Rethinking Required: Complex Systems Are a Fundamental Barrier to Human Progress

Systemic Modeling and Application Seminar | CLEA | Vrije Universiteit Brussel (VUB)

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2025-05-06

The Big Question: Is The World Actually Unstable?

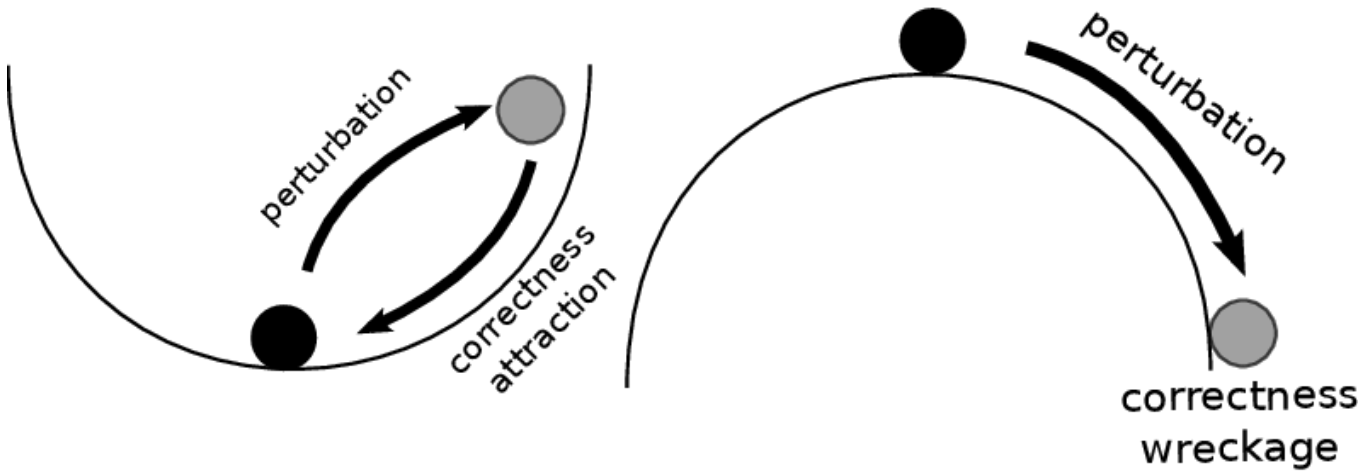


Figure 1: Systems in stable and unstable equilibrium[1]

[1] Benjamin Danglot et al., "Correctness Attraction: A Study of Stability of Software Behavior Under Runtime Perturbation," Empirical Software Engineering 23 (2018): 2086–2119.

Main Thesis

The main challenge facing human civilization's progress through the 21st century is the exponentially growing complexity of the systems we interact with, design and manage.

Clarifying questions:

- How can we define progress for human civilization?
- What are these complex systems?
- Are they really the root impediment to progress?

Even if we get answers, we are still left with a final question:

What should we actually **do**?

About

Career:

- Worked at the MPI for Marine Microbiology, focus on analyzing deep sea metagenomic data
- Data scientist → CTO → Principal
- Author of Python and R for the Modern Data Scientist (O'Reilly) and Elements of Data Strategy
- Writer for Handelsblatt, CDO Magazine and others

Projects and research:

- studyofprogress.org
- datamanifesto.org
- Explainability of black box machine learning systems (Figure 2)

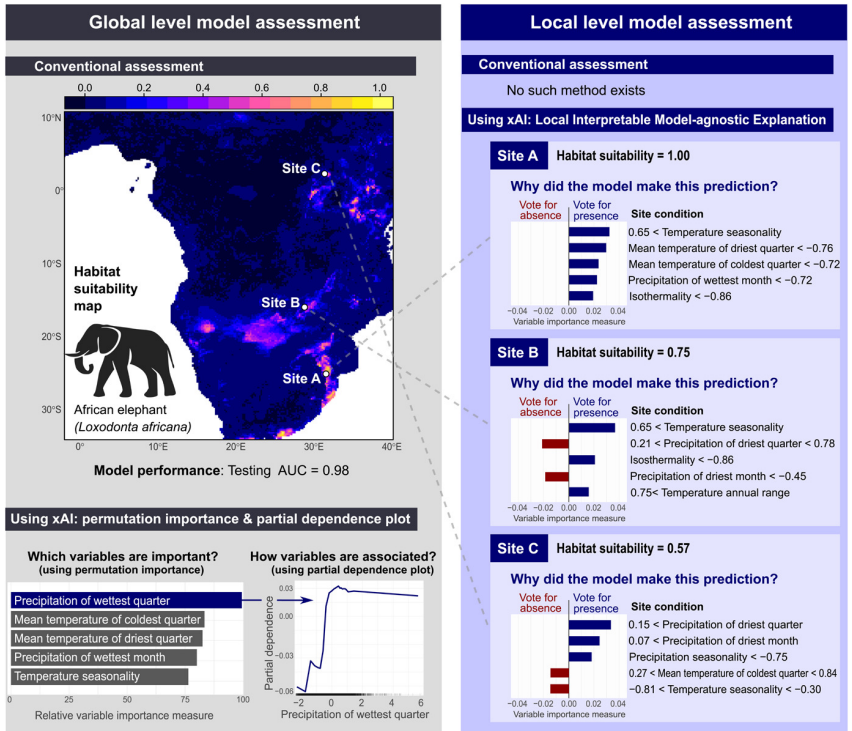


Figure 2: Explainable artificial intelligence enhances the ecological interpretability of black-box species distribution models[a]

[a] Masahiro Ryo et al., "Explainable Artificial Intelligence Enhances the Ecological Interpretability of Black-Box Species Distribution Models," Ecography 44, no. 2 (2021): 199–205.

Housekeeping and Agenda

Background:

- Gathering feedback for the upcoming book
- On the intersection of history, sociology, economics, complexity science, and others
- It is a synthesis of ideas from different sources
- There are political elements in this project

Talk structure:

1. Motivations, assumptions and context
2. Supporting evidence
3. Paths forward (rethinking)

$\rightarrow$ The end goal is to combine ideas in a new way, form a new perspective and transmit it to a larger audience.

Motivations, Assumptions and Context

Early Inspiration I: Environmental Degradation of the Sea of Azov

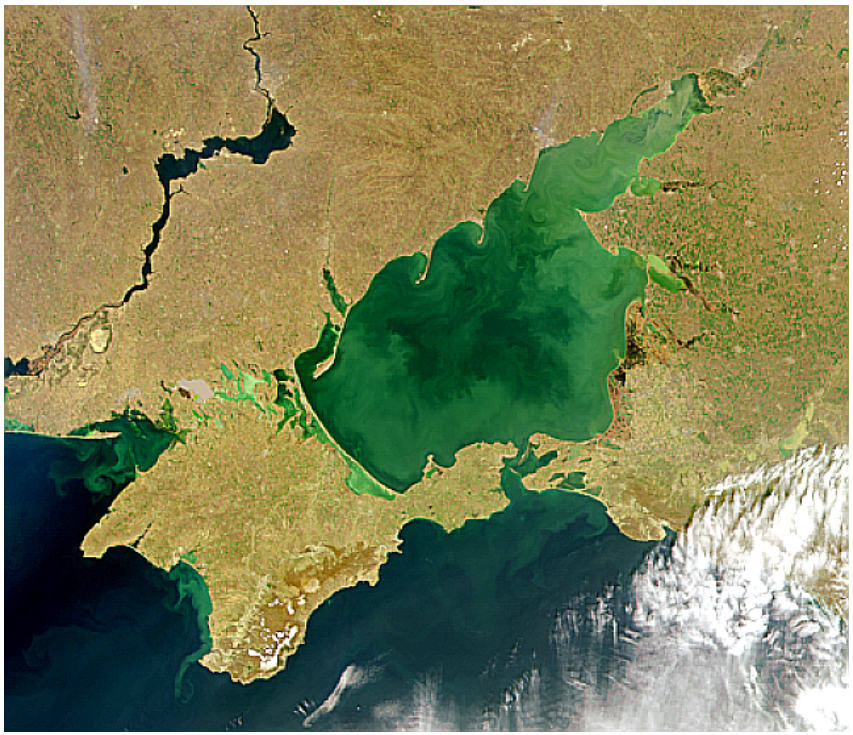


Figure 3: Satellite image of southern Ukraine showing the eutrophic Sea of Azov[a]

[a] SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE, "SeaWiFS Project" (NASA/Goddard Space Flight Center and ORBIMAGE, n.d.).

