World Meteorological Organization

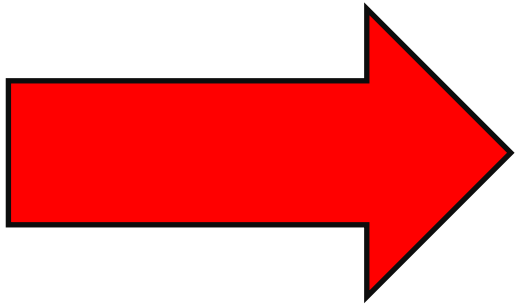
Weather • Climate • Water

Primary, Secondary and Tertiary Hazards

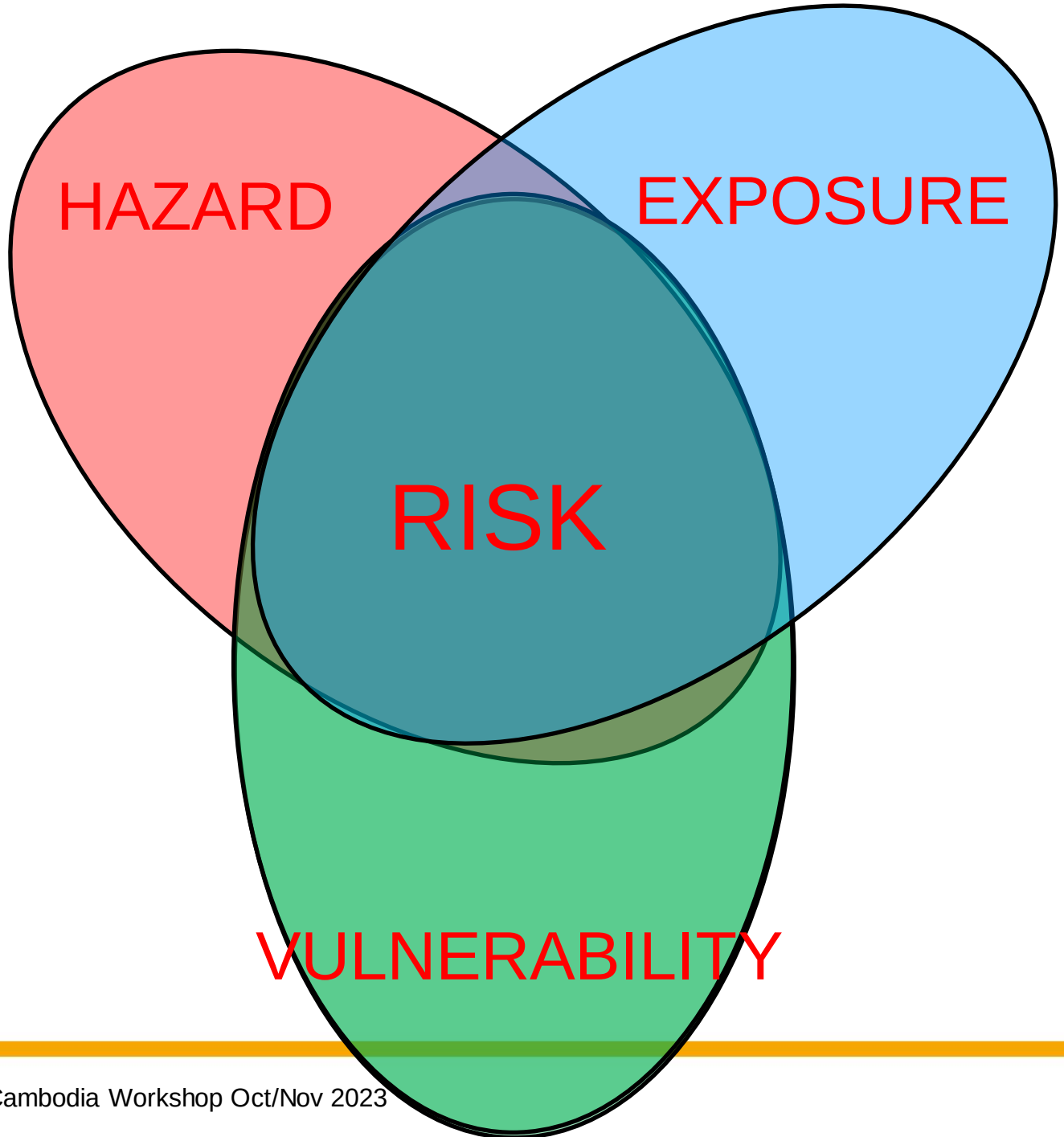
Gerald Fleming

The Case for Impact-Based Forecasting

Weather Forecasts and Warnings



Impact-Based Forecast and Warning Services


HAZARD
EXPOSURE
RISK
VULNERABILITY

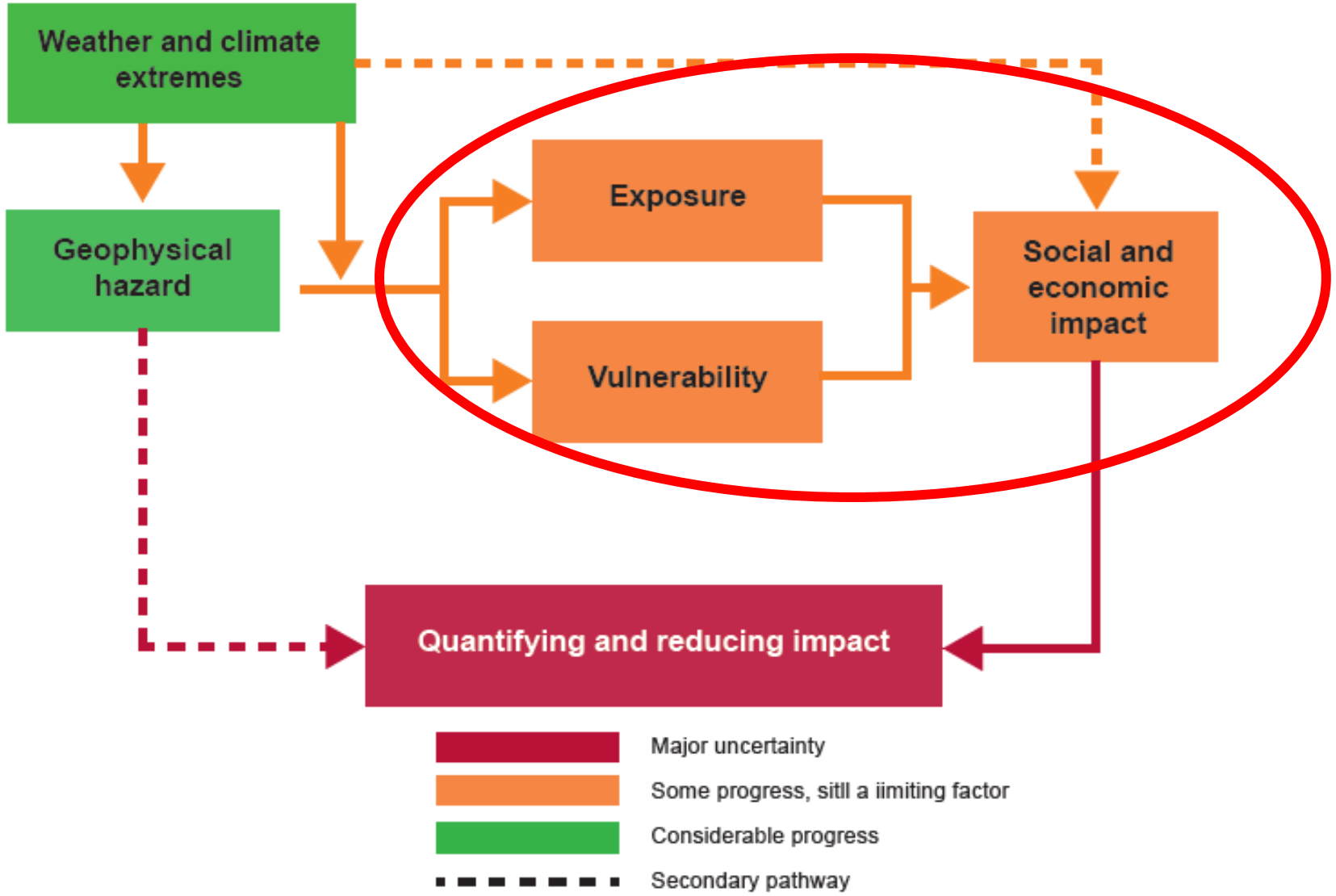


Figure 1. Relationship among the key elements of an impact forecast system

Impacts

- Impacts on society of natural hazards depend on many factors, which have nothing to do with the weather!
- Impacts on society are about how the weather hazard interacts with the environment (including the built environment), with human activity, with human behaviour, and with the facilities and infrastructure that sustain our daily lives.
- Just as some buildings might be highly vulnerable because of their location (such as a building close to the shoreline), so some people can be highly vulnerable because of their situation (such as the very young or very old, those infirm, disabled, or lacking in mobility, or weak due to illness)

Impacts

- Physical Infrastructure that may be vulnerable:
  - Transport infrastructure (roads, bridges, piers or slipways)
  - Electrical infrastructure (power stations, transformer stations, transmission network)
  - Gas infrastructure (gas pipelines)
  - Water supply infrastructure (water treatment works, pipelines)
  - Sewage infrastructure (treatment plants, pipelines)
