiliency

R_S = Social systems resiliency

F = Functionality

Built - Environment Resiliency - R_B

System design basis:

a. Modern design codes,
b. Network redundancy,
c. Robustness of components and overall network,
d. Shock-absorbing elements,
e. Self–repairing capacity of networks,
f. Material properties, and
g. Quality of construction,
h. ---------------

Operational basis:

a. Enforcement of codes and regulations,
b. Maintenance of networks,
c. Periodic review of age and condition of networks,
d. Retrofit requirements, and
e. Incentives for retrofit,
f. --------------------

Capacity Building - Technical

- **Building capacity to minimize the Technical hazard risk**
  - Physical infrastructure capacity
    - New design approaches, e.g. performance –based design
    - Retrofit of existing facilities
    - Development of new materials – composites
    - Better understanding of material behavior, e. g. nanotechnology

Achieved through policies of various agencies of Govt., Professional Societies & academic Institutions

Economic System Resiliency - R_E

System design basis:

a. Sound economic structure of the community,
b. Availability of low-cost business insurance,
c. Government policies to promote business environment,
d. Infrastructure to conduct daily business, and
e. Availability of needed workforce,
f. ---------------------------------

Operational basis:

a. Business association to address common issues,
b. Emergency plan for workforce,
c. Business continuation plan,
d. Ability to quickly restart business, and
e. Willingness to partner with other businesses and community leadership, and government agencies,
f. ---

Capacity Building - Economic

- **Economic Capacity Building**
  - Strong industrial and financial base
  - Insurance and other financial instruments
  - Free markets and effective regulations
  - Material and manpower resources
  - Public-private coordinated efforts

Social System Resiliency - R_S

System design basis:

a. Established social institutions,
b. Community volunteer groups,
c. Appropriate government agencies for assistance,
d. Established lines of communications,
e. Community facilities for mass temporary housing,
f. Emergency plan for the community, and
g. Stock of basic supplies for 72 hours,
h. ---------------------------------

Operational basis:

a. Regular evacuation drills,
b. Workable evacuation routes,
c. Clarity in hierarchical authority structure, and
d. Community education in risk and risk management,
e. ---

Capacity Building - Social

- **Social Capacity Building**
  - Developing *social capital*
  - Social services to respond to hazards
  - Empowered NGOs
  - Community resources
  - Readiness for quick response
  - Communication networks
- **Organizational structures**
  - Clarity of responsibilities and authority

1 May 2013 – ESCAP UN – Bangkok, Thailand Meeting on Asia-Pacific Region on Disaster Management Recommendations

1. Definitely need to make disaster risk reduction part of the development paradigm and reach out to the private sector, civil society, academia and the scientific world,

2. Governments must invest in prevention and preparedness,

3. It is far more effective and less costly than recovery efforts,

4. This can be as straightforward as updating building codes and retrofitting unsafe buildings, or as far-reaching as coordinating regional monetary policies.

Source- Google

Conclusions

1. The impact of a hazard depends not only on its frequency, magnitude, and duration but also on the pre-existing vulnerability conditions of infrastructure systems ,
2. All natural hazards need to be considered,
3. Pre-existing conditions can be assessed in three broad areas: *built environment, economic structure and social institutions*
4. Infrastructure system is a sub-system in the overall community system,
5. Overall resiliency of a community comprises of resiliency *of built environment, resiliency of economic structure, and resiliency of social institutions,*
6. Rebuilding needs to consider the full life span of infrastructure, and effects of climate change,

Conclusions

7. **Infrastructure must be built for all segments of populations considering social equity,**
8. **Social Capital and Cohesion play an important role in developing greater resilience,**
9. **Economic incentives are necessary to increase resilience in systems,**
10. **Policies need to be designed to include *resilience* in all infrastructure systems,**
11. **Resilient cities require: functioning infrastructure, good governance, social and economic partnerships, policies and incentives for rebuilding quickly, and *greater resilience than before.***

THANK YOU

MUCHAS GRACIAS