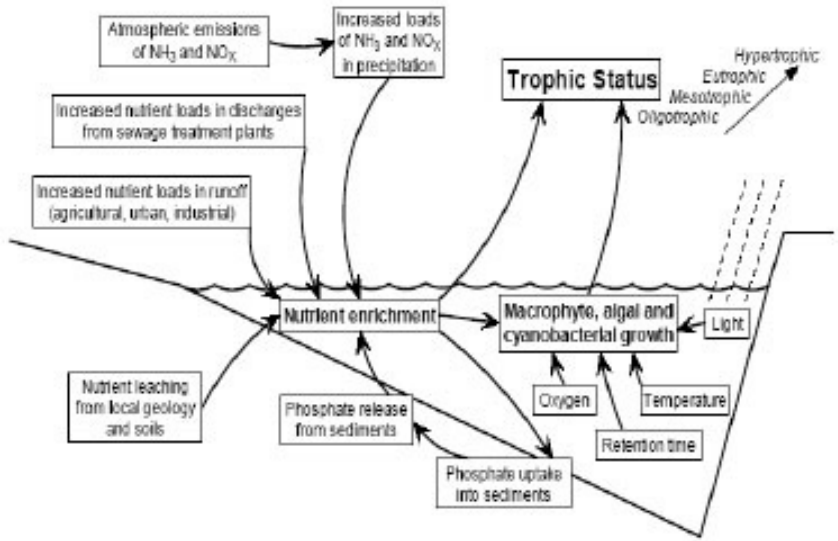


Figure 4: Mechanisms of eutrophication[a]

[a] CE Van Ginkel, "Eutrophication: Present Reality and Future Challenges for South Africa," Water Sa 37, no. 5 (2011): 693-702.

Early Inspiration II: Chaos Theory and Fractals in Jurassic Park

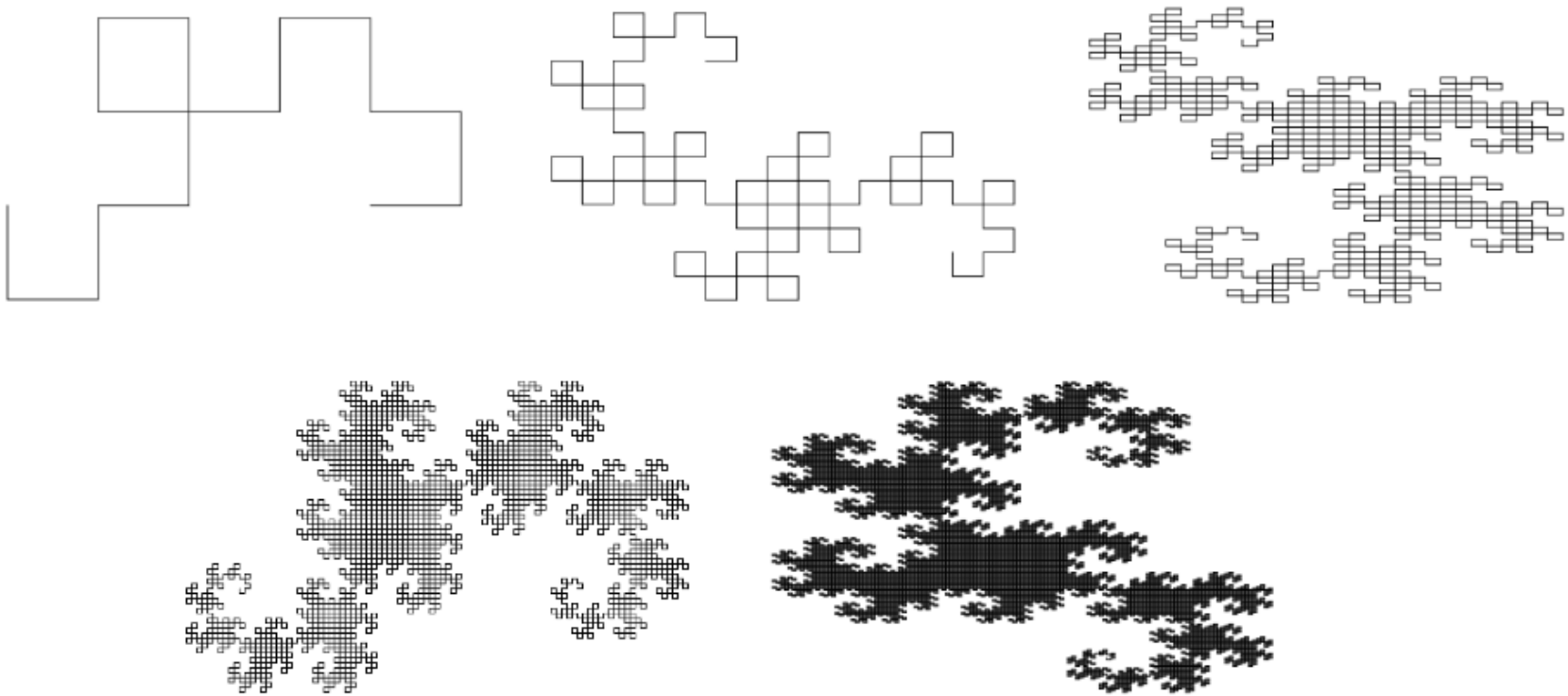


Figure 5: Usage of dragon curve fractals in Jurassic Park[2]

[2] Michael Crichton, Jurassic Park: A Novel, vol. 1 (Ballantine Books, 2012).

Early Inspiration II : Chaos Theory and Fractals in Jurassic Park

- Unpredictability of complex systems
- Overconfidence in control
- Tipping points
- Feedback loops
- Emergence and adaptation

"The system always kicks back" - John Gall[a]

[a] John Gall, Systemantics (Wildwood House, 1977).

Figure 6: A map of the fictional Isla Nublar island (credit: Filip Povanzo)

Motivating Factors I: Divergent Narratives in Society and Academia

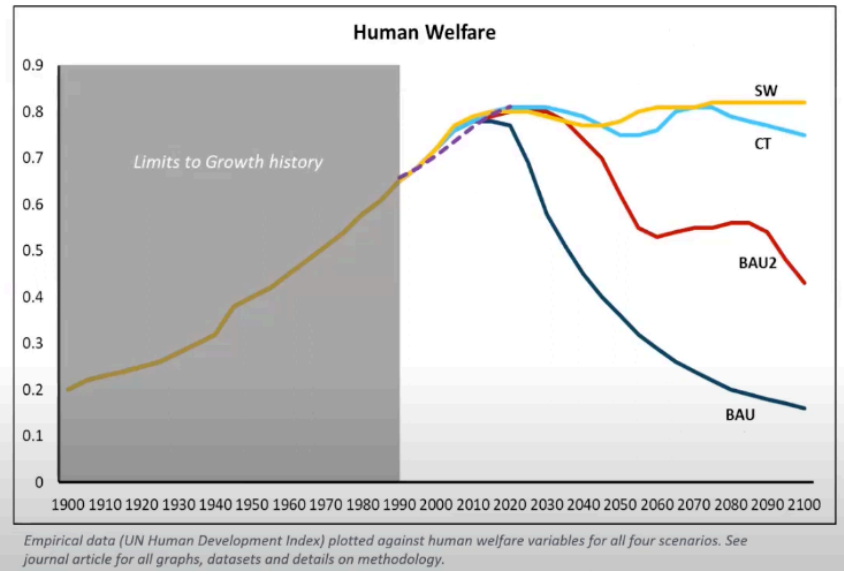


Figure 7: Update to Limits to Growth: Comparing the World3 model with empirical data[a]

[a] Gaya Herrington, "Update to Limits to Growth: Comparing the World3 Model with Empirical Data," Journal of Industrial Ecology 25, no. 3 (2021): 614–26.

