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UNDRR :
Agent-Based Modeling of Institutional Decision Failure

A digital twin approach to urban flood governance

Case study: the 2023 Osong underpass flooding disaster, Republic of Korea

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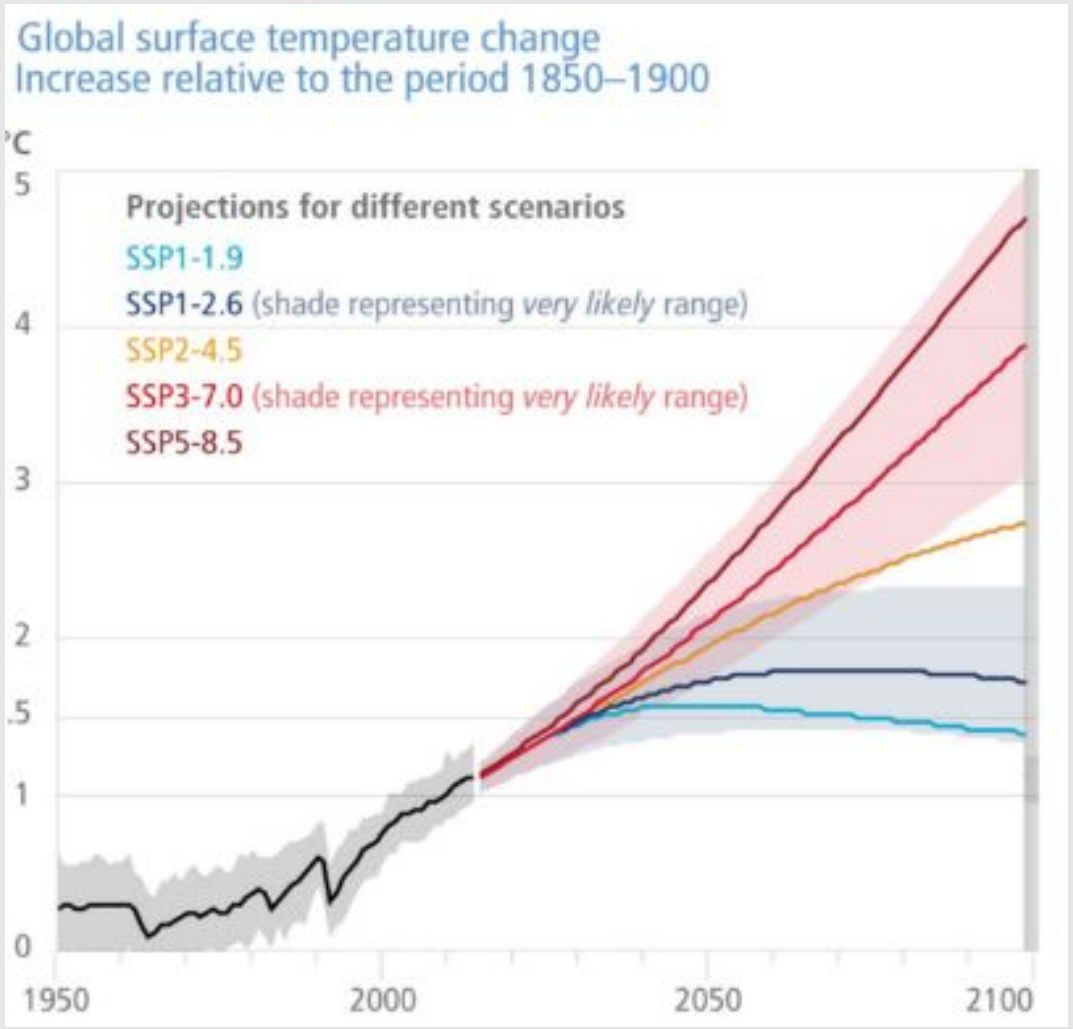
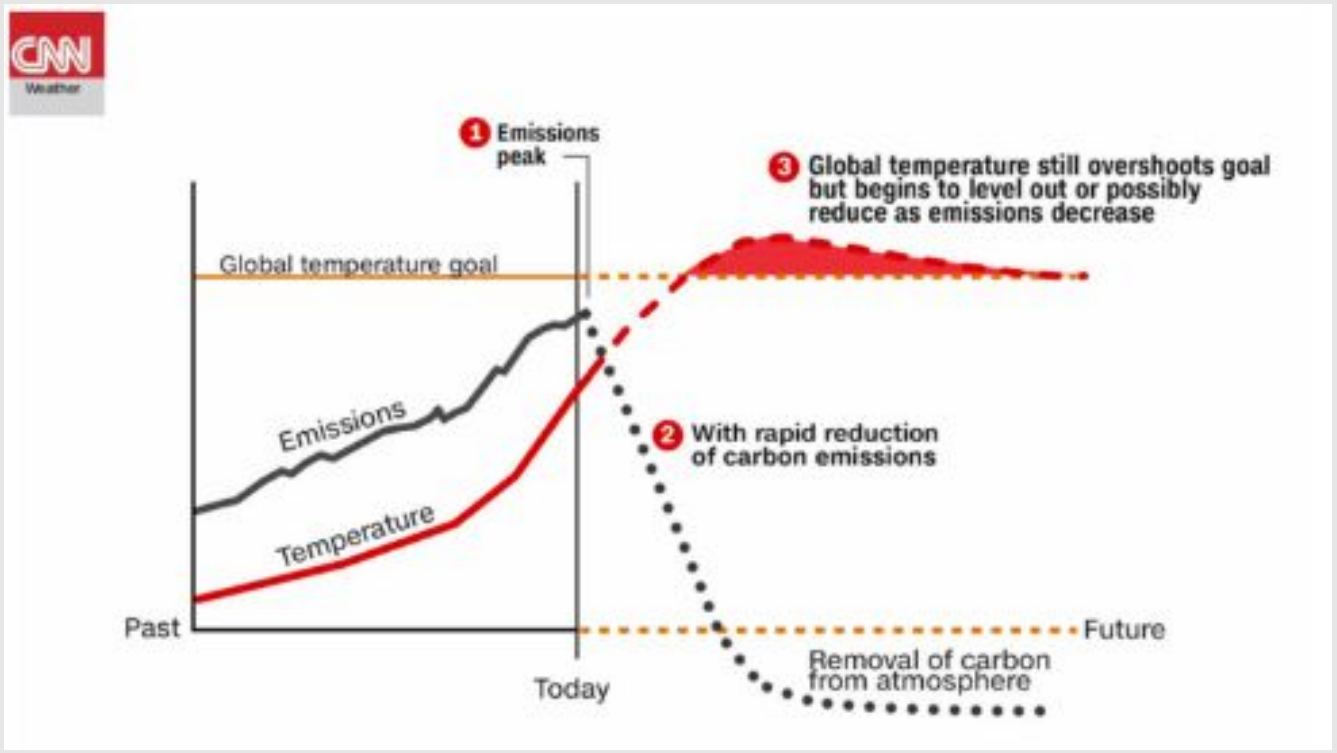
IPCC 6th Assessment Report & Risks in the near term (2021-2040)