  - Health infrastructure (hospitals, clinics, house visits by nurses)

Impacts

- What are the consequences of damage to infrastructure?
  - There may be consequences for health
    - Gastrointestinal disorders due to lack of clean water, lack of sanitary facilities, lack of refrigeration for food etc.
    - Respiratory disorders due to lack of air conditioning, increased indoor air pollution (more use of open fires..) etc.
    - Falls and broken bones (especially a challenge for the elderly)
    - Lack of ability to secure necessary medication
    - Lack of access to emergency treatment..

Impacts

- What are the consequences of damage to infrastructure?
  - There may be consequences for livelihoods
    - Damage or failure of crops, so reduced income for farmers
    - Damage to boats, so reduced income to fishers
    - Damage to commercial business such as shops – stock destroyed, interruptions to supply chains, maybe even looting.
    - Interruptions to service industries – people cannot get to work, or need to spend time repairing properties or dealing with storm damage
    - Interruptions to manufacturing industries – physical damage to factories, interruptions to supply chains, labour shortages etc.

Impacts

- What are the consequences of damage to infrastructure?
  - There may be consequences for social activity
    - Travel made more difficult due to damage to roads, bridges
    - Lack of electrical power, light…
    - Communication issues caused by lack of electricity
    - Schools closed due to damage to buildings, or unavailability of teaching staff, or transport issues..
    - Sporting / leisure facilities closed due to damage to buildings, or unavailability of staff, or transport issues..
- Consequences can range from the inconvenient to life-threatening

Impacts

- Cascades of Impacts happen when the Primary Hazard (strong winds, heavy rains, lightning etc.) interacts with some element of our physical and/or social infrastructure to cause further impacts.
- These can be difficult to predict in any rigorous manner; we need to depend on our experience of what happened during previous events to understand how these might occur.
- Wide communication and consultation will help to understand and anticipate these cascading impacts – with emergency managers, local authority staff, health sector staff, infrastructure managers / engineers, community leaders etc…

Cascading Impacts

- An example from Ireland…
  - The west of Ireland, which is predominantly rural in character, is prone to strong winds from Atlantic storms.
  - Above a certain wind threshold, the school bus service in the rural areas is suspended, for safety reasons.
  - With the school bus service suspended, schools are closed.
  - Children must stay at home, and parents must also remain at home to mind them.
  - The health sector reports problems with staff availability – many rural health workers have small children, and they must stay at home to mind them.
  - Appointments with patients are cancelled or curtailed.