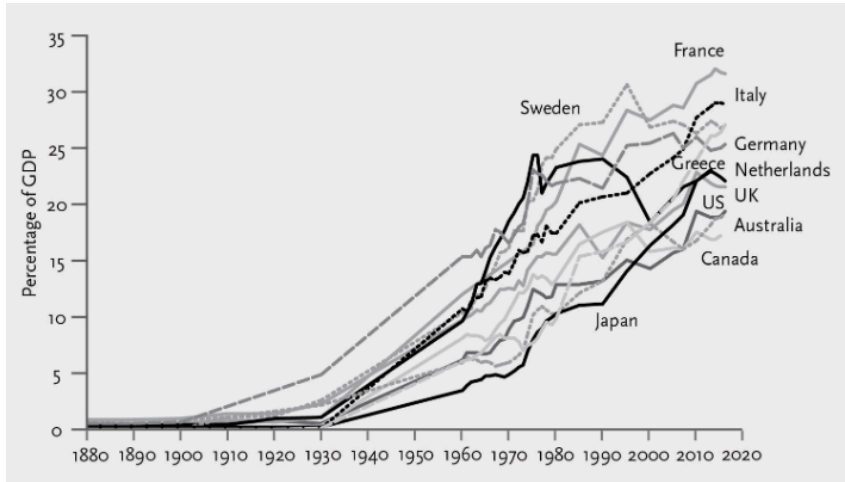


Figure 8: Social spending, OECD countries, 1880–2016[a]

[a] Steven Pinker, Enlightenment Now: The Case for Reason, Science, Humanism, and Progress (Penguin UK, 2018).

Motivating Factors II: Mismatch Between Problems and Solutions

- Frustration with the lack of conclusive, based on evidence answers
- Frustration with the lack of actionable advice, that goes beyond individual actions

$\rightarrow$ We have become excellent in diagnosing problems, but need to come up with more solutions

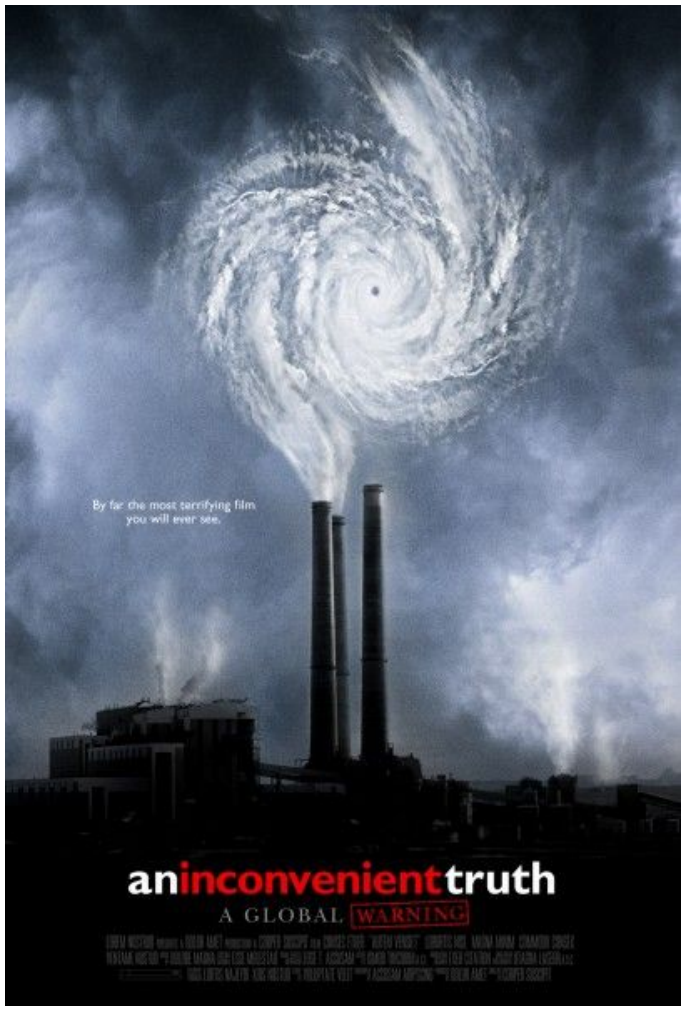


Figure 9: “An Incoventient Truth” (2006)

Assumptions

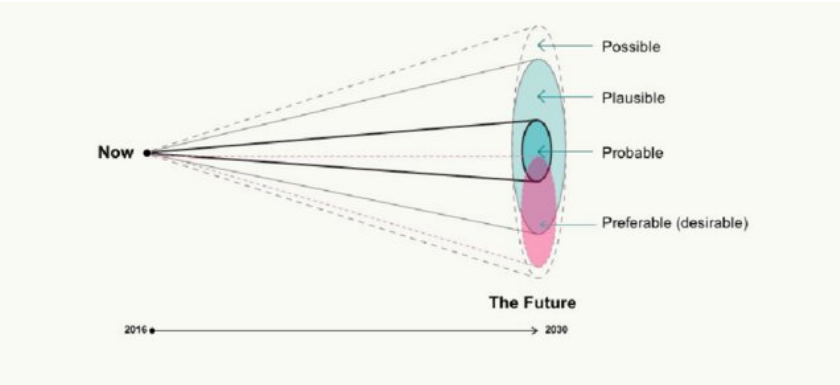


Figure 10: Some scenarios are more probable than others[a]

- The world **is** unstable
- Quantative answers are difficult, but **qualitative** ones are feasible
- We can (roughly) **predict the future**
- There is a **moral imperative** (out of scope)
- We can commit to **objective reality**
- There is an **availability of answers** in the literature

[a] J Bühring, Jeanne Liedtka, et al., "Foresight by Design: Supporting Strategic Innovation with Systematic Futures Thinking," 2018.

The Foundation of Progress Studies

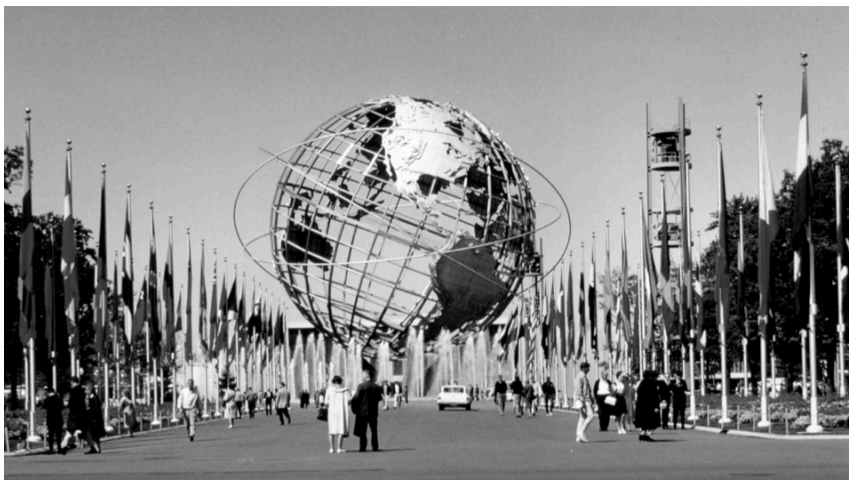


Figure 11: The industrial revolution and world trade fairs are a common theme in Progress Studies[a]

[a] John Findling and The Editors of Encyclopaedia Britannica, "World's Fair: Modernism and Cold War Rivalries" (https://www.britannica.com/topic/worlds-fair/Modernism-and-Cold-War-rivalries, 2025).

- Origin in an article by Tyler Cowen and Patrick Collison in The Atlantic[a]
- Roots of Progress Institute

It is a good start, but there are significant gaps:

- It is **techno-centric**
- It is **reductionist**
- It is **"western" first** in perspective

[a] Patrick Collison and Tyler Cowen, "We Need a New Science of Progress," The Atlantic, 2019, https://www.theatlantic.com/science/archive/2019/07/we-need-new-science-progress/594946/.

Human Progress is Often (Justifiably) Criticized

- Environmental degradation
- Significant focus on growth and GDP
- Rising social and economic inequality
- Cultural erosion, alienation and mental health
- The world wars followed the industrial revolution

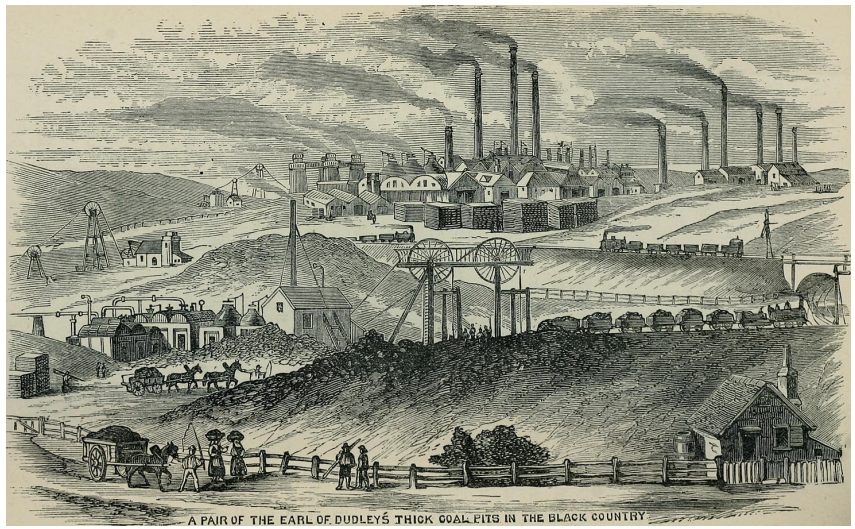


Figure 12: A typical scene in the Industrial Revolution, the Black Country (Birmingham, England)[a]

[a] Samuel Griffiths, "Griffiths' Guide to the Iron Trade of Great Britain: An Elaborate Review of the Iron and Coal Trades for Last Year, Addresses and Names of All Ironmasters, with a List of Blast Furnaces" (Published for the Proprietor, 1873).