Climate change already disrupting human & natural systems

+1.5 °C → unavoidable hazards & risks (very high confidence)

Near-term action limiting to ~1.5 °C → fewer losses & damages (but not zero)

Intergovernmental Panel on Climate Change. (2021). Summary for Policymakers. In V. Masson-Delmotte et al. (Eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

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Case Study I: Thailand

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The 2011 Great Flood — a governance failure, not just a weather event

- Severe monsoon rains & typhoons flooded **65 of 77 provinces** (Jul–Nov 2011); over 800 deaths, 2M+ homes damaged
- Economic loss **1.4 trillion Baht**; industrial complexes and global supply chains devastated

- Yet the scale of loss was not rainfall alone: **water-release and evacuation decisions were delayed and uncoordinated** across ministries, provinces and the flood command
- Authority was **fragmented and contested**; warnings existed, but who should act, and when, was never resolved in time

- The binding failure was **institutional — a failure of decision, not prediction**
- This is exactly what must be studied and modeled. **A smaller, sharper case makes it visible: Osong.**

World Bank. (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning. *Overview*. The World Bank, Bangkok.

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Case study II: Osong underpass — an AcciMap analysis

The disaster is read as an institutional failure. An AcciMap layers the causes across six levels, from government and legislature down to equipment and environment.