Cascading Impacts

- A very serious example:
  - In 2011 an undersea earthquake happened just east of Japan
  - The earthquake set off a tsunami, which impacted the Japanese coast
  - About 20,000 people died due to drowning and other direct effects
  - Huge amount of property damage
  - Failure of electricity supply to Fukushima reactor AND damage to the back-up generators
  - Cooling systems failed, leading to explosions and the release of radioactivity
  - Contamination of soils and evacuation of surrounding population
  - International emergency at IAEA severity level 7 (its highest)

Primary Hazards

- Heavy Rain
- Drought
- High (or Low) Temperatures
- Strong Winds
- Storm Surge
- High Waves
- Fog
- Thunderstorms / Lightning
- Earthquake

These are things we cannot change (but can often forecast)

Secondary Hazards

- Flooding (Heavy Rain)
- Crop Failure (Drought)
- Human and Animal Health Issues (High Temperatures)
- Fallen Trees (Strong Winds)
- Traffic Accidents (Fog)
- Power and Internet Outages (Thunderstorms / Lightning)
- Damage to homes (Earthquake)

These are a result of vulnerabilities to the infrastructure that society has created

Tertiary Hazards

- Cholera Outbreaks (Flooding)
- Famine / Food Costs (Crop Failure)
- Death / illness (Human and Animal Health Issues)
- Blocked Roads (Fallen Trees)
- Death / injury / vehicle damage (Traffic Accidents)
- Loss of critical infrastructure e.g. hospitals (Power and Internet Outages)
- Health Issues / Refugees (Damage to Homes)

These are effects on people's lives and livelihoods

Primary, Secondary and Tertiary Hazards – Tropical Cyclone

Event	Primary hazards	Secondary hazards	Tertiary hazards
Cyclone	• Strong wind • Lightning • Heavy rainfall • Tornado	• River flood • Surface water flooding • Flash flood • Landslides • Storm surge • Water level rise in reservoirs • River bank erosion • Muddle	• Damage in Dams and appurtenant structures, embankment, irrigation and drainage facilities, pumping facilities • Submerging paddy fields • Migration • Food shortage • Loss of infrastructure systems and services (shelter, transportation, schools, hospitals, energy supply, communication) • Waterborne diseases • Environmental degradation • Snake bite • High sediment transport into reservoirs

Exercise – Identify Hazards and Impacts

Which of these are Impacts?

- Widespread damage to roofs
- 100mm of rain in one hour
- Fallen trees
- Hypothermia
- Strong wind gusts
- Restoration of the water table
- Lightning strike
- 5cm hail
- Flooded roads
- Power lines down

Exercise – Identify Hazards and Impacts

Which of these are Impacts?

- Widespread damage to roofs √
- 100mm of rain in one hour
- Fallen trees √
- Hypothermia √
- Strong wind gusts
- Restoration of the water table √
- Lightning strike
- 5cm hail
- Flooded roads √
- Power lines down √

Flooding

Is flooding a hazard, or an impact?

Maybe it depends on the context…

Coastal flooding due to a storm surge – Hazard / Primary Hazard

Road flooding following heavy rain – Impact / Secondary Hazard

Either way, flooding is a very important consequence – it causes more damage than strong winds, lightning etc.

Cultural Aspects to Impacts

- The community at risk includes people with a range of vulnerabilities exposed to hazards, including poverty, disability, gender, culture, understanding, knowledge, ability to transfer risk and trust, among many other factors.

- Very often the human dimensions of vulnerability and exposure to hazards, particularly those dimensions which marginalise people, are underemphasised compared with the vulnerability of infrastructure.

Dr. Linda Anderson Berry

Cultural Aspects to Impacts

- Who does not have easy access to warnings?
  - Maybe the elderly or infirm
  - Schoolteachers while they are in the classroom
  - Women at home
  - Fishers at sea
  - Farmers working the fields
  - People who are deaf or blind
  - Those with mental disability
  - The poor

Cultural Aspects to Impacts

- Who cannot take effective action upon receiving a warning?
  - Maybe the elderly or infirm
  - Carers for the elderly or ill
  - Children
  - Women at home
  - People who are deaf or blind
  - Those with mental disability
  - Those without transport
  - The poor

Exercise – Primary, Secondary and Tertiary Hazards

Phnom Penh has experienced 160mm of rainfall over the past 5 days. The forecast is for another 75mm to fall within 24hrs tomorrow, Tuesday.

- Write out the primary hazards that are likely tomorrow
- Write out a list of secondary hazards that will follow the primary hazards as above
- What are the tertiary hazards that might follow the secondary hazards?

Big data enabling impact-based decision-making