Current State

What we Learned (and din't) from the Pandemic

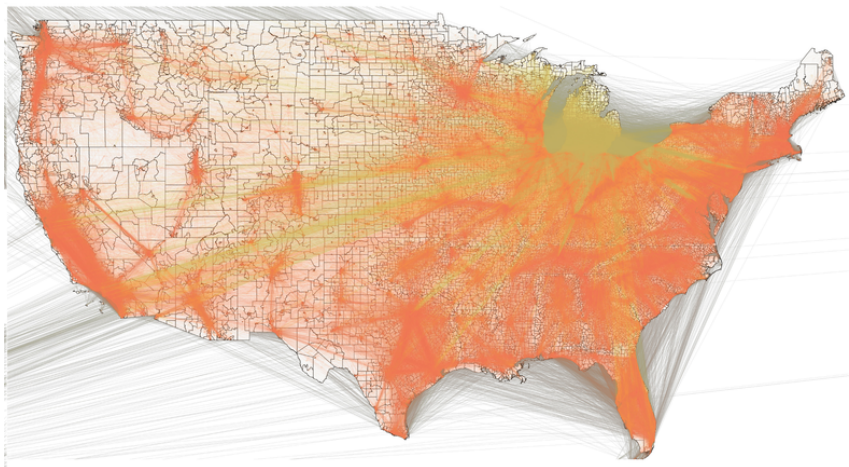


Figure 13: The complexity of the U.S. mobility network[a]

[a] Alexander Mercier, Samuel Scarpino, and Cristopher Moore, "Effective Resistance Against Pandemics: Mobility Network Sparsification for High-Fidelity Epidemic Simulations," PLOS Computational Biology 18, no. 11 (2022): e1010650.

On one side:

- Interconnectedness was a problem
- Many of our systems were not prepared
- Conspiracy theories became widespread

On another side:

- Vaccination rates
- mRNA vaccines
- Global collaboration
- Social distancing

→ The world ... was fine after that?

Mapping to Current State: Technological Progress

Current state:

- Major breakthroughs require large teams
- Many foundational discoveries are already made
- We might be entering a period of technological stagnation[a]

Why complexity is a root cause:

- Diminishing returns of effort - more coordination is required
- Paradigm-shifting discoveries are rare[b]
- Increased specialisation of research is required

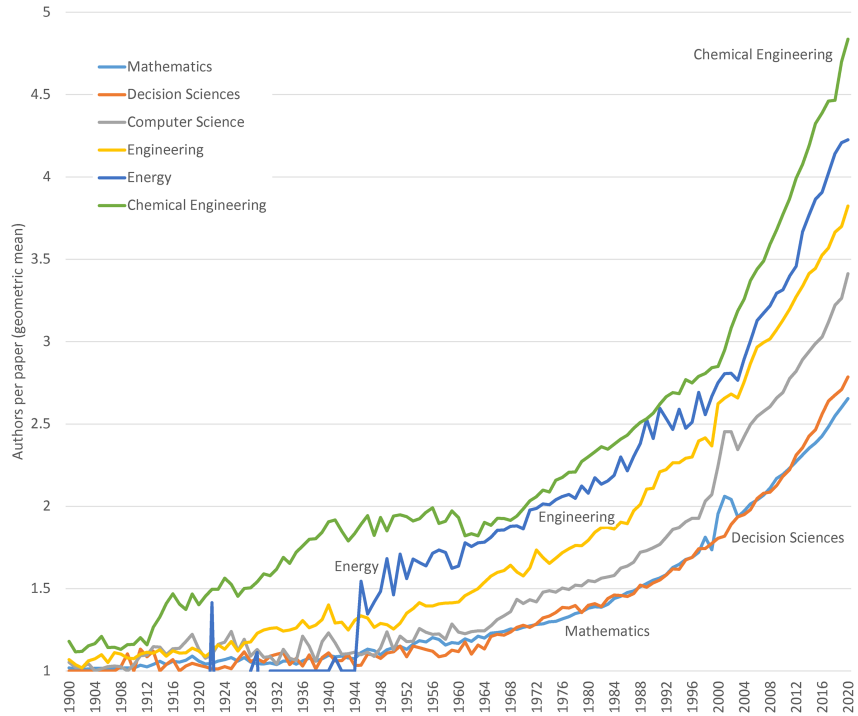


Figure 14: The average number of authors per journal article in science and engineering.[a]

[a] Tyler Cowen, The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better: A Penguin eSpecial from Dutton (Penguin, 2011).

[b] Thomas S Kuhn, The Structure of Scientific Revolutions, vol. 962 (University of Chicago press Chicago, 1997).

[a] Mike Thelwall and Nabeil Maflahi, "Research Coauthorship 1900–2020: Continuous, Universal, and Ongoing Expansion," Quantitative Science Studies 3, no. 2 (2022): 331–44, https://doi.org/10.1162/qss_a_00188.

Mapping to Current State: Economic Progress

Current state:

- Unbounded growth over resilience
- Systemic brittleness
- Widening inequality

Why complexity is a root cause:

- Ethical economic progress requires a balance of power
- This “narrow corridor” is rare and fragile
- Institutions are path-dependent
- There is no “end of history” in sight

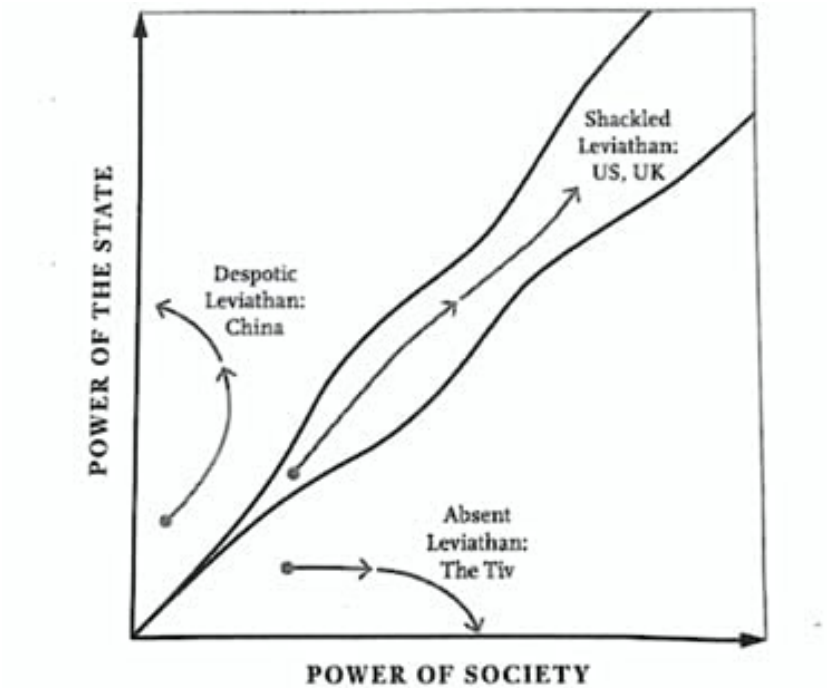


Figure 15: The narrow corridor for socio-economic progress[a]

[a] Daron Acemoglu and James A Robinson, The Narrow Corridor: How Nations Struggle for Liberty (Penguin UK, 2019).

Mapping to Current State: Social Progress

Current state:

- Hauntology: society has lost belief in the future[a]
- The post-truth world[b]
- Depolitisation and hypernormalisation
- Conspiracy theories, nobody is at the wheel
- Algorithmic bias and the amplification of bias and division

Why complexity is a root cause:

- Causality is difficult to establish
- Overabundance of information (signals)
- Decreasing trust in institutions because of a (perceived) loss of control

Figure 16: The paintings of Simon Stalenhag capture the nostalgia for a future that didn't happen[a]

[a] Mark Fisher, Ghosts of My Life: Writings on Depression, Hauntology and Lost Futures (John Hunt Publishing, 2014).