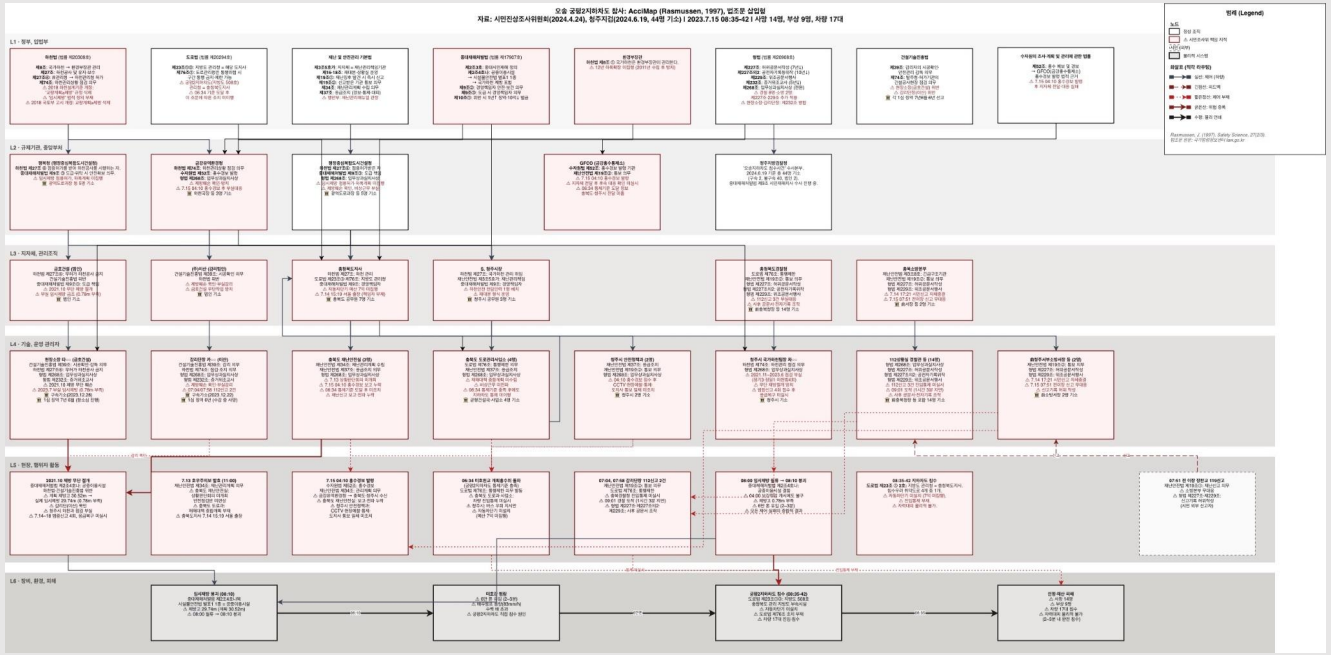
15 Jul 2023
Gungpyeong 2 Underpass, Osong, Cheongju

14 / 16
lives lost / injured

17
vehicles trapped (incl. city bus)

> 4 h
warning lead time before inundation

A temporary levee that replaced the natural levee during bridge widening was overtopped and breached; the underpass filled in 2–3 minutes. A flood warning (04:10) and an explicit “traffic control required” notice (06:34) preceded inundation (08:40) — the road was never closed.



[AcciMap output — insert figure here]

Osong underpass disaster, causal factors by institutional level

AcciMap levels (6)

1	**Government & legislature**	National law, budget, statutory duties
2	**Regulators & central ministries**	River-basin authority, flood control office, construction agency
3	**Local government & managing organizations**	Province, city and district offices, contractor
4	**Technical & operational managers**	Site supervision, on-call and duty officers
5	**Field actors & activities**	112 call, warning relay, road left open
6	**Equipment, environment & losses**	Temporary levee, 500 mm rain, breach, inundation

AcciMap method: Rasmussen (1997); Branford, Naikar & Hopkins (2009); Korean precedent: Lee, Moh, Tabibzadeh & Meshkati (2017). Case evidence: Office for Government Policy Coordination (2023); Cheongju District Prosecutors' Office indictments (2024–2025). Figure reconstructed by the author from legal and audit records.

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From AcciMap to ABM (Agent-Based Model)

The AcciMap is static — it shows what failed. Each of its actors becomes an agent whose decision rule can be simulated.

Each AcciMap actor → one agent

Flood control office	issues warning; source of information signal
District / city offices	relay nodes — where the signal was passed sideways
Province (road mgmt.)	holds closure authority — never activated
Contractor / field	levee works; 112 call; local action

What the ABM adds to the AcciMap

- AcciMap links are fixed lines. In the ABM they become live channels with delay and a pass-on probability.
- Each actor node carries four behavioural parameters, estimated from the same records that built the map:

perceived authority · blame aversion · information confidence · responsibility threshold

- The map's three failure mechanisms — fragmented authority, diffusion of responsibility, blame aversion — become tunable rules, not just labels.

Legal & audit records
indictments, inspection report, statutes

→

AcciMap
causes by institutional level

→

Agent + rule set
actors, parameters, links

→

Counterfactual runs
which change closes the road in time

The AcciMap defines the agents; the ABM lets them act differently.