[b] Carl Sagan and Ann Druyan, The Demon-Haunted World: Science as a Candle in the Dark (Ballantine books, 1997).

[a] Simon Stålenhag, 2025, https://www.simonstalenhag.se/.

Complex Systems I: Wicked Problems

The sum of all fears: it is complexity all the way down.

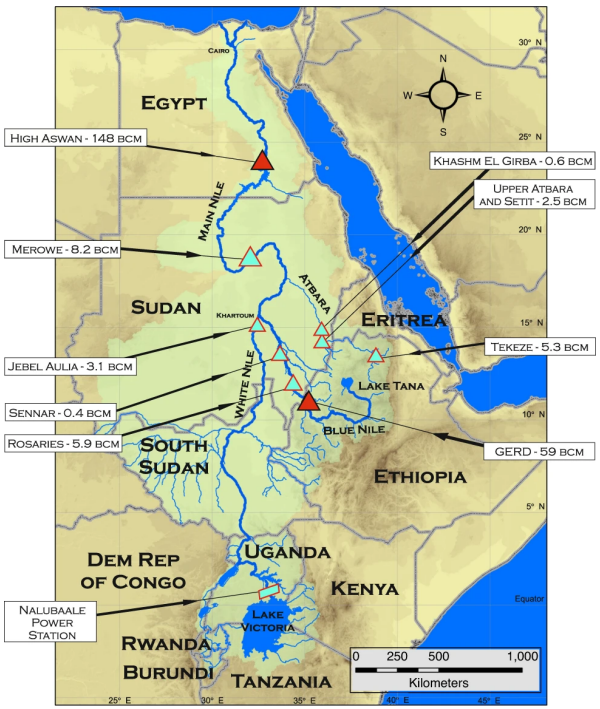


Figure 17: The Grand Renaissance Dam (GERD) project impacts a whole region[a]

[a] Kevin G Wheeler et al., "Understanding and Managing New Risks on the Nile with the Grand Ethiopian Renaissance Dam," Nature Communications 11, no. 1 (2020): 5222.

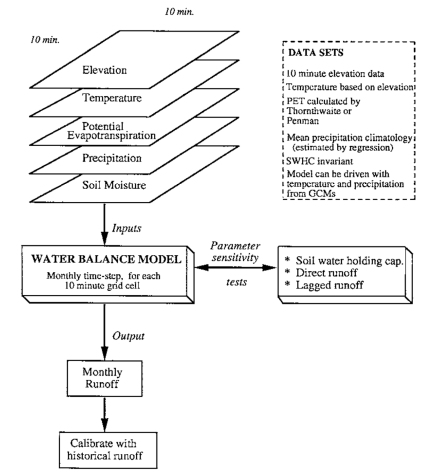


Figure 2. Structure of the water balance model of the Blue Nile River Basin (SWHC = Soil water holding capacity).

Figure 18: The complexity of one of many subsystems relevant to GERD[a]

[a] Declan Conway, "The Impacts of Climate Variability and Future Climate Change in the Nile Basin on Water Resources in Egypt," International Journal of Water Resources Development 12, no. 3 (1996): 277–96.

Complex Systems II: Facts and Information

"The road to hell is paved with good intentions".

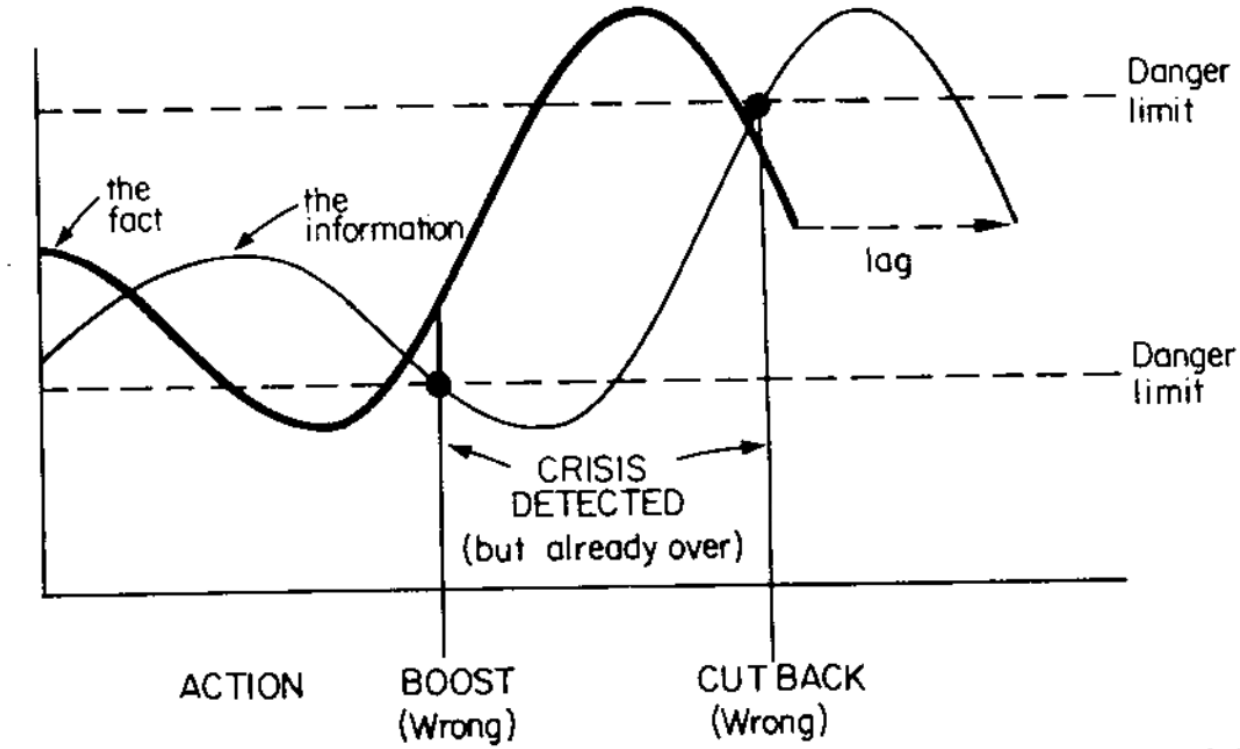


Figure 19: A delay between facts and information is inevitable[3]

[3] Stafford Beer, "Platform for Change: A Message from Stafford Beer," 1975.

Paths Forward (Rethinking)

Stay in the Game by Reducing Global Catastrophic Risk

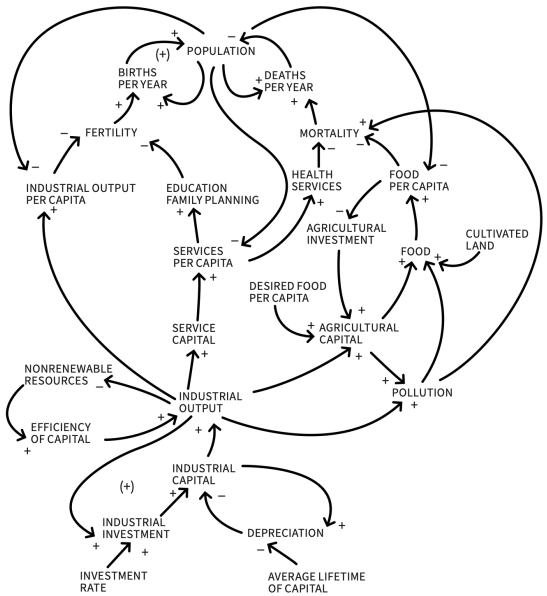


Figure 20: Critical variables for civilization's survival[a]

[a] Donella H Meadows et al., "The Limits to Growth," in Green Planet Blues (Routledge, 2018), 25–29.

Via negativa:[a] the purpose of life is not to win the game, but stay in the game. If we avoid the risks - we are good to go?

Global risks:

- Climate change
- Global (nuclear) conflict
- Bioweapons
- Rogue AI
- ...

[a] Nassim Nicholas Taleb, Antifragile: Things That Gain from Disorder, vol. 3 (Random House Trade Paperbacks, 2014).

Acknowledge the Trajectories

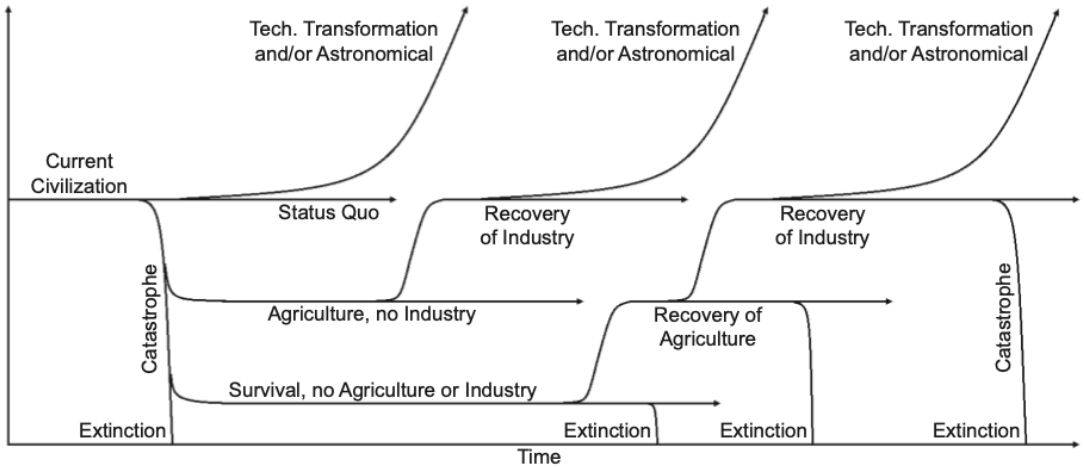


Figure 21: Potential futures[4]

- There is a (rough) consensus where things are going, and the data to support this[5]
- History repeats itself
- Individual agency matters and there are tipping points, but systemic inertia dominates
- Historical lock-in determins which futures remain possible[6]

$\rightarrow$ The window for transformation narrows over time.

[4] Seth D Baum et al., "Long-Term Trajectories of Human Civilization," Foresight 21, no. 1 (2019): 53–83.

[5] Herrington, "Update to Limits to Growth."

[6] William MacAskill, What We Owe the Future: The Sunday Times Bestseller (Simon; Schuster, 2022).

Look at the Forest and the Trees

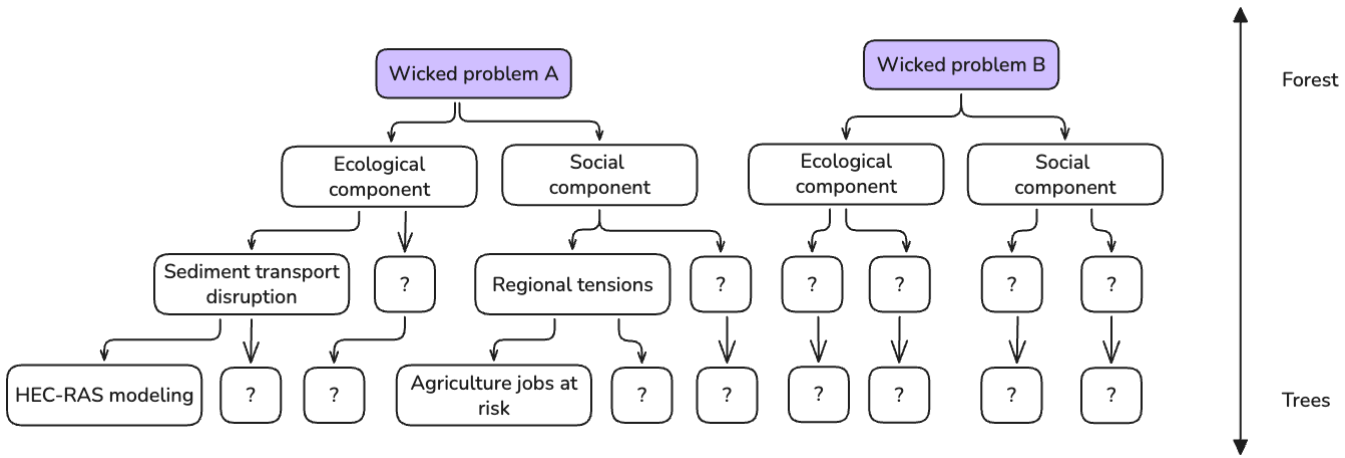


Figure 22: Similarities and differences in breaking down wicked problems (complex systems)

- Wicked problems (complex systems) can look different at a glance, but share systemic similarities on a high level
- On lower levels we need deepening domain knowledge
- We must pay attention to all levels at the same time

Accept Objective Reality I: Computation is (Somewhat) Possible

		00000000011111111112 12345678901234567890	
1	Achillea millefolium	13..222..4.....2...	Ach mil
2	Agrostis stolonifera	..48...43..45447...5	Agr sto
3	Aira praecox	..............2.3.	Air pra
4	Alopecurus geniculatus	.272...53..85..4....	Alo gen
5	Anthoxanthum odoratum	....432..4.....4.4.	Ant odo
6	Bellis perennis	.3222....2.....2..	Bel per
7	Bromus hordaceus	.4.32.2..4.....	Bro hor
8	Chenopodium album	..........1.....	Che alb
9	Cirsium arvense	...2.....	Cir arv
10	Eleocharis palustris	.....4.....458...4	Ele pal
11	Elymus repens	44444...6.....	Ely rep
12	Empetrum nigrum	..............2.	Emp nig
13	Hypochaeris radicata	.....2.....2.5.	Hyp rad
14	Juncus articulatus	.....44.....33...4	Jun art
15	Juncus bufonius	.....2.4..43.....	Jun buf
16	Leontodon autumnalis	.522333323522222.2562	Leo aut
17	Lolium perenne	75652664267.....2..	Lol per
18	Plantago lanceolata	....555..33.....23..	Pla lan
19	Poa pratensis	44542344444.2...13..	Poa pra
20	Poa trivialis	2765645454.49..2....	Poa tri
21	Potentilla palustris	..........22.....	Pot pal
22	Ranunculus flammula	.....2....2222...4	Ran fla
23	Rumex acetosa	....563.2..2.....	Rum ace
24	Sagina procumbens	...5...22.242.....3.	Sag pro
25	Salix repens	335	Sal rep
26	Trifolium pratense	....252.....	Tri pra
27	Trifolium repens	.52125223633261..22.	Tri rep
28	Vicia lathyroides	.........12.....1..	Vic lat
29	Brachythecium rutabulum	..2226222244..44.634	Bra rut
30	Calliergonella cuspidata	..........4.3...3	Cal cus

Figure 23: Species counts per ecological site in dune meadows in the Netherlands[a]

[a] RHG Jongman, Cajo JF Ter Braak, and Onno FR Van Tongeren, Data Analysis in Community and Landscape Ecology (Cambridge university press, 1995).

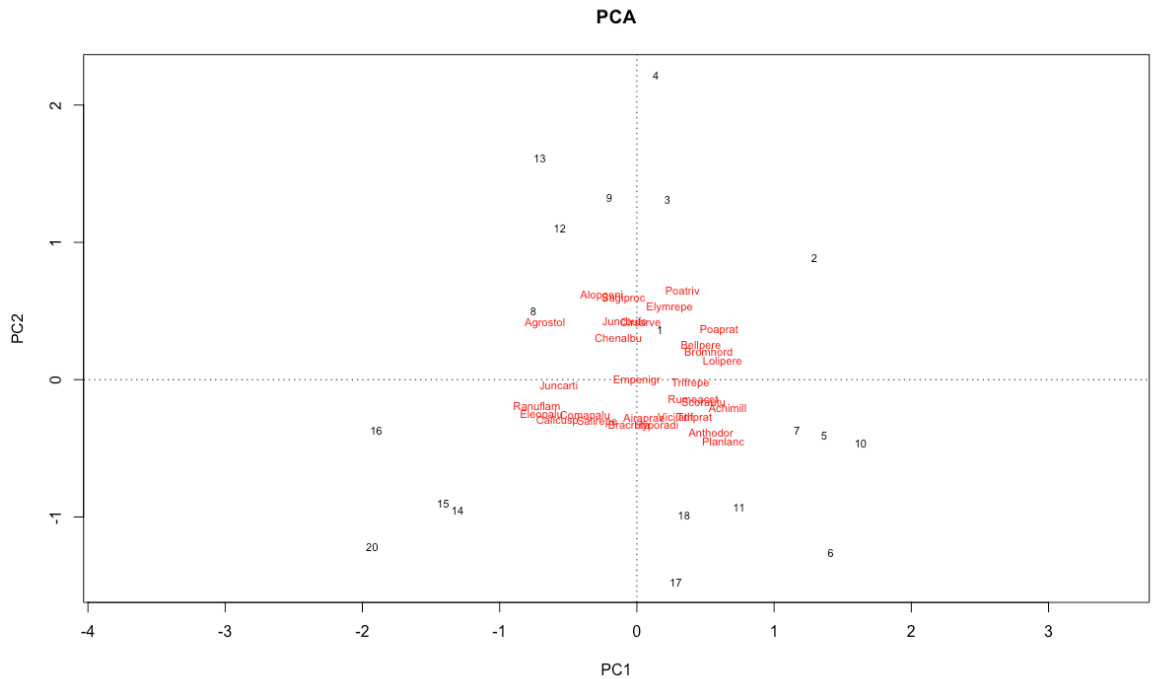


Figure 24: Patterns uncovered in the dataset by doing a Principal Component Analysis (PCA)