AcciMap: Rasmussen (1997); Branford, Naikar & Hopkins (2009). Behavioural parameters: Darley & Latané (1968); Hood (2011); Gim & Miller (2022). Model documentation: Grimm et al. (2020), ODD protocol.

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ABM (Agent-Based Model) of the decision chain

Each organization is modeled as an agent; its decision rule is estimated from the case record, not assumed.

Agents = the organizations in the record

Flood control office · river basin authority · construction agency · contractor · province (road) · city and district offices · police · fire service

Four behavioural parameters per agent

Parameter	Question it encodes	Evidence source
Perceived authority	Is this mine to decide?	Jurisdiction disputes in indictments
Blame aversion	What does acting cost me if I am wrong?	Agency arguments in court records
Information confidence	Do I trust the warning I received?	Inspection report, call records
Responsibility threshold	Where does my legal duty end?	River Act, Road Act, Disaster and Safety Act

Model documented with the ODD protocol (Grimm et al., 2020); implemented in NetLogo or Python/Mesa; behavioural parameters calibrated by pattern-oriented modeling until the simulated run reproduces the observed inaction.

Counterfactual simulation

Only after the calibrated model reproduces what actually happened is one condition changed at a time:

- **a** Information reaches the road authority 30 minutes earlier
  → *tests warning-relay design*
- **b** Authority boundaries are unambiguous: one agency owns closure
  → *tests the 2024–26 reform direction*
- **c** Blame aversion removed from the decision rule
  → *isolates its causal weight*

Output: the share of runs in which the underpass is closed before inundation, per scenario.

The goal is a digital twin of city governance: testing which institutional change prevents the next underpass flooding.

Theoretical basis: Darley & Latané (1968); Hood (2011); Gim & Miller (2022). Model documentation standard: Grimm et al. (2020), ODD protocol. Parameter evidence: indictments, Office for Government Policy Coordination inspection report, and the River Act, Road Act and Framework Act on Disaster and Safety Management.

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From MCR2030 to institutional resilience: localizing decisions, not just cities

MCR2030 builds resilience by localizing it to cities through city-to-city learning; this model extends that logic to the institutional decisions that govern them.

01

From attribution to design

Identifies which decision rule produced inaction rather than which official was at fault — evidence for institutional redesign, not for assigning liability.

02

Testable policy levers

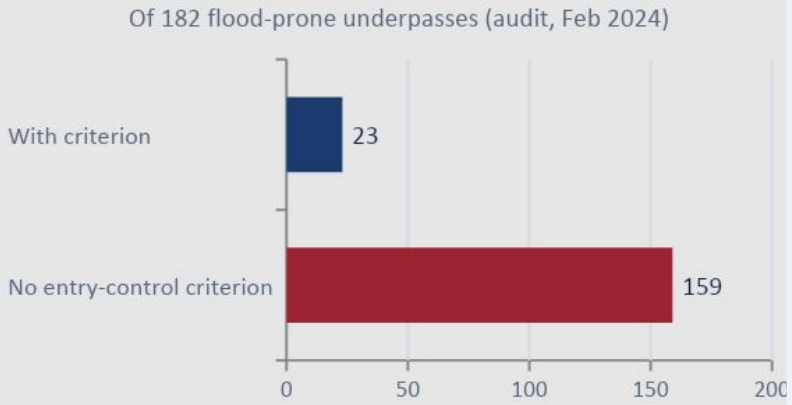
Candidate measures can be compared against the same case before the next event, instead of being evaluated only after an inquiry.

03

Transferable framework

Parameters can be re-estimated from any documented case, adding an institutional decision layer to digital twins that today represent only physical infrastructure.

Why decision rules are the binding constraint



- 1,086 road underpasses are managed nationally; 182 were assessed as flood-prone, and as of February 2024, 159 of them (87.4%) had no criterion for closing the road to traffic (Board of Audit and Inspection, 2024).
- Post-Osong reform has changed exactly two things: the closure threshold (maximum inundation depth tightened from 15 cm to 5 cm) and role assignment (four designated responders per underpass) (Ministry of the Interior and Safety, 2025–2026).
- Both are decision-rule parameters. The model estimates their effect before the next event rather than after it.

Sendai Framework Priority 2 — *strengthening disaster risk governance to manage disaster risk.*

From city resilience to institutional resilience — *MCR2030 makes resilience work by localizing it to cities; this model carries that same localization into any institution and any hazard, beyond city resilience alone.*

Sources: Board of Audit and Inspection of Korea (2024), audit on preparedness for inundation of underground space due to river overflow; Ministry of the Interior and Safety press releases (2025, 2026); UNDRR (2015), Sendai Framework for Disaster Risk Reduction 2015–2030.

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