Accept Objective Reality II: But Not for Wicked Problems

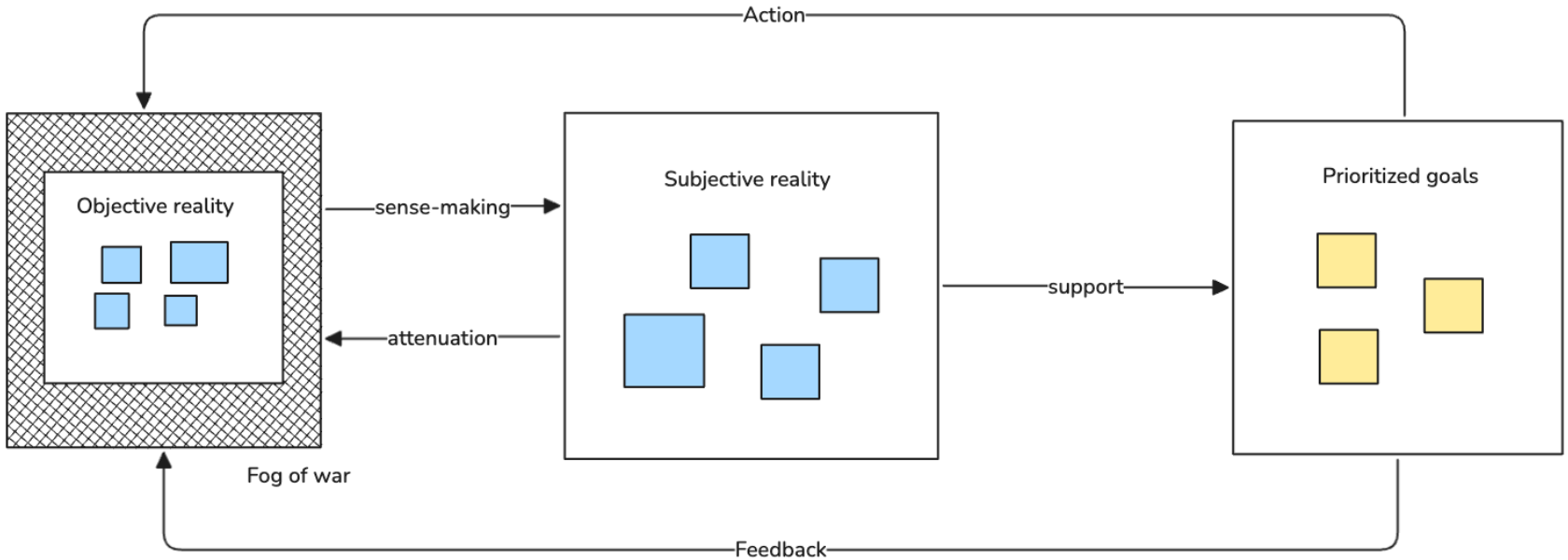


Figure 25: Making decisions in a complex environment

- Reality would never match our models
- But it exists nevertheless
- If we accept this, and have good goals the steps are clear

"The map is not the territory" - Alfred Korzybski[7]

[7] Alfred Korzybski, Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics, 1st ed. (New York: The International Non-Aristotelian Library Publishing Company, 1933).

Case Study: the Subak Irrigation System in Indonesia I

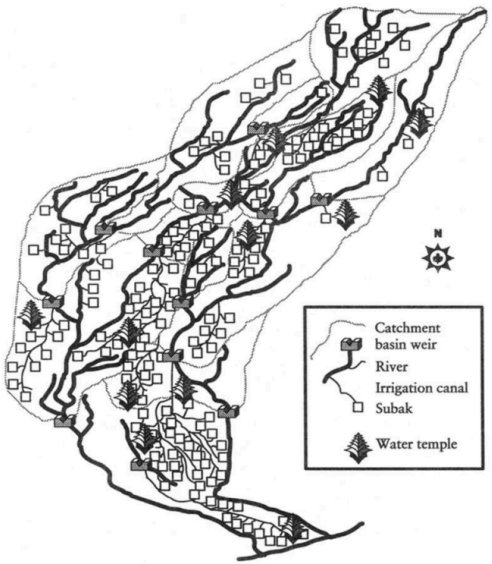


Figure 26: The subak system[a]

[a] J Stephen Lansing and Murray P Cox, Islands of Order: A Guide to Complexity Modeling for the Social Sciences (Princeton University Press, 2019).

Context:

- Multi-stakeholder governance: farmers, priests, and water temple councils
- Interlinked upstream–downstream dependencies
- Synchronised water distribution and crop cycles to mitigate shortages and pest outbreaks

What can we learn from it?

- Distributed governance enables resilience in complex, interdependent systems
- Ecological and social synchrony outperforms centralized control
- Top-down interventions often disrupt finely tuned local equilibria and produce unintended consequences

Case Study: Pleistocene Park in Siberia

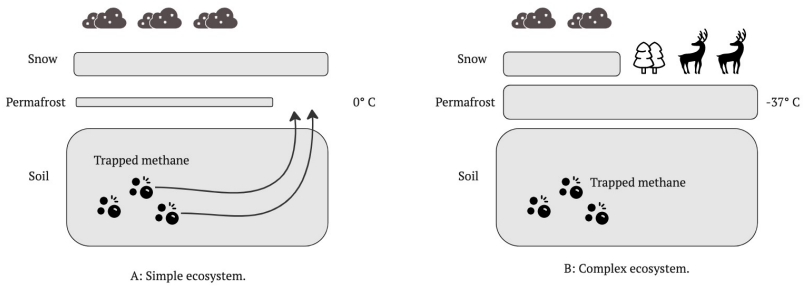


Figure 27: Attempts at complex system control in Pleistocene Park[a]

[a] Boyan Angelov, "Managing the Century of Complexity: Origins, Evolution and Productive Future Avenues with Systems Thinking," n.d.

Context:

- Grazing megafauna reduce snow insulation, accelerating surface cooling
- Permafrost thaw leads to methane emissions—a potent climate feedback

What can we learn from it?

- Ecological engineering can harness feedback loops to stabilize complex systems
- Nonlinear dynamics and time-lags are crucial—effects may emerge decades after interventions
- Restoring functional diversity can be more impactful than direct technological fixes

What to do: Example in Rethinking

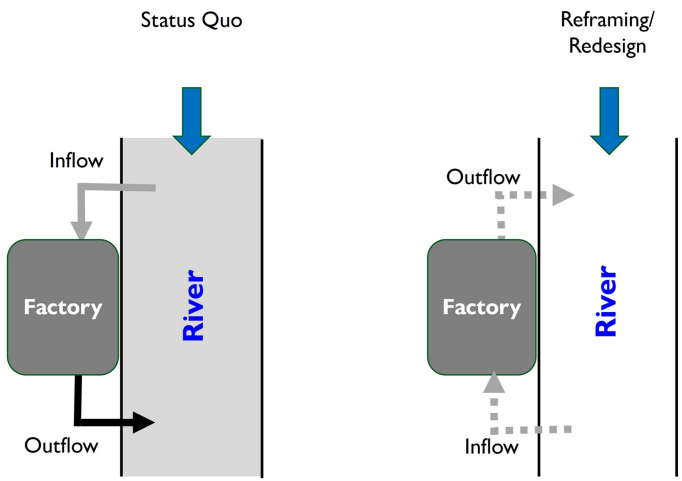


Figure 28: Readjusting incentives through variety engineering[a]

[a] Markus Schwaninger and Stefan Ott, "What Is Variety Engineering and Why Do We Need It?" Systems Research and Behavioral Science 41, no. 2 (2024): 235–46.

Context:

- Factory on the bank of a river
- Pollutant discharged
- Status quo: seen as a **policing** problem

What can we learn from it?

- Reframe as a **design** problem
- Understand incentives

$\rightarrow$ the factory manages itself

What to do: a New Branch of Progress Studies

- Expand the definition: social, economic, and technological progress are codependent
- Objective reality: anchor to shared frameworks (Universal Declaration of Human Rights, UN SDG, planetary boundaries)
- Adopt diverse views, beyond the western
- Adopt first principles, transdisciplinary approach

→ And finally - study progress.

Figure 29: The cover of “Science in Life” (1990)

What to Do: Rethinking

- Build more viable, antifragile[8] systems that learn
- Take lessons from complexity
- Avoid catastrophic risk
- Adopt language of complex systems (Lock-in, feedback loops, trajectories and tipping points and scale, etc.)
- Use new frameworks (estuarine mapping, variety engineering, etc.)
- Pause, think, iterate

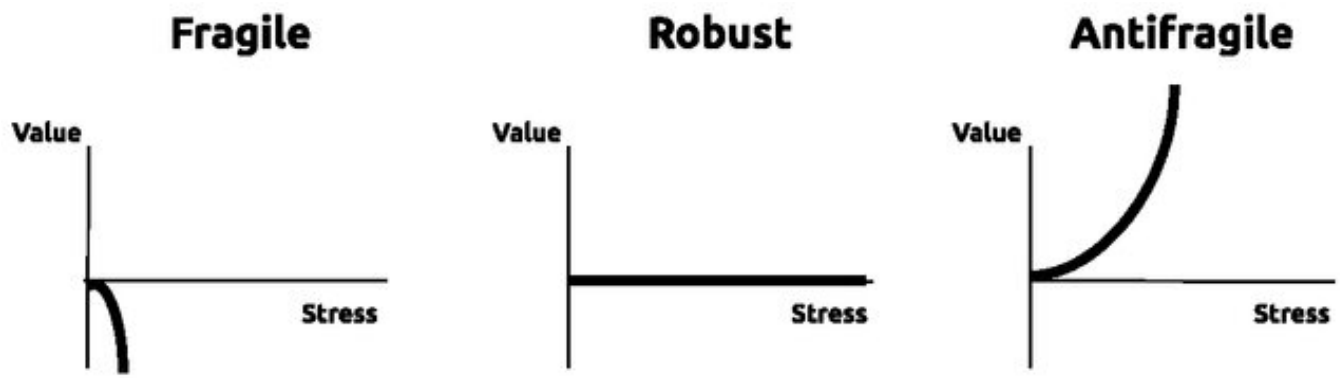


Figure 30: The three types of systems[9]

[8] Stafford Beer calles them ”ultrastable” in his work.

[9] René Bliekendaal, “Towards an Antifragile Public Sector” (PhD thesis, Antwerp Management School, 2022).

Conclusion

Take Home Messages I

If we are to move forward in this fog of war, we must rethink our approach and **transplant learnings from complexity science** into boardrooms, parliaments, and the vocabulary of both experts and citizens

Take Home Messages II

The newly forming “progress studies” field is a new opportunity to do exactly that, if it stays away from technological universalism and takes steps beyond diagnosing the problem and into **sense-making** and **action**.

"The [revolution] not a linear process ... but a constant beginning again" - Slavoj Zizek[10]

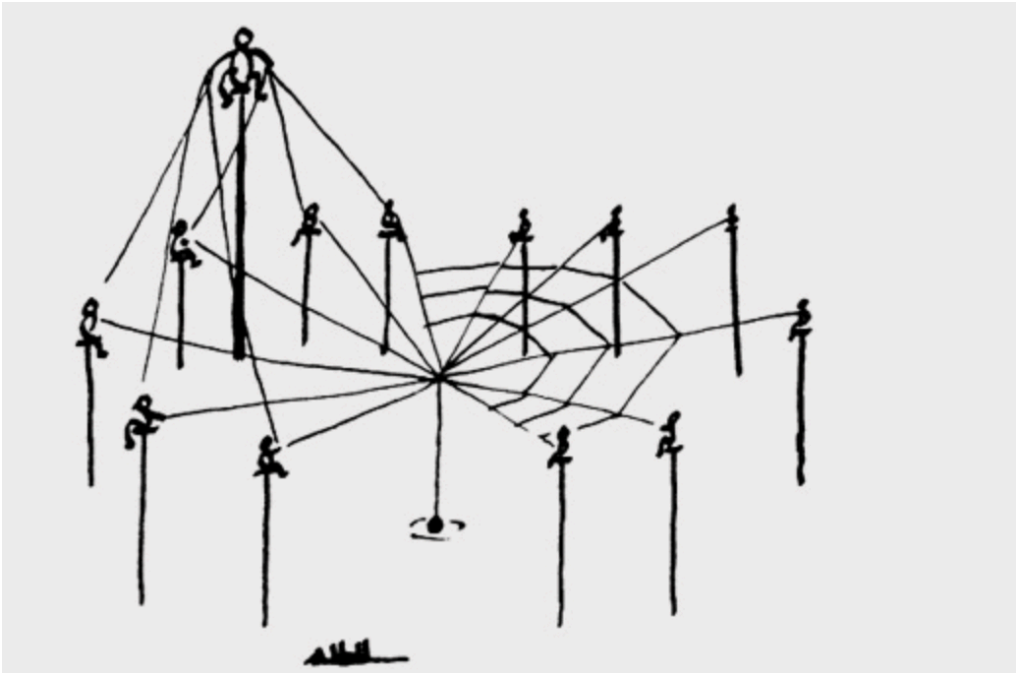


Figure 31: How it feels to make decisions in our world today[11]

[10] Slavoj Žižek, "Against Progress," 2024.

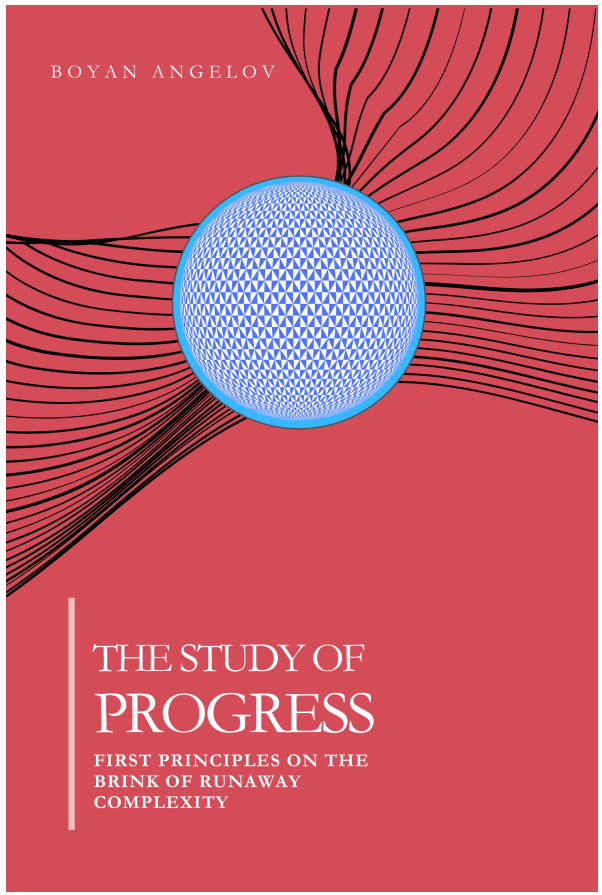
[11] Stafford Beer, Designing Freedom (House of Anansi, 1993).

Upcoming Book

Things I didn't cover today:

- History of thinking about progress
- A moral framework
- More frameworks
- Metalanguage
- Additional case studies
- ...

You can follow my work at studyofprogress.org.



TLDR; A Manifesto

RETHINK!

- Adopt a more complete definition of progress
- Accept that complexity is a barrier to progress
- Start designing systems that are antifragile and that match the complexty of the challenges (at the moment they are naive, even with the best intentions)
- The idea is not to have a straight path from A to B, but to get there
- Let go of hierarchical ideas of centralized control
- Understand there is a rough idea where things are going
- Understand that even though we can't measure everything, we can steer
- See that the tools to deal with it are at our disposal, it requires rethinking
- Avoid catastrophic risk, stay in the game: incremental progress (protopia)[12]

[12] Kevin Kelly, "Protopia" (https://kk.org/thetechnium/protopia/, 2011), https://kk.org/thetechnium/protopia/.